The Extended Structure of Multi-Resolution Database

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Abstract. The aim of the paper is to show how to extend the database of topographic objects for the purposes of automatic data generalization. Generalization is performed basing on topographic databases, that exist in various scales (BDOT10K - scale 1:10 000, BDOO - general geographic objects database 1:100000). Under the law, these databases are fundamental source of information about the spatial location and characteristics of topographic objects in Poland. BDOT is a multi-resolution database, which is fed by the objects with varying degrees of details and accuracy, depending on the data source. It is also assumed that the BDOT will be a source of data for the editorial of standard cartographic studies for various scales. Objects for a given scale are obtained by the generalization processes, which allow to generate less detailed data (for example, in a scale of 1:50 000) from the reference dataset (scale 1:10 000). The authors have proposed the structure of MRDB system, which assumes the existence of Web Generalization Services (WGS). These services can provide a remote access to simplification algorithms and the data generalization "on the fly" [5, 4]. It can significantly reduce the process of data producing through automation of the manual work, resulting in a significant optimization of the database at the level of its power. Therefore, we can observe the optimization of the work with databases, already at the level of their feeding.

Keywords: spatial databases, generalization, MRDB, WGS, topographic database, GIS.

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1 Introduction

The basic functionality of contemporary IT systems, especially Geographic Information Systems (GIS), is the processing of spatial data stored mainly in databases, which often have the ability to process certain selected geometric objects [1, 22, 11]. All of this led to the fact, that the data previously cataloged in analog form - using paper maps, were subjected to the process of digitization, and this required the development of suitable methods for archiving data. Unfortunately, these solutions have a lot of drawbacks, in which the most difficult to accept are the problems with low efficiency of data operations as well as the constraints on data processing and thus the generalization of data.

The first one, as shown in the work [2, 3, 17], can be solved using optimization methods for SQL queries. Unfortunately, in the case of the data, in which the geometry of the objects is different depending on the adopted scale, this approach has the limitations in the form of queries, which can be created only between the tables with same level of detail (e.g.1:5000) [17, 7]. Furthermore, these databases are the source for the editorial process of cartographic maps, according to the agreed model of DCM (Digital Cartographic Model) and WMS/WFS (Web Map Service/Web Feature Service) servers, sharing maps and spatial data in the network. This approach to pure spatial databases would be highly inefficient, due to the need of processing high detail objects. However, the perception varies depending on the scale and some maps do not require the high-resolution data. For example, the objects in the case of small-scale maps are mostly distorted or invisible and some of them change their structure (e.g. from surface to point) [10]. Therefore, the generalization requires an appropriate structure of the database. The structure of database, in which successive data representations are created in the process of reference data generalization, can be called as a multi-resolution. Moreover, the correct process of data generalization is extremely complicated, due to the many aspects of visualization and various topographic data contexts. For this reason, the existing solutions were dominated by a huge amounts of decisions that needed to be taken by the expert (cartographic database administrator) as well as low level of unambiguity (lack of processes automation). The work on the automation of the generalization processes is currently one of the main research problems in the processing of spatial data [16, 18].

2 The Database of Topographic Objects in the SDI Structure

European Parliament directive 2007/2/EC of 14 March 2007 establishes a consistent spatial information infrastructure (ESDI - European Spatial Data Infrastructure) for the European Union and the EFTA. In addition, INSPIRE implies the harmonization of systems operating at different levels of particulars, which means that the multi-resolution database will be the source for databases with less details. Implementation of SDI defines the requirements with respect to topographic objects databases, concerning the harmonization and interoperability of the data. Currently, topographic objects are recorded and stored at three levels of details: BDOT500 (LoD1), BDOT10K (LoD2) and BDOO [19–21]. The database of topographic objects (BDOT) should be a conceptually consistent and nationwide system for collecting, storing, viewing, sharing and managing topographic data at three levels of generalization. Among the competencies of BDOT, it also should include data management, financing and organizing the maintenance of this resource in timeliness. The repository of BDOT at the appropriate level of detail should satisfy the expectations of local and national administration. Furthermore, under the law, a topographic objects database serves as the primary source of information about the characteristics and location of spatial objects. However, the characteristics of the data collected at three levels of detail are different and thus it is difficult to provide a unified model of these databases. The topographic objects databases, at levels from 1: 500 to 1: 5000 (BDOT500) have a registration character, at the level of 1:10 000, BDOT10K is a base topographic reference for standard cartographic studies in terms of medium scales, while the general geographic objects database (BDOO) is responsible for the small scale data.

The topographic database structure will vary according to the level of detail, which is referred by the scale. Therefore, the differences are visible also at the level of the base feeding. For example, data sources of BDOT10K (scale 1:10 000) include records collected in the state of geodesy and cartography, that is responsible for: register of land and buildings, national register of borders and surface units of territorial divisions of the country, the national register of geographical names, register of the villages, streets and addresses, aerial and satellite imaging. However, in the field of building classes, built-up area and territorial development, the main source of the data will be BDOT500 (scale 1:500 or lower). Due to the large amounts of data used in creating and updating BDOT10k, there are used a multiple sources of reference data. In addition, the supplement and verifying of the data from registers are obtained by terrain interview.

