GEOMORPHOLOGIC INFORMATION SYSTEM

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Abstract

Geomorphology is a science which deals with systematic study of landforms and their landscapes as well as the earth surface processes that create them.

Geomorphologic information system (GmIS) is being developed in a team containing of professional geomorphologists and geoinformatics from Commenius University in Bratislava (Slovakia) and University of West Bohemia in Pilsen (Czech Republic). The Geomorphologic Information System is a special type of Geographic Information System (GIS), which can be helpful to geomorphologist in various situations in research. It can be understand as a specific type of GIS, focused on geomorphologic data.

GmIS 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 geomorphologic database (GmDB). GmDB consists of both collected data and other fundamental data (topography, geology, hydrology, etc.). But the core of GmIS 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.

Geomorphologic information system consists of three main parts: geomorphologic database, geomorphologic tools and workflows (Use Cases).

The geomorphologic database (GmDB) is conceptually divided in three main groups of layers:

Adopted layers are layers which have been taken from external sources, such as hydrology, geology, topography and others.

Basic layers are layers which are 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 layers are layers created by special geomorphologic analysis, such as morphostructural analysis, comprehensive geomorphologic analysis, geomorphologic hazard evaluation and so on.

Geomorphologic tools (GmT) are instruments which can be used by Geomorphologist in various situations during his or her research of area of interest. They are implemented in ArcGIS and can be divided into two separate groups:

First group consists of typical batch oriented tools where one (or more) layer is the input and another layer(s) is the output. These tools are grouped in Geomorphologic Toolbox - specific set of tools which can be added as typical ArcToolbox.

Second group consists of interactive tools whose can be used in different situations. These tools are accessible from Geomorphologic Analyst - an extension of ArcGIS conceptually similar to e.g. Spatial Analyst, 3D Analyst, but focused on Geomorphology.

Geomorphologic tools can be thematically chained into pathways which are described in Use Cases. All Use Cases are described in the article Geomorphologic Information system - Use Cases presented at Symposium GIS Ostrava 2008.

Technologically, the GmIS is a system based on ESRI platform. It can be understand as a plug-in to ESRI software ArcGIS. The GmIS plug-in is published and distributed under the license based on GPL. Of course that ESRI products are not included, they have their own licensing. The GPL applies only on a source code developed by the GmIS authors.

Keywords: Geomorphologic information system, geomorphologic tools, geomorphologic database, system design and development

Introduction and definition of objectives

This paper summarizes the work which has been done on the development of Geomorphologic information system (GmIS) during last five years. It describes the design, development and implementation process of GmIS from the conceptual model to the physical model and implementation.

First, it is important to quote definitions of terms used in the article (already mentioned e.g. in Jedlička 2009):

Geomorphology is the interdisciplinary and systematic study of landforms and their landscapes as well as the earth surface processes that create and change them IAG 2009.

Geomorphologic Information System (GmIS) can be broadly understood as a geographic information system which deals with geomorphologic data (e. g. Barsch, Dikau 1989, Dikau 1992, Minár 1996, Kusendová 2000, Voženílek et al. 2001). The author of this paper cooperates at development of GmIS, as is described in Minár et. al 2005 and Mentlík et. al 2006:

Geomorphologic Information System (GmIS), as a special type of geographic information system (GIS) focused on collecting, maintaining and analyzing geomorphic information, is an excellent tool for geomorphologic analysis. Mentlík et. al 2006.

The object of GmIS is an elementary (land)form of georelief. The purpose of GmIS is comprehensive geomorphologic research. Minár et. al 2005.

The GmIS described in above mentioned publications is understood as a tool, which helps an expert to improve his/her work in both quantitative and qualitative way. GmIS can automate and thus speed up many operations but also can offer new methods and techniques.

From the geomorphologic point of view, the GmIS is based on a concept of elementary forms of georelief, whose continuously cover the area of interest. The definition of elementary form follows:

Elementary form (of georelief) is (at particular level of detail) geometrically homogeneous face with uniform genesis and assumption for homologous run of recent geomorphologic processes (dynamics of development). Therefore, elementary form boundaries mark breaks in geometric, genetic and dynamic homogeneity. Thus it is possible to say that elementary form is, at particular level of detail, naturally bounded fundamental segment of georelief. Adapted from Minár 1996.

