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USING UML CASE TOOLS FOR DEVELOPMENT OF AN OPEN PIT ARCGIS GEODATABASE

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ABSTRACT

Opportunities offered by geographic information systems are very modestly exploited in Serbian mining industry. It is the authors' wish to bring closer to the mining public at least a small part of the possibilities offered by GIS, both in mining activities and in environment protection. This paper outlines a methodology for development of a spatial database, that is, a geodatabase, for open pit mines. The geodatabase dubbed OpmGIS has been modeled using UML and CASE tools that support the development process. The class model of the OpmGIS geodatabase has been developed in the MS Visio tool. The logical model of the geodatabase was transformed to the physical model for the ArcGIS development environment, which is being used at the Faculty of Mining and Geology in Belgrade for development of GIS applications. Thematic classes presented in this paper encompass only a part of the data related to mine production, and pertain to an important segment that demands visual representation. More precisely, the paper tackles exploration works, sample analysis, infrastructure within the mine and in its environment, excavating and loading equipment, etc. The physical implementation of the OpmGIS geodatabase model has been illustrated by the example of the "Field G" open pit, followed by an outline of the way spatial-temporal data are handled, as well as by an example of visualization of spatial classes in ArcMap.

Keywords: geographic information system, GIS, geodatabase, UML, ArcGIS, open pit

INTRODUCTION

The growing complexity of engineering tasks creates a need for tools that offer possibilities for high quality situation monitoring and comprehension, as well as prediction of our future line of action. Geographic information systems (GIS) are precisely such a tool. They offer support for implementation of various types of projects aimed at economic development, resource management, and high quality decision making. GIS can also improve various everyday procedures by offering fast access to data necessary for decision making on a large number of issues.

According to a general definition, geographic information systems are a powerful set of tools for collecting, storing, searching, transforming and presentation of real world spatial data [Burrough & McDonnel, 2006]. Simply put, spatial or geographic data are data on geographic entities, that is, data that identify the geographic position and shape of natural and artificial objects, such as roads, rivers, cadastral parcels or landfills. Namely, any object that can be represented on a map, as well as its properties and relations with other objects. GIS allows users to create queries, analyze spatial information, manage data and maps, and present results of all these operations.

GIS enable the user to create regional and detailed maps of both active and prospective open pits, model the geology and the terrain, estimate the reserves, plan the yearly production, monitor statistical data on exploitation costs, monitor the position and availability of mining equipment (excavators, conveyor belts, trucks, etc.), the state of mining objects, works on mine benches coal and waste dumps. The application of GIS is especially important in the environment protection area, as it enables active monitoring of the impact of mining operations to environment: air, water and soil quality, determination of the level of risk to human health, flora and fauna, as well as planning of protection measures.

An important advantage offered by geographic information systems is the establishment of relations between descriptive, alphanumeric, non-spatial data and spatial data within a geodatabase, and enabling their analysis, processing and presentation. In a traditional databases the user cannot make spatial queries such as: "Which boreholes are at a distance of 50 meters from the L1 profile line?", "Which objects are in the area planned for exploitation in 2016?", "Which boreholes are in the area that is to be excavated by the end of the year?" and the like. Namely, relations between objects

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that are discovered based on geometry rather than alphanumeric data cannot be obtained by classical SQL queries from traditional databases. For this type of queries, dedicated databases are used that have a built-in system for storing and indexing both alphanumeric and geometric data.

The Irish company ESRI² created one of the most complex GIS platforms named ArcGIS®. This integrated software family provides all functions necessary for developing a geographic information system. ArcGIS encompasses a palette of software that can be adapted to the needs of one or more users, either on desktop computers or on servers, on the web or mobile devices used in the field. The GIS development platform used for the project outlined in this paper, but also for many other GIS projects developed at the University of Belgrade, Faculty of Mining and Geology, is precisely the software package ArcGIS.

