GEOMORPHOLOGIC INFORMATION SYSTEM – USE CASES

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Abstrakt. Geomorfologie je interdisciplinární a systematická věda zabývající se studiem krajiny, jejího charakteru a procesů, které ji utvářejí a mění. Geomorfologický informační systém (GmIS) je speciálním typem geografického informačního systému (GIS) se zaměřením na geomorfologii. Geomorfolog jej může využívat při celé řadě úkonů. Základní funkcionalita GmIS spočívá v podpoře sběru, ukládání a správy dat v geo(morfologické) databázi. Dále GmIS nabízí nástroje pro zpracování dat a geomorfologickou analýzu. Také by měl uživateli poskytnout nástroje pro vytváření korektních (karto)grafických, statistických a dalších výstupů. Účelem článku je představit situace (případy užití ~ Use Cases), ve kterých může použití GmIS usnadnit geomorfologovi práci. Dokument je určen k vyvolání diskuse o návrhu systému, která umožní vyjasnit řadu věcí pro účely jeho implementace. GmIS je složitý systém a proto autor považuje širokou odbornou diskusi za klíčovou.

Klíčová slova: geomorfologie, geomorfologická analýza, geografický informační systém, geomorfologický informační systém, geomorfologická databáze, případy užití.

Abstract. Geomorphologic Information System – Use Cases. Geomorphology is a science which deals with systematic study of landforms and their landscapes as well as the earth surface processes that create them. The Geomorphologic Information System (GmIS) is a special type of Geographic Information System (GIS), which can be helpful to geomorphologist in various situations in research. The fundamental functionality of GmIS is to collect, store and maintain relevant geomorphologic data in a geomorphologic database. It also has to offer special analytical tools for geomorphologic analysis. It should allow the user to generate specific geomorphologic information and create (carto)graphic, statistical and other outputs. This article specifies and describes concept of GmIS and situations in which the GmIS can be helpful to a geomorphologist – Use Cases. The document will hopefully start a discussion of the concept, which has to be done before the start of the implementation. GmIS is a complex system, so the detailed clarification and description of the concept is a crucial thing.

Keywords: geomorphology, geomorphologic analysis, geographic information system, geomorphologic information system, geomorphologic database, use cases.

1 Concept of the geomorphologic information system

Geomorphologic information system (GmIS) is being developed in a team containing of professional geomorphologists and geoinformatics. The team described the GmIS visions in precedent articles (Minár et al. 2005 and Mentlík et al. 2006). GmIS can be understood as a specific type of GIS, focused on geomorphologic data[1]. It provides useful geomorphologic tools and techniques, which can be used in various situations. First is a field survey, where GmIS can work as a mobile GIS solution for data collection. Next necessary activity is to store the collected data to the structure of geomorphic database (GmDB). GmDB consist of both collected data and other fundamental data (topography, geology, hydrology, etc.). But the core of its functionality is in geomorphologic analysis, where GmIS can offer efficient tools to process geomorphologic methods in computer environment. Last but not least it of course can serve tools for presentation of created outputs, such maps, graphs, etc.

The concept of the GmIS can be seen from two points of view, technologic and geomorphologic.

From *the geomorphologic point of view*, the GmIS is based on the concept of Elementary forms of a georelief[2]. These areas are elementary parts of a spatial representation of area of interest (AOI). Necessary attributes are being connecting to elementary forms during following geomorphologic research. Elementary forms are (for now[3]) empirically delimitated by a geomorphologist from a digital elevation model (DEM) and derived surfaces of planar and profile curvatures. These forms are consequently revised by field survey. The layer of elementary forms, digital elevation model and layers derived from both of these layers forms the core of the structure of the geomorphologic database (see fig. 1 and next chapter).