As can be clearly seen from above mentioned definitions, the objective of building GmIS is to help geomorphologist in all situations during the geomorphologic research. GmIS is not a tool replacing the expert, it is a tool which helps him/her to speed up and automate as many activities as is possible, but the result interpretation is still the task for geomorphologists.

GmIS development

Geomorphologic information system is being developed in a team containing of professional geomorphologists and geoinformatics from Commenius University in Bratislava, University of West Bohemia in Pilsen and University of Jan Evangelista Purkyně in Ustí nad Labem. The team consists of geomorphologists:

- *Jozef Minár, Ján Sládek* – Comenius University in Bratislava.
- *Pavel Mentlík* – University of West Bohemia in Pilsen.

And geoinformatics:

- *Karel Jedlička, Jakub Šilhavý* – University of West Bohemia in Pilsen.
- *Jan Pacina* – University of Jan Evangelista Purkyně in Ustí nad Labem.

Geomorphologists play the key role in definition of general concept and user needs of GmIS. Concepts of GmIS are described in Minár et. al 2005 and Mentlík et. al 2006. Geomorphologic analysis which can be done in GmIS environment is described in Mentlík 2006. |User requests were recorded in the form of Use Cases and are described in Jedlička 2008.

Geoinformatics afterwards design and implement the GmIS concept into the digital environment. Author of this article is the main system designer, even if he does not implement the whole system alone. Implementation of physical structure of geomorphologic database (GmDB) was started in diploma thesis Vracovský 2007 (supervisor Jedlička). Pacina 2008 described methods of automated delimitation of elementary forms of georelief. Šilhavý developed some tools, whose can be used for field survey and processing of collected data[1]. Now he works on client/server solution of GmIS.

General system design

Plenty of methods of system and database design and development are described in literature. But all of them can have three main models/stages:

- Conceptual model – description of user needs.
- Logical model – transforming user needs into proposed data structures and system processes.
- Physical model – a blueprint for system implementation.

These models are designed stepwise and the process of system design can be iterative.

There are also two main system parts: data structures and processes. Processes can be modelled using e.g. flowcharts (see e.g. http://www.flowchart.com/). Entity Relationship Attribute model (ERA model) can be used for designing the data structures (see e. g. Longley et al. 2001 or Arctur & Zieler 2004 for geographic databases). But methods based on Unified Modelling Language (UML) allow the designer to use one

[1]http://git.zcu.cz/wiki/index.php/GmIS_GmT_DEMProfileLinesComparsion,
http://git.zcu.cz/wiki/index.php/GmIS_GmT_GUIForEditingElementaryForms

language and environment for modelling the whole system, see more in Bell 2003a,b,c and Quatrani 2003. Nowadays the mainstream of system design uses methods based on UML. E.g. Kruchten 2000 describes the Rational Unified Process (RUP) methodology, which is based on UML.

Design and development of GmIS

The knowledge of above mentioned formal methods of system design system was being acquired continuously during the system development. Therefore there exist a clear way from conceptual to physical model, but different descriptive instruments were used.

The main vision and concept of GmIS is outlined in Minár et. al 2005. There is depicted the geomorphologic point of view on GmIS and designed a fundamental conceptual-logic model of a geomorphologic database (GmDB), which is the core of GmIS – see figure 1.

