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Geomorphologic informatic system – prototype

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Abstrakt:

Geomorfologický informační systém (GmIS) je specifický typ GIS zaměřený na analýzu geomorfologických dat. Prototyp GmIS je založen na softwarové platformě firmy ESRI, kterou rozšiřuje a přizpůsobuje pro potřeby geomorfologie. Analytické jádro GmIS je postaveno nad desktop software ArcGIS. Sběr dat v terénu je prováděn s využitím GPS a mobilního geografického software ArcPad. Je uvažováno o budování tenkého klienta komunikujícího s ArcGIS Serverem. GmIS však není pouze software, jedná se, podobně jako u klasického GIS o hardware, software, data, metody i uživatele.

Strukturní základ dává GmIS geomorfologická databáze (GmDB) navržená pro potřeby uložení geomorfologických dat. Je uložená v ESRI Geodatabase a spravovaná pomocí standardních i přizpůsobených (geomorfologických) nástrojů v aplikaci ArcCatalog. Geomorfologické nástroje (Geomorphologic Tools – GmT) zaměřené na dávkovou analýzu jsou uživateli k dispozici v ArcToolbox v aplikaci ArcMap. Z ArcMap lze také spustit Geomorphologic Analyst – nástrojovou lištu, umožňující provádění interaktivních analýz. V ArcMap je dále možno připravit podkladová data pro terénní výzkum a hlavně potom sebraná data zpracovat a analyzovat. V rámci vývoje prototypu GmIS vznikla celá řada publikací, která slouží jako dokumentace k systému. Odkazy na publikace i základní popis GmIS lze nalézt na webové adrese http://git.zcu.cz/wiki/index.php/GmIS. Příspěvek byl podpořen Výzkumným záměrem MSM 4977751301.

Klíčová slova: Geomorfologický informační systém, geomorfologické nástroje, geomorfologická databáze

Abstract:

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.

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.

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 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. The author was supported by the Research Plan MSM 4977751301.

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

1 Concept overview

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.

This paper describes the prototype of GmIS, which is the result of GmIS development in last five years. It presents the way of possible usage of the GmIS in a geomorphologic research. The process of design, development and implementation of GmIS is summarized in Jedlička 2009b. Minár et. al 2005, Mentlík et. al 2006. Jedlička 2007, 2008 describes the system design and the way of system development. The sample of implementation of geomorphologic tools is described in Jedlička 2009a. 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.

The GmIS is based on the concept of elementary forms of georelief. From the geomorphologic point of view, **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. Elementary forms are stored in GmIS using dual representation: polygon for area each of each elementary form and polylines for segments of elementary form boundaries (see more in Jedlička 2009a).

2 Used technology

This subsection shows the detailed view on technology which is used for implementation of GmIS[i]. ESRI software platform has been selected and ArcGIS is used as a framework of GmIS development.

The *Geomorphologic database* (see more detailed description bellow) is stored in a specific structure in ESRI geodatabase. The geodatabase is a common data storage and management framework for ArcGIS and can be utilized wherever it is needed – on desktops, in servers (including the Web), or in mobile devices. It supports all the different types of data that can be used by ArcGIS such as attribute tables, geographic features, satellite and aerial imagery, surface modeling data and survey measurements. See more at page:
http://www.esri.com/software/arcgis/geodatabase/index.html.

ArcGIS also provides the framework for development further tools – in this case *Geomorphologic Tools* (GmT, their descrition see also bellow). This framework is based on ArcObjects. ArcObjects is a set of platform-independent software components, which provides services to support creating of both GIS applications and tools on the desktop and on the server. See more at page:
http://edndoc.esri.com/arcobjects/9.2/NET/5bd93a2b-1c00-4927-ab26-5fbe3891a448.htm.

There are used three programming languages for ArcGIS customization during the GmIS development:

- ModelBuilder – a graphic scripting language. See more at page: http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=An_overview_of_ModelBuilder.
- Python – scripting language. More about python integration into ArcGIS can be found at page: http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=720&pid=717&topicname=Writing_Python_scripts.
- Visual Basic for Application (VBA) – tiny programming language. The VBA code can be easily used into Visual Basic. See more at page: http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=5623&pid=5622&topicname=Getting_started_with_VBA.