From *the technological point of view* is GmIS an environment, which allows the user (geomorphologist) to collect, store and maintain the geomorphic database. Further, it allows user to use and even to create geomorphologic tools for both analysis and presentation of results. Therefore technology demands are high, because selected technology has to have to cover almost all types of geographic software described in Longley 2001:

- Collection of geomorphologic data layers and their storage to geomorphic database (Mobile GIS and GPS for data collection and geographic database for data storage).
- Processing and analysis of geomorphic and geographic layers (Desktop or professional GIS).
- Programming of specific geomorphologic analysis (Component GIS).
- Multi user editing support, data and results publishing (Distributed GIS).

This comparison shows that GmIS could use almost all types of geoinformation technologies. Therefore it was necessary to select sufficiently robust technological platform. ESRI technologies have been selected[4].

[1] The GmIS homepage is: http://gis.zcu.cz/projects/GmIS.

[2] Elementary forms (of georelief) are indivisible fundamental mapping elements of georelief. The whole area covered by one elementary form has homogenous morphometric characteristics (such as altitude, slope, aspect, curvature, etc.) and bounded by breaks in these characteristics (see more in e. g. in Minár 1996, Mentlík et al. 2006).

[3] An algorithm for automatic delimitation of elementary forms is being developed at University of West Bohemia in Pilsen and Comenius University in Bratislava (SK) – Pacina 2007.

[4] Detailed description of technology selection process is in Jedlička 2007.

It follows from above mentioned facts, that a user of such a system cannot be any one but a user with both geomorphologic and geoinformatic knowledge. User roles are outlined later in the chapter of geomorphologic analysis.

2 Geomorphologic database

Geomorphologic database (GmDB) is the structural base of whole GmIS. The unified data base is an integral factor, which subsequently enables development of consequent work flows. Thereby the database has to have understandable and well documented structure and has to be open and extensible of further layers. The key role in the database structure plays the possibility to represent attribute, spatial (geometric and topologic) and temporal relationships among layers. Database structure is described on a conceptual respectively logic level (see fig. 1) in this article, but Entity relationship attribute models (ERA) can be seen in Mentlík et al. 2006 and Jedlička 2007.