GEODATABASE MODELING

The fundamental component of a geographic information system is a spatial database or geodatabase. The concept of a database pertains to a collection of various types of geographic data, stored in the system's data catalogue or a RDBMS (relational database management system) database (such as Oracle, IBM DB2, PostgreSQL, Informix or, as is the case here, Microsoft SQL Server 2008). More precisely, a geodatabase represents a collection of interrelated data, namely: attributes (data describing a geographic entity numerically or textually), geometry (data defining the shape and size of an entity and its position in space) and topology (data defining relations between different geographic entities). Consequently, there are three basic groups of data in a GIS, namely: vector data, attribute data and raster data. Geodatabase development followed the specifications and recommendations of international organizations involved in standardization, primarily OGC (*Open Geospatial Consortium*), outlined within the series of documents "OpenGIS Abstract Specification" [OGC AS] and "OGC Reference Model" [OGC 2008]. There are three basic ways of creating a geodatabase. If collections of geographic data that are to be merged within a geodatabase are available in one of the acceptable formats, then these data are simply imported in the newly formed geodatabase. ArcGIS, namely, offers possibilities for importing data from traditional relational databases, XML and Excel documents, as well as vector content of AutoCAD and other CAD software. In the case of raster data, there are also possibilities for import of various formats, as well as for grouping of raster data in the so-called raster datasets or raster catalogues. Another way of creating a database is the design of a new spatial database using the tools from the ArcCatalog application and the ArcToolbox toolbox. They enable a direct, that is, "ad-hoc" creation of a physical database model, without previous conceptual and logical modeling. In this paper we shall outline the third, most systematic way: the creation of a database model using the Unified Modeling Language (UML) and Computer-Aided Software Engineering (CASE) tools, which support the geodatabase development process. The first two approaches to geodatabase creation are suitable when smaller geodatabases or geodatabases of a simple structure are developed, while the third approach is used in the development of complex geodatabases with a larger number of feature and attribute classes.

In the software engineering field UML is the standard object-oriented modeling language, which encompasses a set of techniques enabling visual representation of the model [Naiburg, Maksimchuk, 2002]. The model represents the foundation upon which all geographic information systems are built. The concept of "model" pertains to a semantically closed system abstraction, which represents complete and simplified reality, created in order to better understand a system.

In the case of geodatabases, UML models can be created by means of various CASE tools. In this paper we used Microsoft Visio because it has developed integration with ArcGIS through the "vsl" stencil. This is a specialized dynamic library, which can be loaded into Microsoft Visio and which enables its integration with ArcGIS. This library contains object models and a number of packages necessary for UML modeling. These packages are, in the first place, *Workspace*, *ESRI Classes* and *ESRI Interfaces*, where user classes are stored, either directly, or further grouped into packages. In addition to that, this library contains the *Semantic Checker*, which enables semantic verification of the geodatabase. If any kind of error is registered, the user is informed, by means of a report, of its type and position within the model. Upon this verification, the UML model is exported into an XML file by means of the *ESRI XMI Export* feature.

² The Economic and Social Research Institute, <http://www.esri.com/software/arcgis/index.html>

The ArcGIS development environment has built-in tools which generate the geodatabase based on its UML model, with all the classes defined in the model and their mutual relationships. As in the case of classical, relational databases, the development should start from conceptual modeling, followed by logical modeling, and finally creation of a physical model, upon which the geodatabase is ready for implementation. This systemic approach to development reduces data redundancy and enables better documenting and maintenance of the entire system.

The general strategy for using UML CASE tools for design and development of geodatabases entails the use of UML for defining the database schema, creation of classes, and only after that, filling with necessary data. The entire process of database creation can be represented through three steps:

1. Geodatabase model generation using UML;
2. Import of the UML model into a XMI (*XML Metadata Interchange* – standard format for data interchange) file or repository;
3. Import of the UML model schema from XMI format into ArcCatalog and optional generation of code that defines specific behavior of objects.

Figure 1 depicts the general schema of the use of UML CASE tools for design and development of geodatabases, including the use of UML for defining the geodatabase schema and for geodatabase creation [ESRI, 2010].