All above mentioned languages have a built in development environment encapsulated in ArcGIS, thus no additional software is needed. The choice of using particular language is of course a question of programmer skills but mainly it depends on whose ArcObjects can be accessed using the particular language.

First two possibilities are similar and allow a programmer to access a subset of ArcObjects focused on geoprocessing[ii]. The advantage of programming in ModelBuilder/Python is in their cohesion (the model can be converted into a python script and the script can be added into a model) and simplicity: once a tool is created, it can be used in another model by any user.

The advantage of using VBA is in accessing the full ArcObject model. Whence it follows that a programmer has possibility to automate any process in GIS, which can be formalized in design model, or customize any part of GIS graphic user interface.

The usage of particular language in GmIS development is driven by a character of concrete task. The selected technology allows a developer to profit from many existing GIS tools for data processing. The developer can use ArcObjects as building blocks for creation new data processing and analytic tools. Even the possibility to migrate from the desktop environment to the web is open in the future, because compatible ArcGIS Server technology can be used.

3 Structure and ways of usage of the prototype

The GmIS prototype is a set of tools whose can be used in several ESRI applications. The prototype is built to help a geomorphologist during the whole research. Thus it follows typical GIS operations (used during data collection, processing and storage, analysis and presentation of results) and complements them with geomorphologic aspect.

The basic description of GmIS prototype is in Jedlička 2009b. 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. As mentioned above, there is also a plan to migrate GmIS into network environment, using ArcGIS Server.

Thus it is clear that the GmIS is not just software. It is composition of (of course hardware), software, data structures and data, methods and people, who operates the GmIS[iii].

The structure of GmIS prototype is depicted at the figure 1.