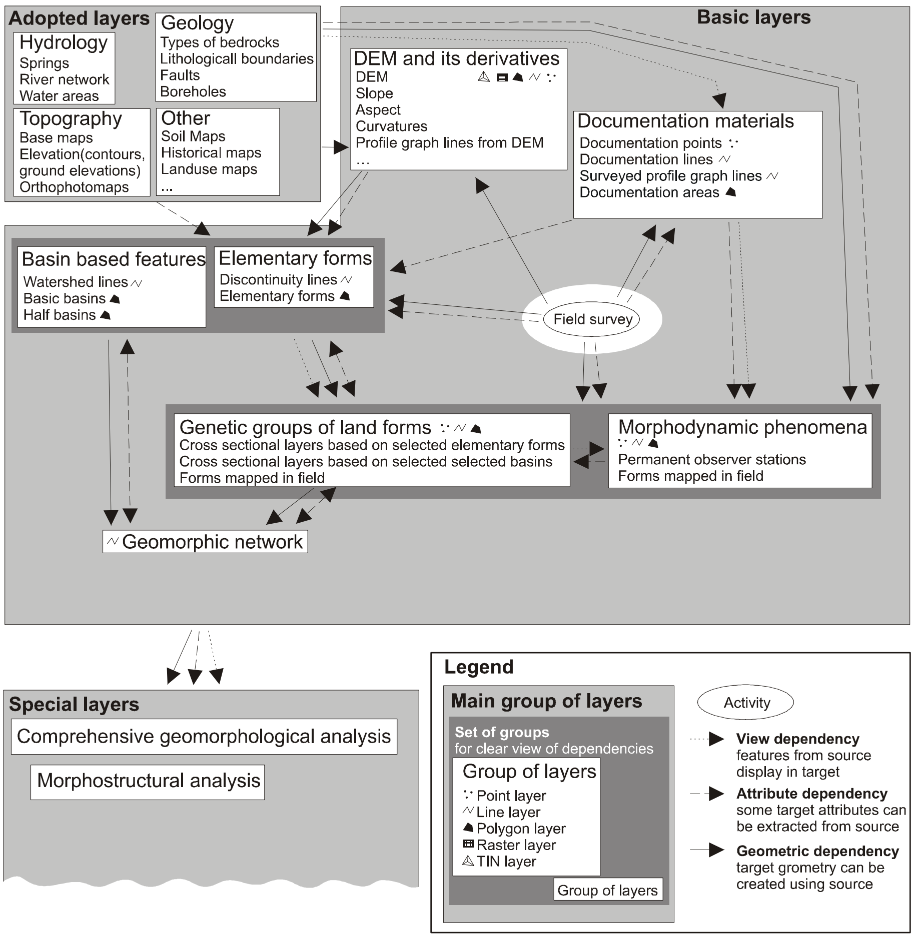

Fig. 1. Logical model of geomorphologic database[5]. Adopted from Minár et al. 2005.

The database structure is divided into three basic groups (taken over Mentlík et al. 2006):

- Adopted Layers – layers taken from external sources. It consists mainly from topographic, hydrologic and geologic data.

[5] Just basic division into layers and groups of layers and functional dependencies are highlighted, to keep the diagram legible. Some kind of naming conventions should be used during the geodatabase design process. Conventions, which followed (ESRI 2007) and (Jedlička 2005), were used in the logical model diagram.

- Basic (geomorphologic) layers – layers created by a geomorphologist; by field survey or by derivation from adopted layers or using them in combination. This group is composed of layers of elementary forms, a digital elevation model (DEM) and its derivatives, documentation materials, genetic groups of landforms, morphodynamic phenomena, basin based features and geomorphologic network.
- Special (geomorphologic) layers – layers created by special geomorphologic analysis, such as morphostructural analysis, comprehensive geomorphologic analysis, geomorphologic hazard evaluation and so on.

The schema of the logical model of the geomorphologic database is depicted at the fig. 1 and deeply described in Minár et al. 2005. Every GmIS built on the geomorphologic database has to have some mandatory layers (adopted layers and basic geomorphologic layers). But each concrete GmIS solution will differ from others, depending on the area of interest. E. g. it can be useful to add some layers (or analytic algorithms). Therefore the GmIS has been drawn as an open system. Detailed information of GmDB structure can be found in Mentlík et al. 2006 and Jedlička 2007.

3 Geomorphologic analysis

Geomorphologic database determines the structure of the GmIS. The structure has of course a naturally static character. Processes are the dynamic part of the system. They shift the system (and of course also the database) from one state to another. GmIS processes can be (according to Longley's 2001 division) divided into following groups:

- Processes for data import from existing sources (to the adopted layers group) ~ geoinformatic role.
- Field survey and collection of thematic (geomorphologic) data ~ geomorphologic role.
- Data processing (storing do the GmDB, building of further database structures, such as various types of relationships) ~ geoinformatic role.
- Geomorphologic and other analyses ~ geomorphologic role.

Two types of user roles come out from this division. A geoinformatic role consists of processes focused on data mining from existing sources, their processing and storing into designed structure. The majority of these operations can be done using standard GIS tools or their chaining; the rest GmIS functionality has to be developed.

The second user role is geomorphologic. A geomorphologist uses GmIS for two main purposes. First time when a geomorphologist can meet GmIS is a field survey (described e. g. in Voženílek et al. 2001 and Voženílek & Sedlák 2004). Second time a geomorphologist can use a GmIS is during geomorphologic analysis. These activities are often specific and standard GIS tools can be used only in limited cases. Usually it is necessary to chain GIS tools into work flows or to create some algorithms, whose do not exist in standard GIS tools. These tools also often have to be combined with interactive inputs of an expert user – the geomorphologist.