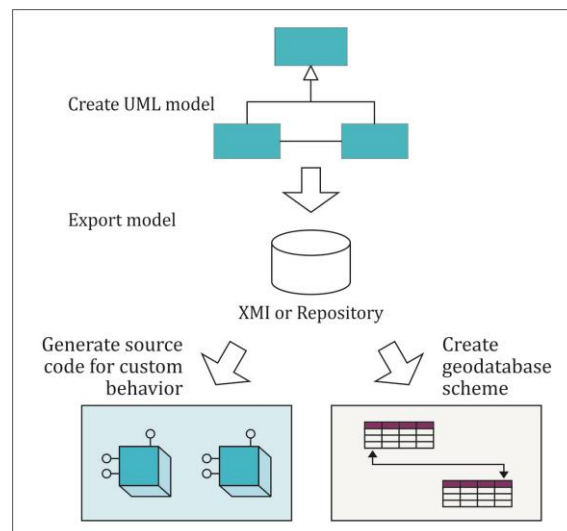


Figure 1. Design and development of a geodatabase using the UML CASE tool

PHYSICAL IMPLEMENTATION OF OpmGIS GEODATABASE MODEL

The OpmGIS geodatabase, as the key element of the information system, is a repository for spatio-temporal data sets, aimed at planning, monitoring and managing work at open pits. It enables not only visualization, but also analysis of stored data. Data registered in this database are the following: data on geological research, physical-chemical analysis of ore samples, infrastructural objects, natural objects, work environment (pit, levels, technological blocks...), excavating and loading equipment, raster backgrounds (orthophoto photographs, topographic backgrounds, elevation models...).

The development of the OpmGIS geodatabase started with the creation of the *PovrsinskiKop* package, within the *Workspace* package, followed by the creation of class diagrams. A class is the basic unit of the system model, where class examples are objects with the same structure, behavior, relations and semantics. For example, the class *Busotina* represents all exploration_boreholes with all the necessary data. The class diagram, as one of the basic structural diagrams, describes the system structure using classes, attributes, operations and relations between classes. There can be several such diagrams within one geodatabase, namely, as much as needed to make its structure clear and understandable. In this paper we will present three class diagrams: *IstrazniProstor*, *Objekti* and *Tehnologija*.

Figure 2 depicts the class diagram *IstrazniProstor*, which models the exploration works (boreholes and observed lithology, interpretation of stratigraphy, results of performed analyses, as well as deposit contour). The central position in this diagram is taken by the class *Busotina*, defined geometrically as a point (*EsriGeometryPoint*). It has the following attributes: X, Y, Z coordinates, borehole depth and year of drilling. Each of the attributes is defined, according to the data that are to be entered, as numerical, with different levels of precision. Thus, for example, the coordinates have to be in double precision floating-point format (*esriFieldTypeDouble*). The class *Busotina* inherits the abstract class *ProstorneKlase*, and via this class also ESRI classes *Feature* and *Object*. Namely, a hierarchy can exist among the classes, in which derived classes or sub-classes inherit attributes from their ancestor classes. Abstract classes do not have objects of their own, but they have attributes, which are inherited by their subclasses. The essential purpose of abstract classes is precisely to group attributes of their subclasses. Thus the class *Busotina* inherits the attributes, relations and operations from all three aforementioned classes.

For each borehole different analyses are performed (petrographic-mineralogical, physical-mechanical, qualitative, which encompasses technical, elementary analysis, ash analysis and ash fusibility), and lithologic and stratigraphic characteristics are established. Results of this research are modeled by classes: *Analiza*, *Litologija* and *Stratigrafija*. Their common features are modeled by the abstract class *Intervali*, and via this class also by abstract classes *GenerickiAtributi* and ESRI class *Object*.

