

Vývoj geomorfologických nástrojů v prostředí Geomorfologického informačního systému

Development of geomorphologic tools in the framework of Geomorphologic Information System

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Abstrakt: Geomorfologický informační systém (GmIS) je v tomto článku chápán jako systém postavený na konceptu elementárních forem georeliéfu. Je postaven na třech pilířích – geomorfologické databázi, metodách a nástrojích. Geomorfologické metody jsou realizovány geomorfologickými nástroji s daty v geomorfologické databázi.

Cílem článku je představení analytického pilíře GmIS – geomorfologických nástrojů. Ty rozšiřují standardní nástroje GIS pro správu a analýzu dat. Příklad vývoje je zaměřen na nástroje vypočítávající morfometrické charakteristiky hranic elementárních forem: index zakřivení hranice, orientaci hranice a ostrost hranice. Implementace je postavena na datové struktuře okřídlené hrany a topologických vztazích. V článku jsou zmíněny možnosti dalšího vývoje. Je očekáváno širší využití vyvinutých nástrojů, ale zatím byly testovány ve dvou oblastech zájmu: na Devínské Kobyle a v okolí Prášílského jezera.

Klíčová slova: Geomorfologický informační systém (GmIS), Geomorfologická databáze (GmDB), Geomorfologické nástroje (GmT).

Abstract

Geomorphologic Information System (GmIS) is in this article understood as a system based on a concept of elementary forms of georelief. The system is built on three pillars – geomorphologic database, methods and tools, where geomorphologic methods in GmIS are realized using geomorphologic tools applied on data in geomorphologic database.

The aim of this article is to introduce the analytical pillar of GmIS – geomorphologic tools. They extend standard GIS tools for handling and analyzing data. The development example is focused on tools computing morphometric characteristics of elementary forms boundaries: boundary curvature index, boundary orientation and boundary sharpness. The implementation is based on winged edge data structure and topologic relationships. The article also mentions the possibilities for further development. A broader usage of developed tools is expected, but so far they have been tested in two areas of interest: Devínská Kobyla and Prášílské jezero surroundings.

Keywords: Geomorphologic Information System (GmIS), Geomorphologic database (GmDB), Geomorphologic tools (GmT).

1 Introduction to GmIS

Firstly the delimitation of Geomorphologic Information System (GmIS) and its technological background should appear.

1.1 Definitions

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, which 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 (for example see chapter 3).

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.

1.2 The framework of GmIS

This subsection describes technology which is used for implementation of GmIS. ESRI platform has been selected and ArcGIS is used as a framework of GmIS development.

The data is stored in a specific structure in ESRI geodatabase¹ – *Geomorphologic Database* (GmDB). Description of GmDB structure can be found in Mentlík et. al. 2006, Jedlička 2008.

There are many possibilities to develop *Geomorphologic Tools* (GmT) using ArcObjects², but three are used in GmIS development:

- ModelBuilder – graphic environment for developing process models³,
- Python – scripting language and environment⁴,
- Visual Basic for Application (VBA) – integrated macro development environment⁵.

These three environments are encapsulated in both AcMap and ArcCatalog applications (parts of ArcGIS), so no additional software is needed.

¹The geodatabase is the 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. <http://www.esri.com/software/arcgis/geodatabase/index.html>

² ArcObjects is a set of platform-independent software components, written in C++, that provides services to support geographic information system (GIS) applications on the desktop in the form of thick and thin clients and on the server. <http://edndoc.esri.com/arcobjects/9.2/NET/5bd93a2b-1c00-4927-ab26-5fbc3891a448.htm>

³ModelBuilder is an application in which you create, edit, and manage models. http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=An_overview_of_ModelBuilder

⁴By definition, Python scripts are modules, which is Python's highest level of code organization. Modules serve several purposes; the most obvious is the ability to save code to a reusable form, a script. Scripts can avoid duplication of code by using programs contained in other modules. Using the import statement, a program can import any number of functions, variables, or both contained in another module. A module creates a natural grouping and naming structure, which eliminates ambiguity when using commonly named programs. http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=720&pid=717&topicname=Writing_Python_scripts