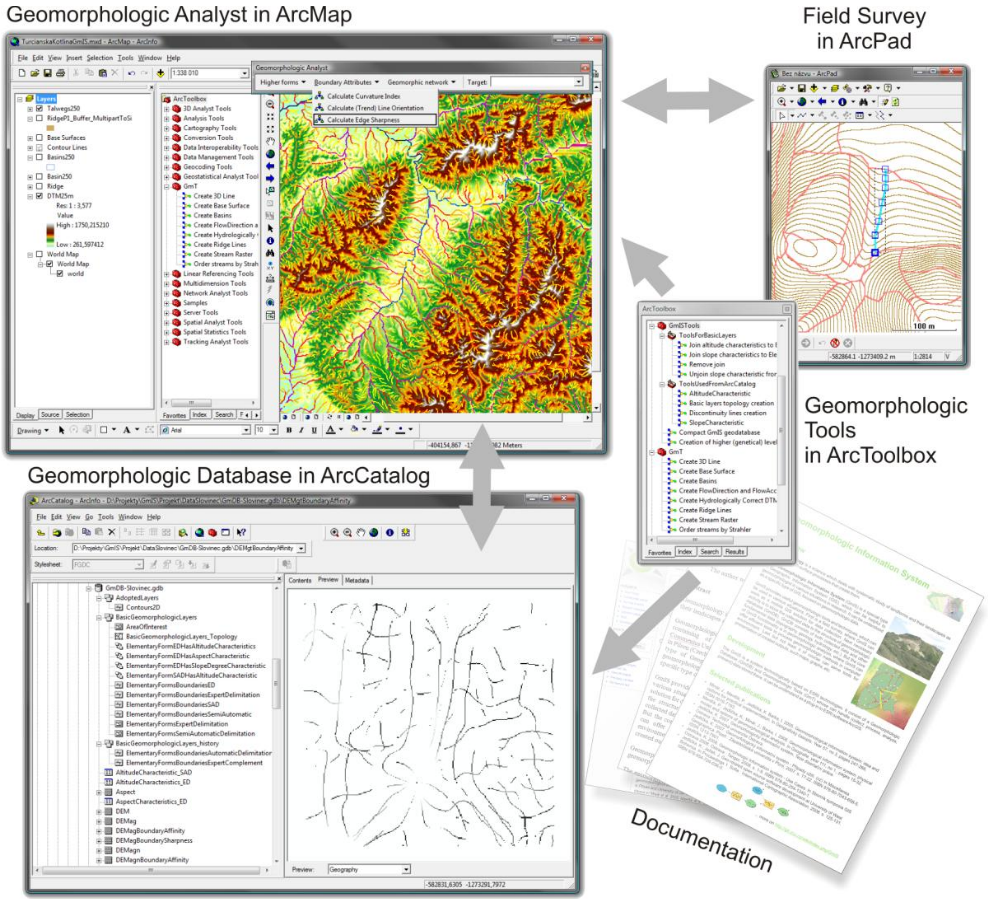

Figure 1. The prototype of GmIS (Jedlička 2009b).

ArcMap allows a user to use geomorphologic tools whose are focused on analysis and also hosts a Geomorphologic Analyst – an 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 also exists more or less documentation of each segment of GmIS.

Particular parts and processes of GmIS are described bellow during the description of typical activities in a project work in the area of interest. Going through the activities, there are mentioned standard GIS tools and described developed geomorphologic tools.

3.1 Geomorphologic database creation and population with fundamental data

The core of GmIS structure is already a geomorphologic database (GmDB) managed through standard and customized (geomorphologic) tools from ArcCatalog. The work with geomorphologic database can be divided into two parts: developing the structure and populating by the data. The structure was defined in Minár et. al 2005 and can be used as a blueprint for geomorphologic database of any area of interest, even it is not necessary to use all designed data layers. The database has three key parts (datasets): adopted layers, basic geomorphologic layers and special geomorphologic layers.

Firstly usually adopted layers are populated, mostly with topographic elevation data (contour lines, elevation spots) and hydrology; sometimes also with geologic data (if it is available). It is managed using standard GIS tools.

Next necessary step starts population of basic geomorphologic layers and consists of creation of digital elevation model (DEM) in raster representation (because many analytic tools work with such a DEM). There is crucial to create raster representation suitable for correct geomorphologic interpretation. Generally it means to create smooth and hydrologically correct DEM. Even if it looks easy and solvable by standard GIS tools, it is not a simple task and it is necessary to carefully set up input parameters. The possible way of creation of such a surface representation is described e.g. in Jedlička, Sládek 2009 or Kadlčíková and Tuček 2008.

Following step is to create a fundamental segmentation/elementarization of area of interest into elementary forms or alternatively into watersheds. The watershed segmentation can be done by chaining existing geoprocessing tools into a model (for theoretical background see e.g. Jedlička and Mentlík 2002). The situation is more complex in a case of elementary forms segmentation, because these days, there is no automatic tool. There exists a semi automatic tool described in Pacina 2008, but it delimits just segments of boundaries and works only with terrain morphometry. However there is also important the interpretation of morphodynamic information which has to be performed by a geomorphologist. The other present possibility is a manual segmentation based on DEM interpretation.

Note: Further just the segmentation on elementary forms of georelief is described and it is also called elementarization of the area of interest.

3.2 Field survey – verification of the segmentation

Regardless of the way of the relief segmentation, it is important to verify the layer of elementary forms in field. The field survey can be of course made in a classic way with printed paper map, but GmIS allows using mobile GIS application ArcPad customized for collecting geomorphologically focused documentation materials.

The standard GIS tools take care of the mechanism of checking the data out and back in the geodatabase. The customization of field survey consists of:

- preparing the right data layers to check out,
- forms, whose helps to easily create the documentation of found facts and georeference them to point, line or polygon features (documentation materials),
- tool *Update Elementary Form* in ArcMap, which opens the edit dialog for attributes of selected elementary form and displays all features from documentation materials, whose are topologically related to the identified elementary form. This help the interpretation of the collected data and their transformation to (mostly morphodynamic) attributes of elementary form (see fig. 2 for sample).