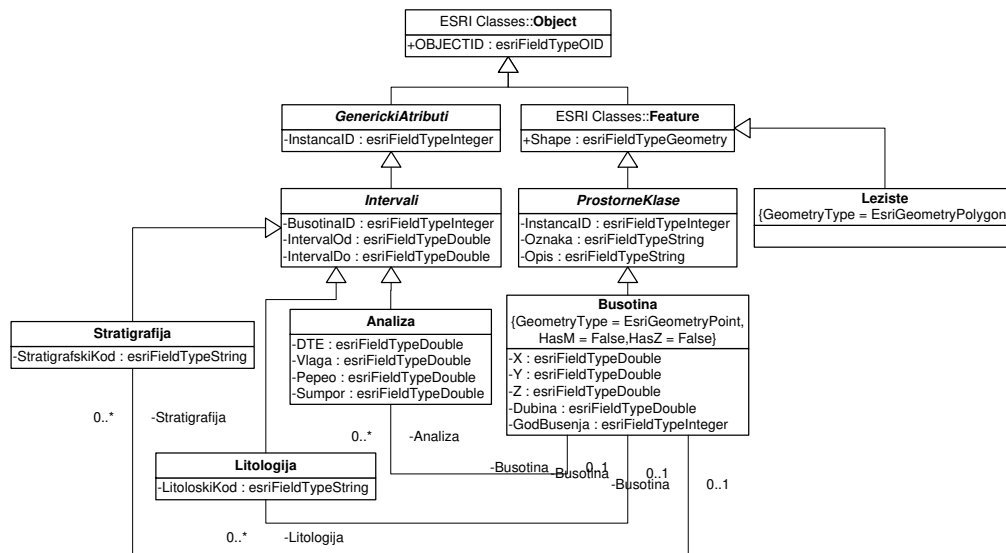


Figure 2. Class diagram *IstrazniProstor*

Classes *Analiza*, *Litologija* and *Stratigrafija* are related to the class *Busotina* by a binary “one-to-many” association. This means that for each borehole results of the analyses, as well as lithologic and stratigraphic members, are entered according to the charting intervals. Figure 3 depicts one of these binary associations. In the phases of development of the OpmGIS geodatabase that are going to follow, these classes will be used for geostatistical modeling of deposits.

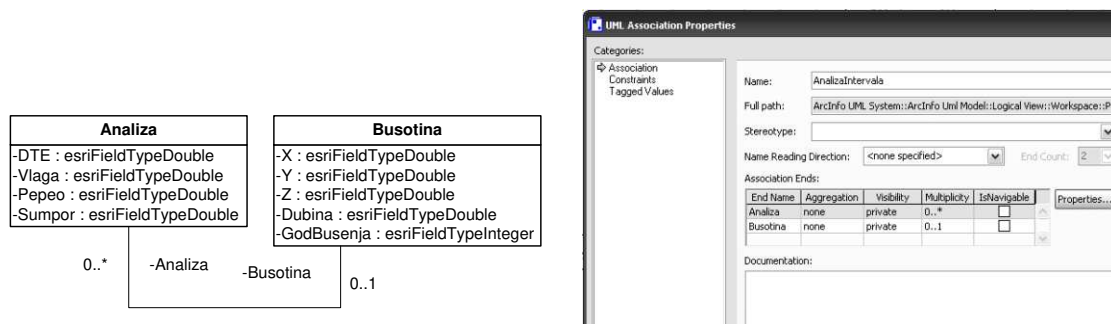


Figure 3. Binary association between *Busotina* and *Analiza* classes

Class diagram *Objekti* (Figure 4) models natural and infrastructural objects within the exploitation area. Having in mind that these objects are often displaced with the development of the pit, the class *StanjeRadova* has been introduced, which models their spatial-temporal dimension [Shumilov et al., 2002]. More specifically, the attribute *Stanje* belonging to the class *StanjeRadova* can take one of the following values: initial, final, three-monthly, half-yearly, yearly, etc. This enables monitoring of the state of works in a specific period of interest.

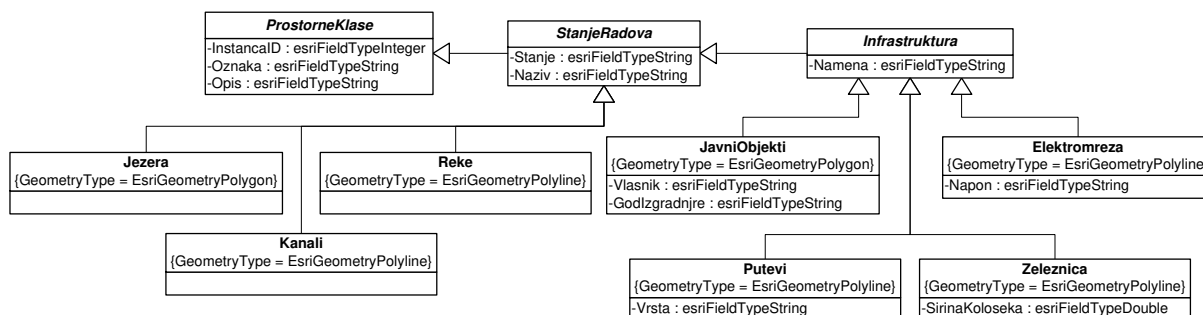


Figure 4. Class diagram **Objekti**

Class diagram *Tehnologija* (Figure 5) models the development phases of the technological process on an open pit (monitors how the works on levels are proceeding, the state of digging, loading and hauling mechanization,...) taking into account the spatio-temporal component [Jovanović et al., 2010].