⁵ArcGIS includes an integrated macro development environment, Visual Basic for Applications (VBA). VBA is not a stand-alone application; it is embedded within all ArcGIS applications (ArcMap, ArcCatalog, ArcGlobe, and ArcScene). You can use it to develop simple scripts and as an interactive prototyping environment for more extensive development with a COM-based language, such as Visual Basic 6, Visual Basic .NET, Visual C#, or Visual C++. http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=5623&pid=5622&topicname=Getting_started_with_VBA

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.

2 Representation of elementary forms in GmlS

Each elementary form can be characterized by its shape and many geometric, morphometric, genetic and dynamic attributes.

For some (mainly geometrical) attributes it is convenient to have not only the value inside the area, but also the description of the value change at the area boundary (discontinuity line). E.g. it is convenient not only to have the information about the average slope of each elementary form, but also to know the difference of the slope between left and right elementary form adjacent to discontinuity line.

The winged edge data structure and topologic relationships is used for representation of elementary forms and their boundaries.

2.1 Winged edge

Winged edge has a link to polygons to the left and to the right of the edge (adjacency) and also information about start and end node (orientation) and whose edges are connected to those nodes (so polygon as a chain of edges can be defined), see detailed explanation:

Each entry in the edge table (see table 1) contains those information: edge name, start vertex and end vertex, left face and right face, the predecessor and successor edges when traversing its left face, and the predecessor and successor edges when traversing its right face. Note that clockwise ordering is used for traverse. Note also that the direction of edge **a** is from **X** to **Y**. If the direction is changed to from **Y** to **X**, all entries but the first one in the following table must be changed accordingly. Shene 2008.

Table 1. Representation of winged edge data structure in computer. Shene 2008.

Edge	Vertices		Faces		Left Traverse		Right Traverse	
Name	Start	End	Left	Right	Pred	Succ	Před	Succ
A	X	Y	1	2	b	d	e	C

Figure 1 shows the information for the entry of edge **a**. The four edges **b**, **c**, **d** and **e** are the *wings* of edge **a** and hence edge **a** is "winged." Shene 2008.

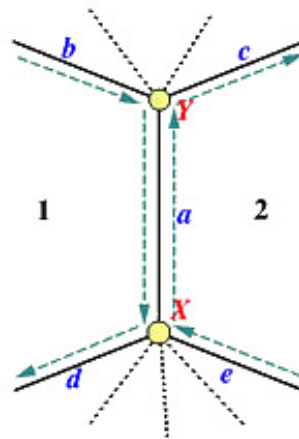


Fig. 1. Winged edge visualization. Shene 2008.

2.2 Representation of winged edge data structure in geodatabase.

It is necessary to use a topological format to store the winged edge data structure. ESRI provides two topological formats: coverage and geodatabase. The geodatabase was selected as native format for data storage in GmIS, because a file format (such as coverage) does not support storage into database environment. The geodatabase offers topologies but also possibilities to maintain relationships, subtypes, store and manage rasters, etc.

Even if geodatabase offers the possibility to store topologic relationships, they have to be built. By default geodatabase stores just geometry (and of course linked attributes). To create a topologic representation of elementary forms it is necessary to take polygons of elementary forms and extract their boundaries to a polyline feature class – (elementary form boundaries / discontinuity lines). After that, the winged edge data structure can be in geodatabase realized as topologically connected dual representation consisting of polygon and polyline layer. (See Fig. 2).