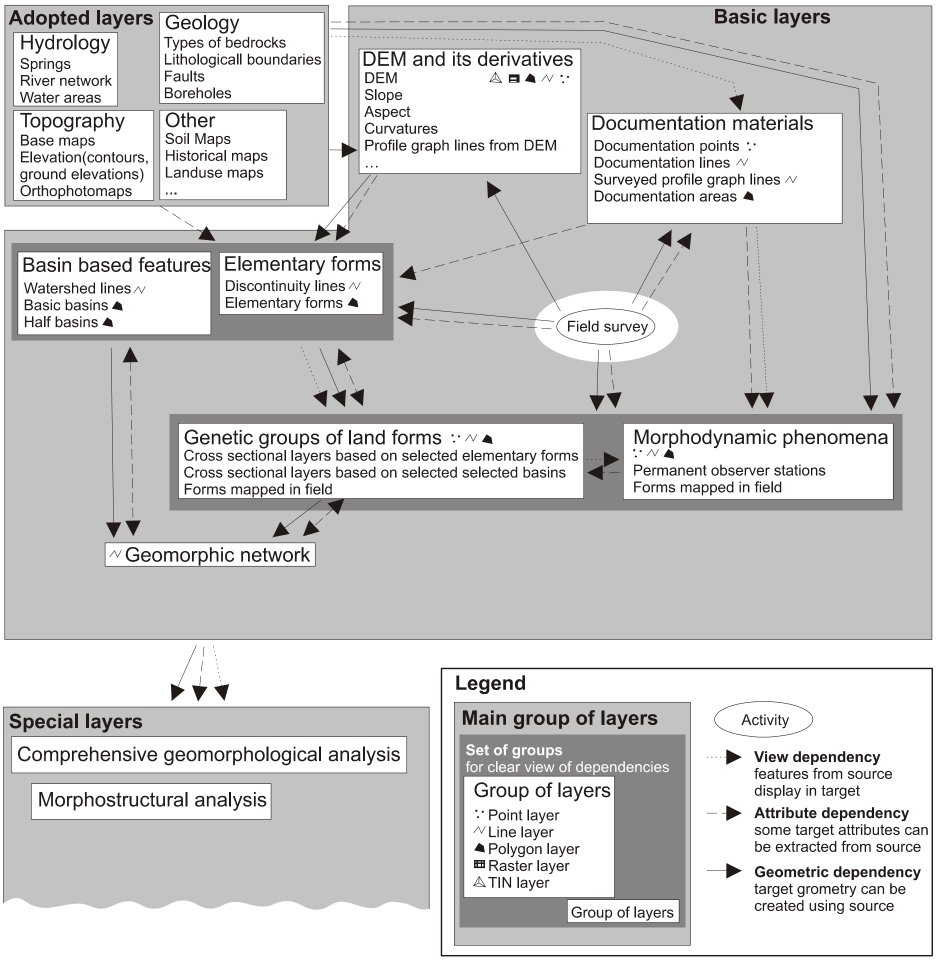

Figure 1. Conceptual-logic model of the complex geomorphologic database with core functional dependencies (Minár et al. 2005).

There is depicted the basic division into logical groups of layers (brief description taken from Mentlík et. al 2006):

- *Adopted layers* – layers which have been taken from external sources, such as hydrology, geology, topography and others.
- *Basic layers* – layers which are 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 layers* – layers created by special geomorphologic analysis, such as morphostructural analysis, comprehensive geomorphologic analysis, geomorphologic hazard evaluation and so on.

Figure 1 also shows dependencies among layers whose indicate the processes in GmIS, which were recorded as Use Cases (see below).

There had to be selected a software platform to use. The ESRI platform was selected because of three main reasons:

- It is wide platform covering all types of geographical software from mobile GIS over viewers, desktop and analytical GIS, to server side GIS.
- It supports a rich spatial database platform (ESRI Geodatabase) which allows a user to take advantage especially from to topologies.
- It has rich possibilities of customization analysis, using models based on flowcharts, scripting or programming.

And last but not least, it is widely spread.

The work which was done at physical database structure and core processes of GmIS is described in (Mentlík et. al 2006). There is described the fundamental part of geomorphologic database – elementary forms[2] and layers and information which are derived from them. There are described models whose were implemented for calculation of basic morphometric characteristics and database structure which maintains computed results. Furthermore the structure for storage of morphodynamic attributes is depicted[3]. This work is important also because it describes the first pilot study of GmIS[4].