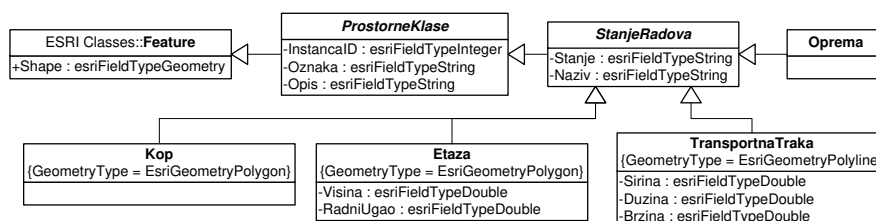


Figure 5. Class diagram **Tehnologija**

MANAGING SPATIAL DATA

Verification of the developed model was performed on data originating from the pre-project and feasibility study for opening and developing the “Field G” open pit (*Idejni projekat sa studijom opravdanosti otvaranja i izgradnje površinskog kopa “Polje G”*). Open pit “Field G” is currently not in function. Its opening, preliminary scheduled for 2015, will provide continuous coal production for the “Nikola Tesla” power plant, even after the open pit “Veliki Crljeni” is closed.

The geodatabase has been populated with data in two ways: by import of relevant data available in appropriate electronic form, from the BpUBS database [Gojak et al., 2011] and by direct import in ArcMap.

Figure 6 depicts the development environment of the OpmGIS base with the content of several thematic layers shown on the left side of the panel, and an overlapped visual representation on the right. The background of the map is set to a spatially referenced orthophoto photograph, followed by polygonal objects (pit contour, deposit contour, public and private objects, lakes), with the line objects (roads, rivers, channels, conveyor belts, railroads, electricity transmission network) and point objects (boreholes, equipment) on top [Stanković et al., 2008]. All objects are georeferenced, that is, entered to an appropriate coordinate system. A simple symbolization and annotation of objects is present on the map, but the system provides for much more complex symbolism (fill patterns, colors, shape of symbols, line patterns,...).

