Integration of analytical GIS-functions in Multimedia Atlas Information Systems

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Abstract

In the implementation of adapted GIS-functions lies a great potential for the future development of multimedia atlases. This paper presents the first results of a study that explores the possibilities of integrating GIS-functionality in multimedia atlas information systems. GIS-functions have to fulfil certain requirements to be successfully applied by atlas users. Primarily, they must be user-friendly and easy to utilize. They should not include data handling or editing, but remain analytical. Examples for suitable analytical GIS-techniques such as database queries, spatial analysis and statistical functions are presented. They will be integrated according to the «GIS in Multimedia» approach: A multimedia authoring system is extended with additional functionality by using external C++ xtras. GIS-functions will be implemented by means of environmental vector data sets. These data must be stored in a topologically adequate way in order to allow analytical techniques to be performed efficiently. In addition, they must offer a high-quality cartographic display. For this purpose, an extended multimedia vector data format is developed, based on existing GIS data structures and cartographic software.

Introduction

Recently, rapid technological development of digital cartography has led to a change of design in atlas cartography. In several countries, traditional paper atlases have been replaced by electronic versions offering a high degree of interactivity. The potential of these electronic atlases lies in the implementation of visualization and navigation techniques, multimedia and adapted GIS-functionality.

Although considerable research was conducted on the development of electronic atlases, the integration of user-friendly analytical GIS-functions has not been sufficiently considered so far. The first digital national atlas, the Electronic Atlas of Canada [Siekierska and Palko, 1986] which was developed as early as the eighties, was already based on a GIS concept. The atlas contained important analytical GIS-techniques such as database queries, overlay functions and statistical calculations but revealed some deficiencies in visualization quality and graphic user interface. These limitations were mainly caused by software available and limited quality of display devices at the time. More recent products, such as the digital atlases of Austria [Ditz, 1997], China [Taylor, 1997], Japan [Kanazawa, 1996], Sweden [Ögren, 1997; Wastenson and Arnberg, 1997] and the USA [Guptill, 1997] strive to overcome these limitations by combining high visualization quality and an interactive user-friendly interface with analytical GIS-functionality. However, there is still a great need to improve the analytical capabilities of multimedia atlases.

The present study investigates the possibilities of integrating GIS-functionality in multimedia atlas information systems (AIS). The final goal is to implement suitable functions in the multimedia version of the ATLAS OF SWITZERLAND [Bär and Sieber, 1997] thus extending its analytical capabilities.

Relation between GIS and multimedia AIS

Geographic information systems (GIS) and multimedia atlas information systems (AIS), also called electronic or multimedia atlases, are both computer-based information systems that handle geographically referenced data. Whereas GIS enable capture, modelling, manipulation, retrieval, analysis and presentation of geographic data [Worboys, 1995], the emphasis of AIS is especially on the presentation of these data. Likewise, AIS often refer to a certain area or topic in conjunction with a given purpose and have an additional narrative faculty [Ormeling, 1995]. Table 1 shows the main differences between modern existing systems. It should be noted that in reality, the contrasts are never as strict as shown in the table.

Table 1. Main differences between GIS and multimedia AIS

	GIS	*multimedia AIS*
use of interface	complex	easy
users	experts	non-experts
computing time	long	short
control by	users	authors
main focus	handling of data	visualization of topics
data	unprepared	edited
output medium	paper	screen

Requirements for GIS-functions in multimedia AIS

One can infer from Table 1 that GIS-functions have to satisfy certain criteria in order to be successfully applied in multimedia atlases. Initially, the interface has to be user-friendly and allow for a maximum of interactivity. All functions should be understood intuitively by expert and non-expert users without extensive explanation. In addition, tasks must be performed within a short time. Actions and settings have to be controlled by the authors to a certain degree to prevent the users from creating useless or even erroneous maps. In contrast to GIS where the emphasis lies on data handling (e.g. data capture and editing, see next chapter), operations in AIS are centered around topics. Accordingly, atlas users can employ previously prepared data and visualize them. Finally, since the output medium is the screen, maps would look good on the screen rather than on paper.

