Eötvös Loránd University, Faculty of Natural Sciences

Theses of the Ph.D. dissertation

Facilities for the solution of geoinformatic problems of geological map processing

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Introduction, objective

I have been working for the Department of GeoInformatics in the Geological Institute of Hungary. I have been engaged in the elaboration and management of the database background of geological maps and the visualisation of geological data, i.e. cartographic processing of maps and profiles and in directing the cartographic–geoinformatic work in some projects .

The traditional task of cartography is the visualisation of spatial data in a way facilitating the recognition of spatial structures and processes providing thus value-added information considering generic geographic as well as specific knowledge of a given profession. Apart from traditional cartographic visualisation methods digital cartography involves geoinformatic and informatic tools as well. Initial data of a digital map is furnished by some database (digital object model). The geo-referenced information stored in a database can be visualised by cartographic methods. Consequently, cartographic modelling is required for digital maps as well. The digital map model can be interpreted as the definition and the application of the graphic attributes of all map objects. In addition to analysing the work phases of the geoinformatic- and cartographic processing it is also necessary to optimise them. In elaborating the technological system an important aspect is the generic, application-independent formulation of the processes.

On the basis of my research tasks the main objectives of the dissertation were as follows:

- to get acquainted with previous national geological maps and map series,
- elaboration of the harmonised geoinformatic database of the superficial geological units of the whole country and the establishment of the optimal technological system,
- support of database-building and harmonisation by automation and algorithms,
- analysis of the cartographic process,
- compilation and cartographic processing of maps of any map-sheet system,
- pre-processing of geological profiles of a drilling database and their cartographic processing,
- support of cartographic processing by geoinformatic tools and automation,
- 3D transformation of printed geological profiles using task-specific algorithms.

The above objectives were formulated essentially during processing two components of the „Geological 3D model of Hungary", such as the 1:100 000 geological map of Hungary and the partially related network of some 150 geological profiles distributed in the country.

Applied methods

During the research work both theoretical and practical methods were used the most important of which can be summarised as follows:

- *overview of science history:* The history of geological maps was addressed from a new aspect. The presentation of their development was focused on their relationship with maps of national significance from the beginnings till today.

- *work analysis*: The work phases of geoinformatic and cartographic processing were examined in the frame of the map model building. The elaboration of the technological system and the phases of the cartographic–geoinformatic tasks were analysed for a national map. In this case, as compared with a one-sheet map not only the elaboration of the map database and the cartographic processes are involved but the sheet division of the seamless database has to be dealt with as well.

- *application of geoinformatic tools:* The establishment of the map database and its analysis proceeds obviously by geoinformatic methods. During visualisation it is important to maintain the database connection of the derived cartographic product as much as possible, ensuring thus the application of primary geoinformatic functions during the cartographic processing as well.

- *statistic analyses:* Different statistic analyses were performed involving the map database to reveal errors of content. The area statistics of map polygons facilitates to filter out the map elements too small to be represented in the given scale. Another statistic test devoted to the determination of the occurrence frequency of the formations on the map enables to separate those occurring rather rarely, which can often be the indication of a mistaken geological index.

- *developing task-specific applications in Visual Basic interface:* Essentially, the geoinformatic softwares provide efficient solutions for map processing tasks but occasionally the user needs to find specific methods mainly in cartographic processing. In general terms, the functions of geoinformatic systems can be accessed in the so-called command mode i. e. by typing in the commands and its parameters which facilitates the running of any different command sets. This interface was used for setting up the automation processes. The applications were developed in Visual Basic interface. These are task-specific applications supporting geoinformatic–cartographic work processes controlling the procedures of geoinformatic systems, as well as pre-processing and using their data.

Results, theses

During the process of map model building, as well as database construction and map compilation the main emphasis was put on maximum automation. Following the analysis of cartographic and geoinformatic work processes I specified the automatable steps and organised their automation by formulating the necessary algorithms.

Theses:

1. *In the process of the geoinformatics-based geological map model building I elaborated the optimal technological workflow concerning the establishment of the national, seamless and harmonised map database and the cartographic processing supported by the cartographic database.*

The work processes were assigned in three main units:

- Map sheet level: development of the database of the map sheet or other processing units as well as checking their geometry and content.
- Map (national) level: edge-matching of the geometry, as well as the content of the processed units and harmonisation of the data of the geological characteristics.
- Cartographic level: cartographic processing of the seamless database, division of the map in sheets.