Note: An overlap of user roles is possible, of course. In fact, an aspiration of a developer of GmIS is to create such an intuitive user interface, that a geomorphologist would be able to maintain (for the most part) the GmIS alone.

The aim of GmIS is to be a supporting system for geomorphologists. It gives a user the support by automation of the most common geomorphologic processes in GIS environment and by the possibility to of extending the system by further modules. Developing of that kind of system has to be based on a well documented source code (including interfaces) and documentation of data processing and analytical processes, e.g. using unified modeling language (UML), more about UML in Quatrani 2003, Bell 2003a-c.[6]

Application of GmIS to an area of interest can be more difficult than a classical geomorphologic work at the beginning, because of a necessity to get involved into the new technology. But in longer time period, the use of GmIS simplifies and speeds up the work and make results more objective, because GmIS can automate and help to document the analysis process and also serves transparent and comfortable interactive user interface.

4 Use Cases

From the geomorphologist point of view, it is necessary to indentify situations in which GmIS can help him or her. They can be identified and described by Use Cases. Use Case is a description of a typical system usage (see more about use cases in Page-Jones & Voráček 2001). It is necessary to identify and describe all key Use Cases, in order to be possible to start further GmIS development and implementation. Author has been determining these user needs and system processes based (Use Cases) on a consultation with professor Minár and based on work Mentlík 2006. Brief description of fundamental Use Cases follows; more details can be found in Jedlička 2007.

4.1 Geomorphologic database structure creation

Creates a blueprint (empty database structure) of a geomorphologic database according to described logical structural model (see chapter 2). It is possible to copy the blueprint and populate it by data from concrete area of interest. The blueprint has a basic division in three groups (adopted, basic and special layers). Just fundamental layers in basic layers section are contained on the blueprint, but it is possible to create further layers, depending on geomorphologist needs. It is just recommended do not to change names of layers and layer groups included in blueprint, because of backward compatibility to other GmIS applications implemented in other areas.

4.2 Import of adopted layers

Import of existing layers can be processed using standard GIS tools. It consists of (geographic) data format conversions, coordinate systems transformations, etc. It is a typical geoinformatic user role.

4.3 Creation of digital elevation model and derived surfaces

Digital elevation model (DEM) and derived surfaces can be created using standard GIS tools. Derived surfaces mean slope, aspect and planar and profile curvature surfaces. GmIS

[6] The developed code will be published under general public license and the documentation under free documentation license.

implemented in ArcGIS can create these surfaces using ESRI technologies or import them from other analytical GIS, such a GRASS GIS.

4.4 Elementarization of area of interest

Elementarization of area of interest means to divide the AOI into small areas in which basic morphometric characteristics of relief (such as elevation, slope or aspect) have constant or constantly changing value[7] and which completely cover the area – elementary forms of georelief[8]. There are two possibilities of relief elementarization. The first consist of an expert (geomorphologist) interactive identifying elementary forms from digital elevation model (and storing into ElementaryForms blueprinted layer). These forms are afterwards reviewed by terrain mapping ~ field survey (see use case). Following creation of line layer of form's boundaries (DiscontinuityLines) has been already automated (Vracovský 2007). Second possibility firstly creates (parts of) discontinuity lines from DEM and derived surfaces using automated extraction methods based on image recognition algorithms. Polygons of elementary forms are created afterwards[9].

4.5 Field survey

There exist a lot of approaches to a geomorphologic field survey ~ terrain mapping. They are described e. g. in Voženílek et al. 2001 and Voženílek & Sedlák 2004. A recommended mapping methodology can be from technological point of view (the point, the GmIS can help to a geomorphologist) based on a digital mobile mapping unit composed on a global positioning system receiver and a personal digital assistant. The software can be a lightweight mobile GIS client (based on software ArcPad). The mapping tools can be of course further complemented by inclinometer, barometric altimeter, precise GPS, theodolite, etc. Crucial for the client is the communication to the central geomorphologic database. It is based on principles of multi user and disconnected editing (ESRI 2001). There are reviewed elementary forms and mapped documentation materials, morphodynamic phenomena and profile lines during the field survey.