The «GIS in Multimedia» approach

Basically, there exist two approaches for the integration of GIS-functionality in multimedia atlases. The first entails basing the atlas development on commercial GIS software and extending the existing functionality with multimedia tools. This approach is referred to as «Multimedia in GIS» [Craglia and Raper, 1995; Bill, 1998]. The second approach attempts to integrate GIS functionality in multimedia authoring systems («GIS in Multimedia»). Both the concept of the ATLAS OF SWITZERLAND [Bär and Sieber, 1997; Hurni et al., 1999] and the present study are based on the second approach which, though more costly, is more flexible. The graphic user interface can be designed system-independently, and cartographic as well as GIS-functionality can be adapted individually.

GIS-functions

In this section, GIS-operations are classified, and their suitability for multimedia atlases is evaluated. GIS-functions can be grouped according to different points of view. There is no comprehensive theory relating to and grouping the various techniques [Berry, 1987; Albrecht, 1996]. The following classification, derived from Goodchild [1990], distinguishes between four main GIS-functions:

- Data capture (e.g. digitizing, scanning)
- Data manipulation (e.g. editing, raster-vector conversion, data integration, generalizing)
- Data analysis (see below)
- Data presentation and output (e.g. map making, printing)

The purpose of data capture and manipulation is the preparation of the data for the actual analysis process. It has already been mentioned in the previous chapter that, in contrast to GIS users who can carry out all these four main functions, atlas users should neither be occupied by data entry nor by data manipulation. In fact, they should rather concentrate on data analysis and presentation. However, data presentation is not part of the present study. Therefore, emphasis is put on data analysis functions.

In the following sections, a list of suitable 2D data analyisis functions is presented, to be implemented in the multimedia version of the ATLAS OF SWITZERLAND. It has to be noted that 3D functions are not considered here because they are treated by Stähli [1998] and Terribilini [1999] within the range of the Swiss national atlas project.

Database queries

By performing query operations, information is extracted from the database while the geometry of the data remains unchanged. Basically, queries are not proper analytical functions. Nevertheless, they are discussed in this study as their spatial component is GIS-specific and therefore unique for databases.
Thematic and spatial as well as topological queries are considered. Users are able to scan the database for objects that contain particular attributes and visualize them on the screen. They are also able to search for objects lying within or next to other objects. Questions such as 'which areas does this river cross?' are answered. Further investigations focus on reclassification of existing attributes based on a set of user-specified rules.

Spatial analysis

Spatial analysis functions are the most familiar and commonly used GIS-operations. New data sets with altered geometry are deduced from the existing ones. First, aggregation functions are considered. Adjacent polygons with identical or similar attributes are merged together while boundaries between them are dissolved. Moreover, buffer functions are implemented. For instance, users are able to determine agricultural soils potentially contaminated by lead around industrial zones or along motorways. Further investigations focus on geometrical overlay. Thus, by combining geology, soil, vegetation, climate and terrain data, the erosion and landslide potential of mountain areas can be determined. Furthermore, maps can be cut out along individually specified lines such as administrative borders.

Measurement and statistical functions

Distances between two points or along a path as well as perimeter and area of polygons can be measured. It is also possible to determine statistical values such as sum, maximum, minimum and standard deviation of map attributes and to chart their distribution. In addition, statistical analysis of temporal data can be performed. For instance, users are able to calculate the loss of agricultural soil due to the expansion of built-up area, and visualize it by means of animation.

Data

Data sets

GIS-functions are implemented by means of environmental vector data sets. In the first stage, the digital soil aptitude map of Switzerland [Frei et al., 1980] is used. This map has a large attribute table, containing information about soil types and properties and is therefore suitable for database queries. In the second stage, when spatial analysis functions are performed, more data layers like geology, vegetation, climate, terrain, landuse and infrastructure (roads, settlements) are required.

Data structure

The successful implementation of GIS-functions in AIS relies largely on a convenient data structure. On the one hand, measurement and advanced analytical techniques should be conducted efficiently. Therefore, the data must be stored in a topologically adequate way including explicit adjacency information. Moreover, attribute information must be linked to the geometric entities. On the other hand, the data structure must enable a high-quality cartographic display of the geographic data. For the second purpose, a versatile multimedia vector file format has been developed for the ATLAS OF SWITZERLAND [Bär and Sieber, 1999; Hurni, Bär et al., 1999]. It features a dynamic representation of cartographically updated GIS data in a multimedia environment. As attributes can be linked to map elements, this format is suitable for simple database queries. If, however, operations get more complex and require explicit adjacency information, the format does not suffice any longer and has to be extended with additional topological information.