After this pilot study, the description of user needs from GmIS was formalized as Use Cases (Jedlička 2008)[5]. It was necessary to identify and describe all key Use Cases, in order to be able to start further GmIS development and implementation. Author determined these user needs and system processes (Use Cases) based on a consultation

[2] Delimited by geomorphologist in field and using digital elevation model in GmIS environment.
[3] And later implemented into GmDB structure in Vracovský 2007.
[4] Further development of GmIS in this area is described in Mentlík 2006.
[5] Use Case is a description of a typical system usage (see more about use cases in Page-Jones & Voráček 2001).

with professor Minár and based on Mentlík 2006. List of fundamental Use Cases follows. The list is ordered according to typical sequence of work in GmIS:

- Geomorphologic database structure creation.
- Import of adopted layers.
- Creation of digital elevation model and derived surfaces.
- Elementarization of area of interest.
- Field Survey.
- Processing of information from documentation materials.
- Calculation of morphometric characteristic of elementary forms
- Construction of higher hierarchic forms (typological, individual).
- Basin (and half-basin) delimitation.
- Calculations of basin related characteristics.
- Calculation of (elementary) forms boundary attributes
- Creation of geomorphic network.

Description of all Use Cases of GmIS can be found in Jedlička 2008. These Use Cases are blueprints for developing methodologies and implementing processes in GmIS. The brief description of current state of GmIS development follows:

There exists a sample geodatabase structure. Handling with the data can be done partially using standard GIS tools and partially using special geomorphic tools (e.g. for hydrologically correct digital elevation model or for creating higher hierarchical levels from elementary forms or computing their basic and special morphometric characteristics). There exists methodology for collecting data in field and storing it into geodatabase. The data processing is focused on interpreting the data from layers of documentation materials. Currently the development is focused on basin delimitation and calculation of their morphometry. The elementarization of georelief was algorithmically solved but it has not been implemented to GmIS environment yet. There is still necessary to do some work on final steps in creating the geomorphic network. Also the system is still opened to new types of use cases. Nowadays, the method of computation of base surfaces (described earlier in Jedlička & Mentlík 2003) is being tested and its involvement to GmIS is planned.

This introduces the current state of GmIS. Shortly said, there is strong structural model of GmIS (based on geomorphologic database) and many tools developed, during heterogeneous activities. Now it is possible to take advantage of the selected platform (ESRI software) and integrate them together.

GmIS prototype

The GmIS prototype is built on ESRI software and can be seen as a geomorphologic extension of ESRI GIS. The analytical core of GmIS is based on the desktop ArcGIS (composed of ArcMap, ArcCatalog and ArcToolbox). ArcPad is used as a mobile solution for field survey. There is also a plan to migrate GmIS into network environment, using ArcGIS Server.

Thus it is clear that the GmIS prototype is not just software. It is composition of (of course hardware), software, data structures and data, methods and people, who operates the GmIS[6]. The prototype is depicted at the figure 2.