4.6 Processing of an information from documentation materials

Data from documentation materials (and from layer of morphodynamic phenomena) can gives the geomorphologist important information of the AOI, so the geomorphologist can determine genesis of elementary forms. Therefore it is possible to fill an attribute GeomorphologicIndividual and Variety (the fundamental morphogenetic attributes), which describes morphogenetic characteristics of each elementary form. The GmIS provides a graphical user interface for these activities.

4.7 Calculation of morphometric characteristic of elementary forms

GmIS provides tools for calculation of fundamental morphometric characteristics of each form (according to Mentlík 2006):

- area of a form, length of a form boundary;

[7] E.g. an area of a constant slope has linearly changing elevation.
[8] More about elementary forms concept see in Minár 1996, Mentlík et al. 2006.
[9] Development of these algorithms is outlined in Pacina 2007.

- minimum, maximum and average altitude of a form;
- average aspect and slope of a form;
- … and others can be specified.

All of these characteristics can GmIS calculate using a zonal function of Map Algebra Tomlin 1990.

4.8 Creation of higher hierarchic levels

Higher hierarchic levels of relief are polygons created from neighboring elementary forms with common morphogenetic characteristics (higher typological forms) or grouped by the geomorphologist (individual higher forms). GmIS uses a star approach to create all types of higher hierarchic levels. See more in Vracovský 2007.

4.9 Watershed delimitation

Delimitation of AOI into watersheds can be an alternative to an elementary form division. A watershed is a natural part of a georelief. In reality the watershed is an area from which water flows into one stream or river. Watershed delimitation is in GmIS based only on a digital elevation model, the geology structure is omitted. A Watershed (basin) can be further divided into half basins. Comparison of half basins can give information of a symmetry or asymmetry of whole basin.

4.10 Calculation of watershed specific morphometric parameters

A watershed has a different character from an elementary form, so it makes sense to additionally calculate some watershed specific morphometric parameters. They are:

- Horizontal segmentation of watershed (basin) – length of a talweg divided by an area of a watershed.
- Horizontal segmentation of half basin – half of a talweg length divided by an area of a half basin.

4.11 Attributes of Elementary form boundaries (discontinuity lines)

Geomorphologic individual and variety of an elementary form is not determined only from its characteristics, but also from characteristics of neighboring forms and their connections and relationships. Therefore it is necessary to develop algorithms whose can compute attributes to describe spatial interaction of elementary forms. These attributes will be connected to form’s boundaries – discontinuity lines. They can be divided into two groups. First are attributes whose can be computed from the boundary geometry:

- length,
- orientation – direction of a trend line,
- curvature – line length divided by the distance between end points.

Second group is composed of attributes whose have to be calculated from shapes of neighboring elementary forms:

- specific sharpness – difference between average values of each meaningful[10] morphometric characteristic,
- general sharpness – spatial angle of trend planes,
- robustness – attribute informing of boundary significance. The easiest way to express it is to maintain information of areas of adjacent forms. There are also other possible methods in discussion.

4.12 Geomorphic network creation

Creation of a geomorphic network is a geomorphologic expert work, but GmIS can offer tools for objectification of such a process. Technologically, the geomorphic network creation is based on attributes of discontinuity lines, where only lines with some level of significance are taken into the network. GmIS can offer some interactive tools for estimation of boundary relevance. See more about this and even previous Use Cases in Jedlička 2007.

5 Conclusion

The article goal is to present the GmIS conception, especially Use Cases and thereby to boost a discussion with potential users. The database structure is almost finished but a discussion is still possible. The main question to discuss are mentioned Use Cases. Some of them are solvable by standard GIS tools or their chaining but some of them have to be programmed almost from scratch. The discussion can help to develop these tools according to user needs.