Hence, efforts are made to develop a data structure which enables both graphic and analytical processing (see Figure 1). Topologically correct vector GIS data with additional attribute information will be imported in the cartographic system *Free-*

hand where the geometric information is divided into a graphic and a topological part. For this separation, an external C programming extension (xtra 1) is used. The graphic information is cartographically edtited whereas the topological and thematic information are kept apart. Possible changes in the topology are recorded by xtra 2. Finally, the separated geometric information of the cartographically updated data is joined and exported to the extended multimedia file format using xtra 3.

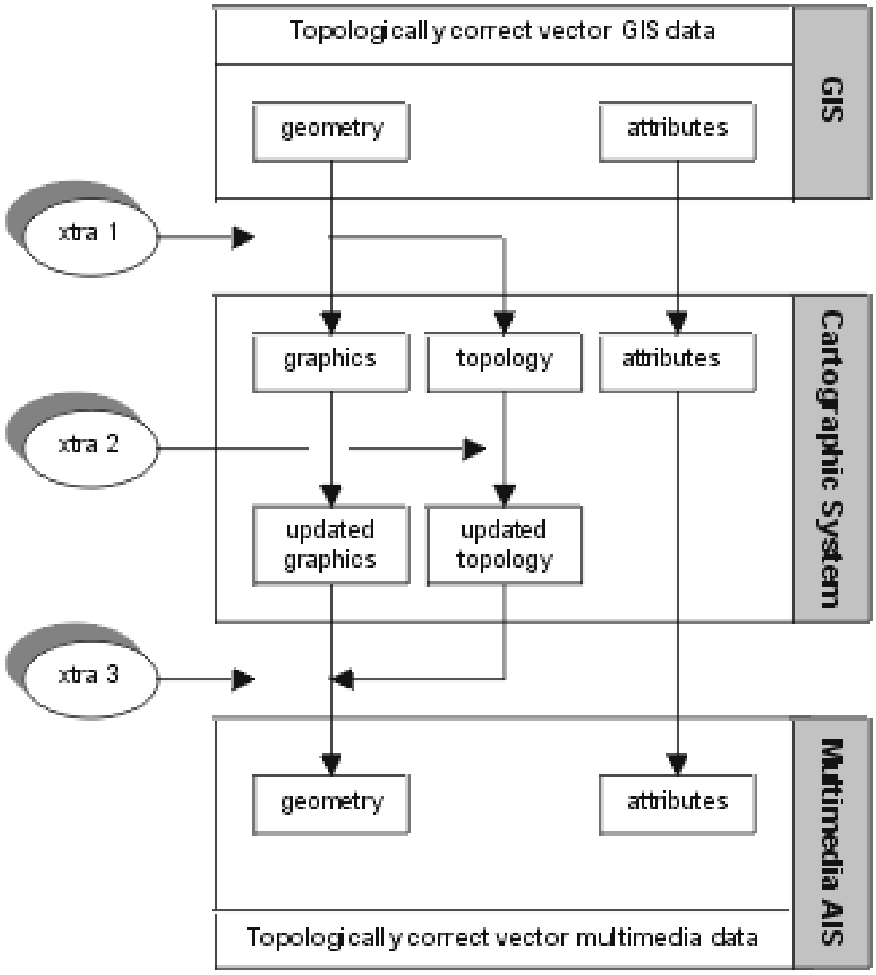

Figure 1. Cartographic updating of topologically correct vector GIS data for multimedia AIS

Implementation

As previously mentioned, the implementation of GIS-functionality in the present study is based on a multimedia authoring system («GIS in Multimedia»). For the design of the graphic user interface, the multimedia authoring software *Macromedia Director* is used. All GIS-functions are programmed by the atlas authors themselves. In *Macromedia Director* programming can be achieved on three levels. On the first level, standard tools can be used to display the graphic components of the atlas. On the second level, to extend these rather limited possibilites and to control the interactive user input by means of buttons and windows, the software provides a built-in scripting language. On the third level, external programming xtras in C and C++, which communicate with the scripting language and are stored as shared libraries, can be written to complete the existing tools. GIS-functions will mainly be implemented by means of C++ xtras. In Figures 2 and 3, geometric overlay and statistical analysis are presented schematically by applying these three programming levels. Figure 2 shows the graphic components of the ATLAS OF SWITZERLAND with the thematic map layer (first level). The atlas users can select an administrative border line. This action is controlled by the built-in scripting language (second level). Figure 3 presents the results of the analysis that was carried out using external C++ extensions (third level).