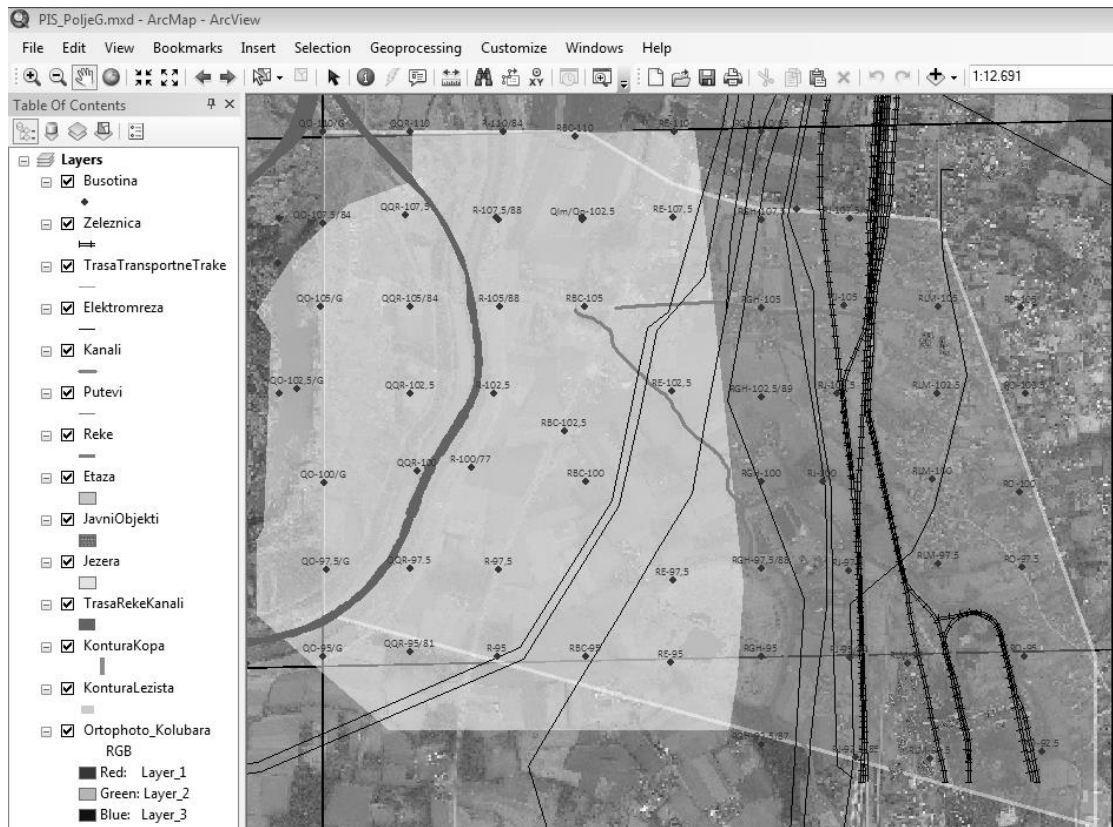


Figure 6. Work map of the OpmGIS base for "Field G" open pit

The power of geodatabases lies in relating geometry and alphanumeric data of spatial objects. These objects can then be represented on a map, while the textual and numerical data assigned to them can be updated. Figure 7 depicts some of the panels used for manipulating data on boreholes. The left side shows attributes of the spatial class, whereas the right side shows characteristic parts of the so-called attribute objects related to the selected borehole. These objects are used for entering interval trials with data on sample analyses, observed lithology and interpreted stratigraphy.

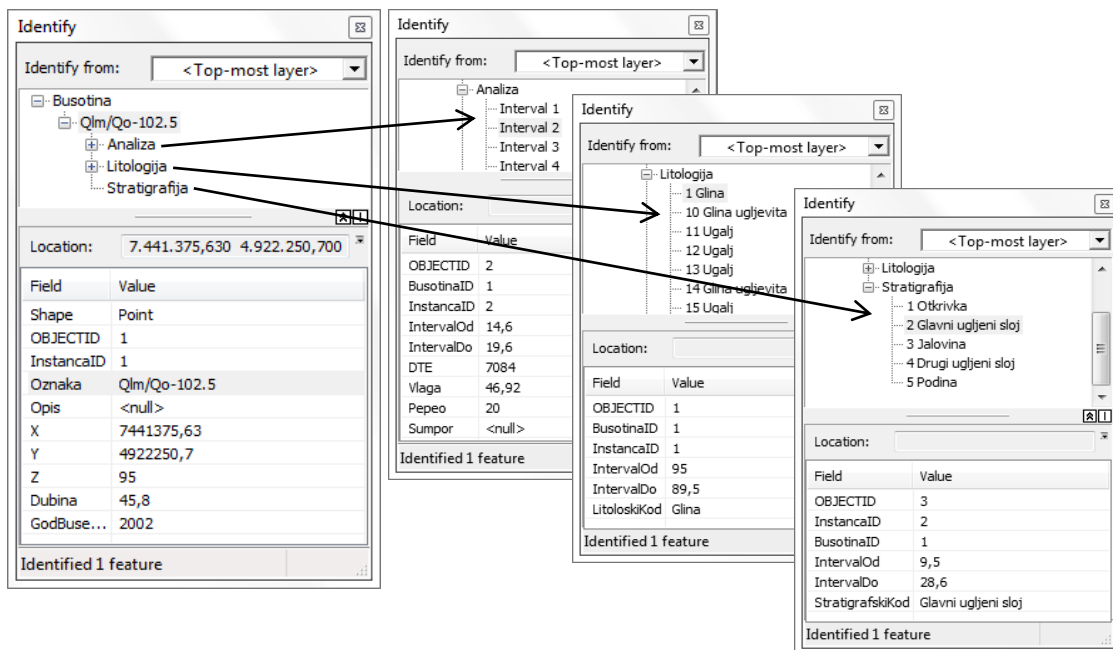


Figure 7. Panels for manipulating alphanumeric data

CONCLUSION

In the paper we outlined the development of a geodatabase for open pit mines, from the phase of logical modeling performed using the UML and CASE tools, to the implementation of a developmental database within the ArcGIS development environment. A systemic approach is suggested for development of complex geodatabases: development of a conceptual model, followed by logical data modeling, and finally creation of a physical model, upon which the database is ready for implementation. Implementation of the OpmGIS database model has been illustrated by the example of the "Field G" open pit. It has been demonstrated how, by means of a visual representation, database users (managers, mining engineers, geologists,...) can have a clear picture of the entire system, and at the same time easily access alphanumeric data. The outlined solution is only the first step in creating an integral GIS system for a mine. Hence, further research in this area will focus on extension of the OpmGIS system with thematic classes related to production, integration with deposit modeling tools, and 3D extension. In the era of web publication of data in all areas, we plan to create a web GIS portal with contents from the OpmGIS database.

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