References

1. BELL, D. 2003a. UML basics: An introduction to the Unified Modeling Language. IBM. 2003. [on-line] <http://www-128.ibm.com/developerworks/rational/library/769.html>.
2. BELL, D. 2003b. UML basics: Part II: The activity diagram. IBM. 2003. [on-line] <http://www.ibm.com/developerworks/rational/library/content/RationalEdge/sep03/f_umlbasics_db.pdf>.
3. BELL, D. 2003c. UML basics: Part III: The class diagram. IBM. 2003. [on-line] <http://www.ibm.com/developerworks/rational/library/content/RationalEdge/nov03/t_modelinguml_db.pdf>.
4. ESRI. 2001. Introducing to ArcSDE using ArcInfo. Redlands, California. Environmental Systems Research Institute (ESRI).
5. ESRI. 2007. Data Models. ESRI Support Center. [on-line] <http://support.esri.com/index.cfm?fa=downloads.dataModels.gateway>.
6. JEDLIČKA, K. 2007. Geomorfologický informační systém. Teze disertační práce. Ostrava: Technická univerzita Ostrava.
7. LONGLEY, P., A. et al. 2001. Geographic information systems and science. Chichester : John Wiley & Sons, Ltd., 2001. 0-471-89275-0.
8. MENTLÍK, P.; JEDLIČKA, K.; MINÁR, J.; BARKA, I. 2006. Geomorphological information system: physical model and options of geomorphological analysis. In Geografie. year 111, no 1., pages 15-32.

[10] Meaningful characteristic has to be identified by the geomorphologist.

9. MENTLÍK, P. 2006. Geomorfologická analýza a tvorba GmIS pro okolí Prášilského jezera a jezera Laka na Šumavě. Česká republika: disertační práce. Bratislava: Univerzita Komenského v Bratislave.
10. MINÁR, J. 1996. Niektoré teoreticko-metodologické problémy geomorfológie vo väzbe na tvorbu komplexných geomorfologických máp Acta Facultatis Rerum Naturalium Universitatis Comenianae 36, 7–125.
11. MINÁR, J., MENTLÍK, P., JEDLIČKA, K.; BARKA, I. 2005. Geomorphological information system: idea and options for practical implementation. In Geografický časopis. Year 57, no 3, pages 247-266, ISSN 0016-7193.
12. PACINA, J., 2007. Geometrické modelování v Geomatice; Automatizované vymezování elementárních forem georeliéfu jako součást GmIS. Teze disertační práce. Plzeň : Západočeská univerzita v Plzni.
13. PAGE-JONES, M., VORÁČEK, K. 2001. Základy objektově orientovaného návrhu v UML. 1. vyd. Praha : Grada. 80-247-0210-X.
14. QUATRANI, T. 2003. Introduction to the Unified modeling language. IBM. 2003. [on-line] <ftp://ftp.software.ibm.com/software/rational/web/whitepapers/2003/intro_rdn.pdf>.
15. TOMLIN, C. D. 1990. Geographic information systems and cartographic modeling. New Jersey: Prentice Hall.
16. VOŽENÍLEK, V., KIRCHNER, K., KONEČNÝ, M., KUBÍČEK, P., LÉTAL, A., PETROVÁ, A., ROTHOVÁ, A., SEDLÁK, P. 2001. Integrace GPS/GIS v geomorfologickém výzkumu. Univerzita Palackého v Olomouci, Olomouc. 185 s.
17. VOŽENÍLEK, V., SEDLÁK, P. 2004. Mobilní geoinformační technologie v geomorfologickém mapování. Geografický časopis, Bratislava.
18. VRACOVSKÝ, F. 2007. Geomorfologická databáze. Diplomová práce. Plzeň : Západočeská univerzita.