Figure 2. Display of a thematic layer of the Swiss soil aptitude map and selection of an administrative border

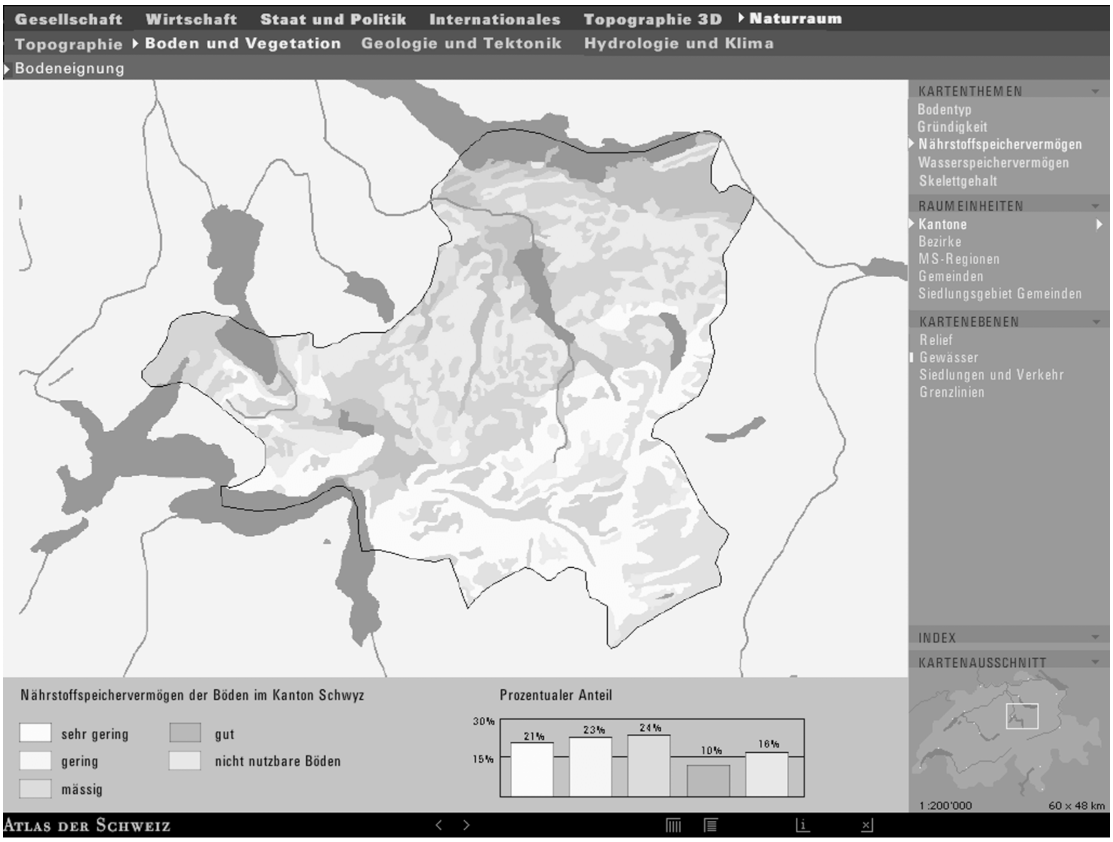

Figure 3. Intersection of the thematic map layer with the administrative border and display of statistical results

Conclusions

The extension of multimedia atlases with analytical GIS-functions offers new perspectives to atlas and geographic information science. Spatial database query and spatial analysis, as yet mainly performed by GIS-specialists, are now also available for a broader range of users. People who neither have a GIS technical education nor do dispose of spatial data sets and GIS systems will have the possibility to analyse spatial data, gaining insight into environmental processes and their complex interactions. In the present study, the first steps towards a sophisticated atlas information system have been taken. The suitablility of GIS-functions for AIS was evaluated and a convenient data structure was designed. The next important step is to design a suitable graphic user interface for these functions. Analytical multimedia atlases are successful only if they are easy to handle.

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