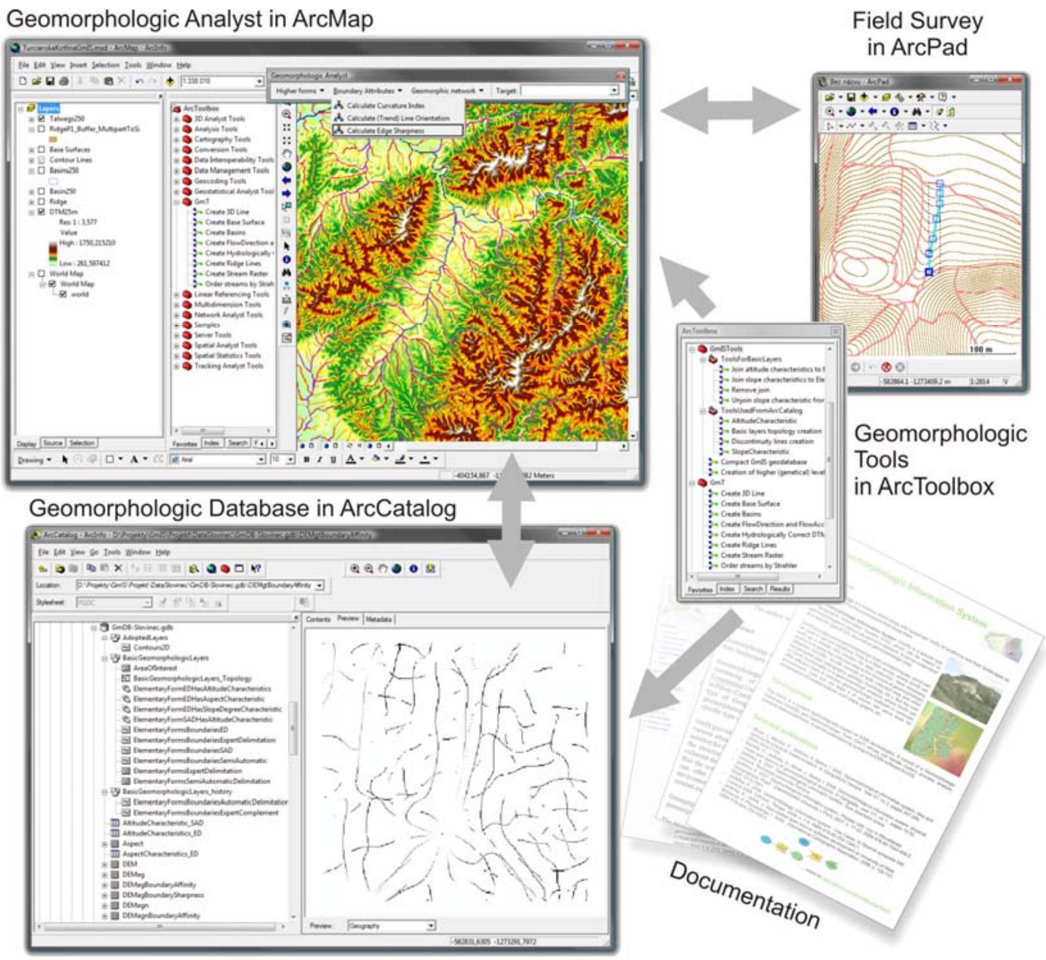

Figure 2. The prototype of GmIS.

The core of GmIS structure is already mentioned geomorphologic database, stored in ESRI geodatabase format and managed through standard and customized (geomorphologic) tools from ArcCatalog. ArcMap allows a user to use geomorphologic tools whose are focused on analysis and also hosts a Geomorphologic Analyst – extension for interactive geoprocessing and analyses. ArcMap of course communicates with ArcCatalog (for data loading and handling) and also can check out and prepare data for field survey with ArcPad and consequently allows user to check the data back into geomorphologic database and process and analyses results from field survey. There

[6] Can be seen that this description follow the structural components of GIS.

also exists more or less documentation of each segment of GmIS. Detailed and continuously updated information of the state of the art of GmIS can be found at project web pages http://git.zcu.cz/wiki/index.php/GmIS.

Discussion and conclusion

This is a summarizing paper which shows brief description of GmIS development and describes the GmIS prototype. It provides references to previous works, whose were published on the GmIS topic.

During the design and development process there were couple problems caused mainly because the knowledge of formal methods of system design system was not be completely known in the team at the beginning. But the open structure of GmIS and selection of robust software platform has eliminated all of them.

The prototype is not ready to download yet, but there are beta testers of GmIS (Czech Republic, Slovakia, Ecuador) and it is possible to contact the author and get both the latest version and the support. Whereas it is an extension of commercial software, it is still necessary to have at least an ArcEditor license of ArcGIS and Spatial Analyst Extension. The use of GmIS still needs a user who has strong geomorphologic and geoinformatic erudition.

Therefore the future development is divided into two ways. First is of course focused on implementing further geomorphologic tools whose can be combined to various types of geomorphologic analyses. The second is focused on encapsulation of the GmIS geoinformatic complexity using server side technologies.

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