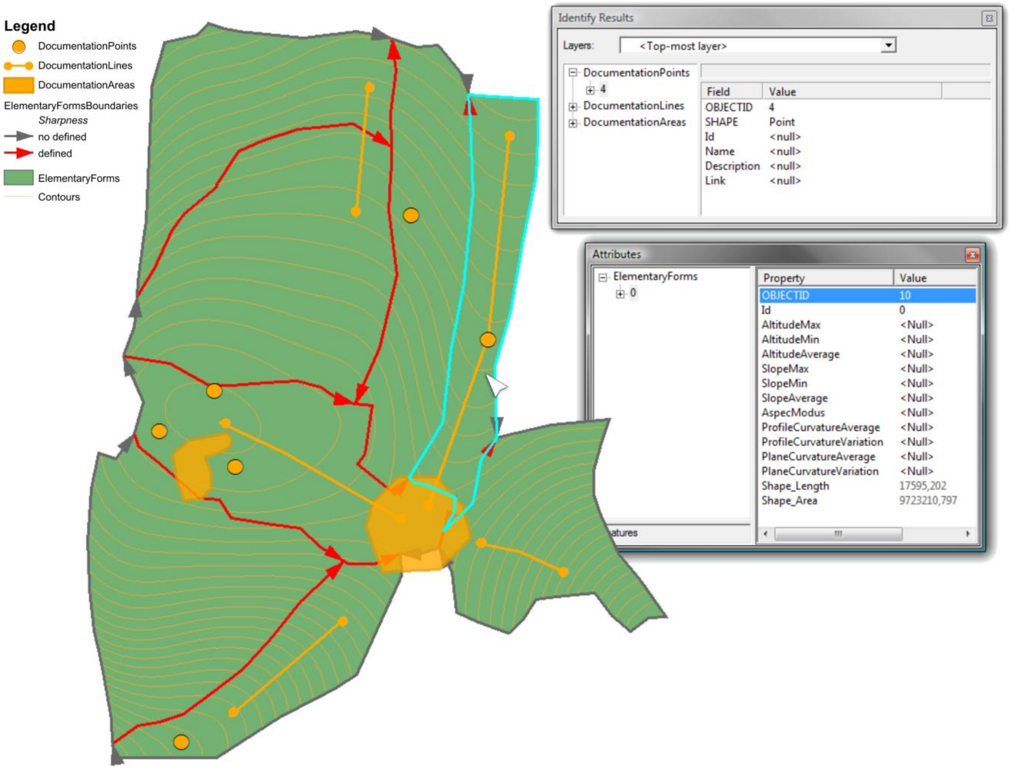

Figure 2. Processing of field survey in ArcMap using *Update Elementary Form* tool.

3.3 Complementation of geomorphologic layers

When the layer of elementary forms is verified in field survey, it is time to continue in population of geomorphologic database. Geomorphologic set of tools (*Calculate Altitude / Slope / Aspect Characteristics*) combines elementary forms with DEM, calculates basic morphometric characteristics of each polygon of elementary form (see fig 3), stores it to geomorphologic database and relates it to the layer of elementary forms.

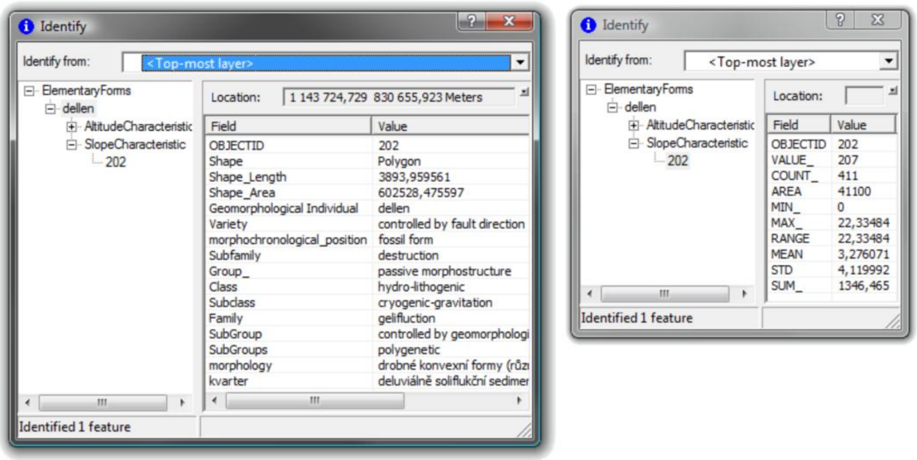

Figure 3. Example of attributes of elementary form with computed slope morphometric characteristics.