2. *In the optimal technological set of the map database construction on national level and of its cartographic visualisation I determined the automatable sections and developed task-specific applications for special sub-tasks executed in practice as well.*

The automatable phases of the work process can be listed as follows:

- error check,
- construction of the map database,
- sheet-based division of the map database,
- application of graphic indexes on the cartographically processed map,
- query of the cartographic characteristics of the formations of the cartographic database,
- attachment of a colour scheme to the map,
- preparation of specific legends for different map sheets,
- support of update management.

The basis of the applications ensuring automation is a generic, parameterisable command generator on which I developed the subsystem supporting the database harmonisation as well as the automation module of cartographic procedures. The application can be characterised by updating a non-specifically parameterised command with database-derived parameters and pre-processing for subsequent cluster processing.

3. *In order to support the building of the geological 3D model of Hungary I developed a generic pre-processing tool for the interpretation of profiles. I performed the mathematical formulation of unfolding the spatial geological profiles along their trace and developed the related application resulting in processing the so-called primary profile framework.*

The profile framework processed upon the available databases provides geologists with substantial help in interpreting geological profiles. Four databases were used for pre-processing including the

- drilling database
- database of the profiles' trace
- DTM (digital terrain model)
- 1:100 000 geological map database of Hungary

The basis of the profiles' geological interpretation is provided by the boreholes defining the trace of the profiles. Consequently, the main tasks are the definition of the spatial position of the profile upon the drilling and the trace database and the emplacement and the visualisation of the drillings and their geological sequences in plane. The latter was performed by the mathematical transformation of the co-ordinates. Additionally, the profile framework must include the line of the surface relief which can be derived by the intersection of the DTM and the trace line database. An important requirement against the interpretation of geological profiles is that their content must correspond with the superficial geological setting. Consequently, the profile framework also displays the geological formations crossed by the trace of the profile which can be derived of the intersection of the trace line and the geological map. The pre-processing of 150 profiles for interpretation involves a number of automatable phases. Automation and the co-ordinate-transformation applications were developed using the Visual Basic interface. As a function of the depth and the vertical exaggeration of the profiles the application can freely be parameterised.

4. *I elaborated a method of the projection of 2D profiles in 3D virtual drillings that can be applied for building the geological 3D model of Hungary. I worked out the mathematical formulation of the conversion method of the database-derived 2D profiles in 3D, I determined the geoinformatic steps of the work process and developed an application for the transformation.*

Traditional 2D profiles are inappropriate to be directly used for digital spatial modelling, therefore it is necessary to convert the profile data in 3D and to adjust it in the required co-ordinate-system. The conversion method must be selected in compliance with the objective of the modelling and the modelling software. The geological content of the graphic profiles was acquired by means of virtual drillings: a regular linear grid was fitted on the profiles followed by the determination of its intersections with the geological boundaries enabling to read the intersections' co-ordinates. I formulated the mathematical rules of the co-ordinate transformation of the intersections and using a selected reference point on the profile I adjusted it in real world. The application for the co-ordinate transformation was developed in the Visual Basic interface. The resulting output was the set of points representing the profiles with real world co-ordinates and geological attributes.

Conclusions

In the process of supervising the cartographic–geoinformatic work of the national geological database the primary objective was to solve the tasks of the project of considerably large volume as efficiently as possible and, simultaneously, in suitable quality. Examining the cartographic–geoinformatic work process of the compilation of database-derived geological maps it turned out that some technical steps in both database construction and cartographic processing phases can be automated which is even required for the work to be more efficient. The elaborated automation routines substantially support, accelerate and even standardise the cartographic–geoinformatic work and they diminish the possibility of human errors.

Spatially related information stored in a database can be visualised by cartographic methods. Consequently, cartographic modelling is required for digital maps as well. Geological maps and profiles are the two main visualisation methods of geological data. Their geoinformatic and cartographic processing proceed on the basis of the same principles.

Though some phases of the cartographic process can be automated, it invariably involves some interactive tasks requiring the professional knowledge and aesthetic interference of a cartographer. Automation is of great help simplifying and accelerating the performance of some processes, ensuring more energy and time for the cartographer to creative cartographic work.

Scientific works related to the subject:

Book:

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