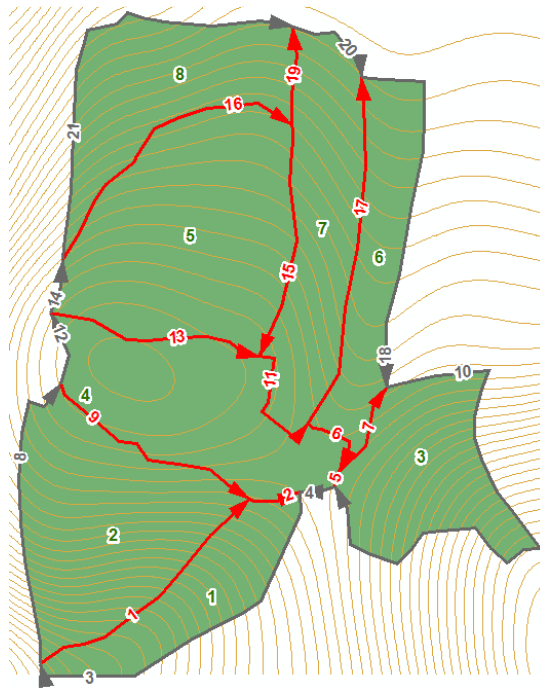


Fig. 2. Elementary forms (green) and their boundaries (gray and red). Screenshot from GmIS environment.

The topology class with following topologic rules has to be created in geodatabase to build the dual representation:

- Elementary forms must not overlap each other,
- Elementary forms must not have gaps (must continuously cover the area of interest),
- Elementary forms boundaries must be covered by discontinuity lines,
- Discontinuity lines must not have pseudo nodes.

See more about ESRI topology in Baars 2003.

Described dual representation is used as a data source for development of tools computing morphometric characteristics of elementary forms and their boundaries (boundary curvature index, boundary orientation and boundary sharpness).

3 Calculation of morphometric characteristics

When the correct topological representation exists, it is possible to automatically compute fundamental morphometric characteristics of elementary forms and their boundaries (lines of discontinuity). Simple graphical user environment (GUI) has been developed for computing these characteristics (see fig. 3). The Visual Basic for Applications and ArcObjects were used for implementation.

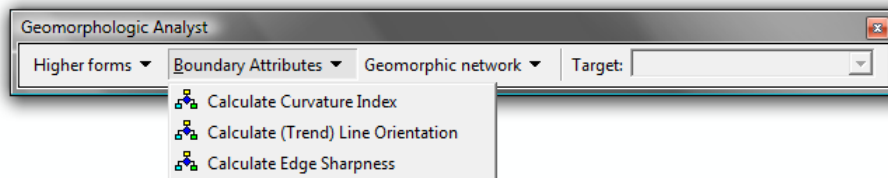


Fig. 3. GUI of geomorphologic Analyst – the analytical part of GmIS.

Morphometric characteristics of forms and boundaries can be divided into three groups from the implementation point of view:

- i. Characteristics possible to compute from the geometry of elementary form (*area* of form and boundary *length*). These characteristics are automatically computed by the database management system (DBMS) – see fig. 4.

Object ID *	Shape *	Shape Length	Shape Area	FID
1	Polygon	297,110185	3010,629063	1
2	Polygon	349,390419	6395,145749	2
3	Polygon	303,23737	4169,320959	3
4	Polygon	361,944214	5408,509855	4
5	Polygon	352,604723	8032,117817	5
6	Polygon	388,385335	3428,579143	6
7	Polygon	396,065565	4758,529754	7
8	Polygon	365,219511	4625,945248	8

Fig. 4. Area and boundary length computed by the database management system.

Possible geomorphologic interpretation of elementary form area and boundary length: the importance of the elementary form is adequate to its size.

- ii. Basic characteristics of discontinuity lines, whose are possible to compute from the boundary geometry (boundary curvature index and boundary orientation).

Boundary length – automatically computed by the DBMS (fig. 6).

Boundary curvature index is a quotient of boundary length and Euclidean distance of start and end node (see fig. 5). 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. 5.

Geomorphologist can search boundaries with similar orientation to explore trends in area. These trends can mean geological faults.