Based on filled morphodynamic attributes (see e.g. on fig. 2, more in Mentlík 2006) it is possible to derive higher hierarchic levels of relief segmentation (see more in Vracovský 2007). These created layers are then topologically connected to original elementary forms layer (based on star approach of generalization – each higher layer is derived directly from the original, see more in Stoter 2006).

Last but not least, more complex morphometric attributes are computed. Above mentioned morphometric characteristics are related to the area of one particular elementary form. But there are also characteristics whose are related to a boundary between two forms. They are divided into two groups. First group is related to the geometry of the boundary:

- *Boundary length* – automatically computed by the DBMS.
- *Boundary curvature index* is a quotient of boundary length and Euclidean distance of start and end node (see fig. 4). From the geomorphologic point of view, wherewith straighter and longer boundary is thereby it is more important.
- *Boundary orientation* is a direction of the direct flowline of start and end node. For the purposes of GmIS, the orientation of boundary outgoing from the node X to the node Y (see fig. 1) is equal to orientation of boundary outgoing from the node Y to the node X. The zero orientation is defined as the direction to the North Pole, see fig. 4.

The second group consist of differential characteristics whose have to be computed from the data of both boundary adjacent elementary forms. Basic example of differential characteristics is general boundary sharpness defined as absolute value of difference between area of right and left elementary form (fig. 4). This is implemented under the tool called *Calculate Edge Sharpness* (and it is possible to modify the developed code to calculate other types of differential characteristics.

Further description of computation of edge characteristics can be found in Jedlička 2009a.

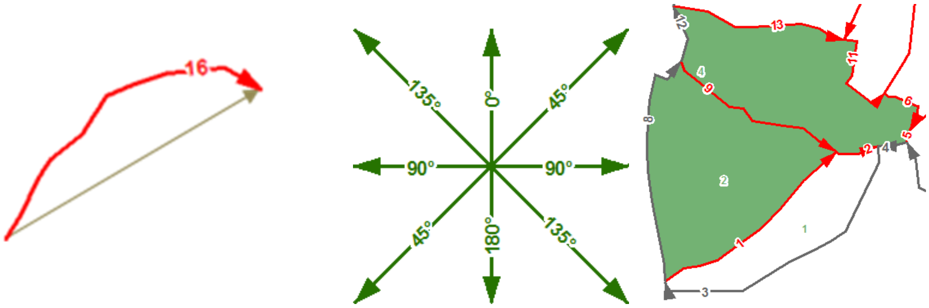

Figure 5. Visualization of boundary curvature index (on the left), boundary orientation (in the middle) and boundary sharpness (on the right), adopted from Jedlička 2009a.

3.4 Geomorphologic expert work

The next work with GmIS is upon a geomorphologist, who has to analyze and interpret the gathered and computed data to turn them into useful and geomorphologically relevant information. This work usually consists of creating a geomorphologic network created from significant parts of elementary form boundaries. The creation of geomorphologic network is described e.g. in Mentlík 2006.

4 Discussion and conclusion

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 GmIS prototype is still under development but it is possible to use its beta version. How to obtain a prototype is accessible at project wiki page http://git.zcu.cz/wiki/index.php/GmIS together with further information of the GmIS project.

GmIS project is open to new people for further development. Nowadays the work is focused on implementation of computation of base surfaces (theory in Jedlička and Mentlík 2002, description of implementation and case study in Jedlička and Sládek 2009). There is also a plan to migrate to client server software architecture which would allow a geomorphologist to use just standard web browser while the ArcGIS Server would operate at the server side.

Geomorphologic information system is an instrument which could be helpful in the hands of geomorphologist. It is just his/her decision whose parts of geomorphologic database to populate and whose geomorphologic tools to use.

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