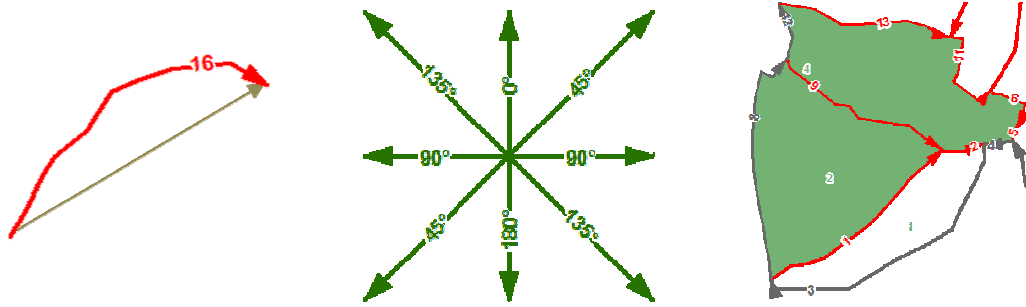


Fig. 5. Visualization of boundary curvature index (on the left), boundary orientation (in the middle) and boundary sharpness (on the right).

- iii. *Differential characteristics* – the winged edge data structure is necessary to compute them (all types of boundary sharpness).

The general boundary sharpness (absolute value of difference between area of right and left face) has been implemented.

There is no exact geomorphologic interpretation of general sharpness, but it is a good demonstration, that it is possible to connect information from topologically adjacent faces and work with them.

It is a question of further development to propose and implement such types of sharpness from such attributes of adjacent forms, whose will have better geomorphologic interpretation (such as e. g. differences of slopes, differences of orientation etc.).

There is a screenshot of table with computed morphometric characteristics of elementary form boundaries in the figure 6. Note there is one straight line (Object_ID=5 and CurvatureIndex=1) and some lines with unspecified (-9999) sharpness – these are boundaries which have only one adjacent elementary form (marked gray at fig. 2).

Object ID	Shape *	Shape Length	CurvatureIndex	LineOrientatio	Sharpness
1	Polyline	116,613572	1,020994	51,908824	3384,516686
2	Polyline	22,712592	1,034483	81,419824	2397,880793
3	Polyline	157,784022	1,181654	56,471479	-9999
4	Polyline	15,26205	1,011853	81,384409	-9999
5	Polyline	6,844609	1	14,931417	1239,188896
6	Polyline	33,513873	1,374928	146,725044	1979,930712
7	Polyline	42,981007	1,041038	29,666698	740,741816
8	Polyline	132,615631	1,101386	4,137756	-9999
9	Polyline	100,161216	1,056192	121,361552	986,635894
10	Polyline	253,411754	5,309688	27,531972	-9999
11	Polyline	57,499354	1,620701	143,714794	649,980101
12	Polyline	32,030529	1,055073	171,773332	-9999
13	Polyline	93,899991	1,028471	101,666354	2623,607962
14	Polyline	23,68037	1,011406	13,075587	-9999
15	Polyline	102,235208	1,02059	8,072356	3273,588063
16	Polyline	132,789154	1,165103	59,47357	3406,172569
17	Polyline	152,598433	1,018661	8,756712	1329,950611
18	Polyline	159,292022	1,197508	175,317313	-9999
19	Polyline	42,129793	1,006316	0,199949	132,584506
20	Polyline	41,602777	1,137014	126,109344	-9999
21	Polyline	190,300564	1,358674	44,585658	-9999

Fig. 6. Boundary length, curvature index, line orientation and boundary sharpness computed in Geomorphologic Analyst.

4 Summary

The article shortly introduces GmIS and focuses on the part of analytical pillar of GmIS which automatically compute fundamental geomorphologic characteristics. Thus the background of data representation and technology used for algorithms development is presented.

The core contribution of this paper is the description of calculations of particular morphometric characteristics and their possible geomorphologic interpretations. Generally it is possible to say that knowing the morphometry can (together with other researched findings) help geomorphologist to determine the genesis of each elementary form and afterwards to synthesize the information of geomorphologic genesis of the whole area of interest.

It is expected broader usage of developed tools, but so far they have been tested in two areas of interest: Devínská Kobyla and Prášílské jezero surroundings.

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