3 The Concept of the Generalization in MRDB

The hierarchical structure of database forces the feed system of generalized data to lead them to the appropriate level of detais. Therefore, it has become necessary to develop algorithms for automatic generalization of the data, as well as feeding and updating databases with lower details "on the fly". Previously proposed models of BDOT do not have all the necessary information which are required to properly perform the process of generalization. Consequently, it is necessary to supplement the multi-resolution database with topographic information from other data schemas. This allows to synthesize geographic information into a single coherent database schema. Synthesis embrace not only the geometry, but also the construction and editing data dictionaries of the attributes. Supplemented model of BDOT allows to generate derivative spatial objects. Spatial objects assume the ready-made base tuples form, which contain information about the object geometry and assigned attributes.

As a result of the research presented in this paper, the authors decided to build an automatic generalization system using geo-portal software type. Its concept provides for the feed and updating derivatives and less detailed databases in an automatic way. Undoubtedly, one of the key functionalities of the system will be the remote access to the spatial processing algorithms as network processing services (Web Processing Services - WPS). WPS services are defined in OGC standard as a Web Generalization Services (WGS), because of its generalization nature [5, 4].

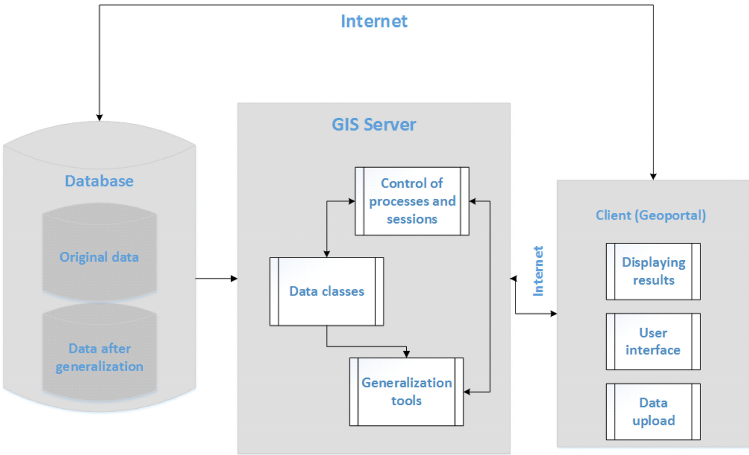

Fig. 1. Reduction of a point on a line

The diagram above (Fig. 1.) illustrates the designed MRDB system with a three-tier architecture. Data layer is a spatial database, which is responsible for the validation of input data, the completeness and correctness of topological objects sent by the user (geoportal). The database allows also to store and share information, obtained as a result of generalization processes, as well as to supply databases with less details. The logic of the system is located in GIS server side, which provides the appropriate generalization tools and algorithms as WGS services. GIS server also exercises protection over the processes and sessions. The presentation tier is a web service (geo-portal), responsible for the management and visualization of the dynamic maps (before and after generalization).

4 The Schemes of Data Acquisition

The primary data source for the generalization system should be the objects BDOT500 database. However, most of these objects requires to be extended with the attributes from other sources. A very important feature of the system architecture are the detailed classes of objects cast, belonging to the basic map,

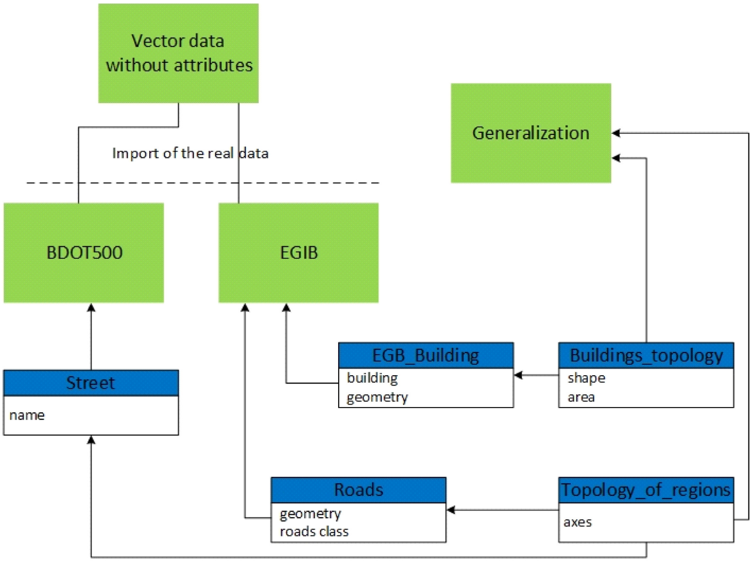

Fig. 2. Illustration of data flow for selected classes of MRDB in the generalization process

on the generalized MRDB model (Fig. 2.). A generalized MRDB model was completely subordinated to the geometry.

The diagram above, concerning the ”edges”, consists of the geometry and attributes originated from the processing of database BDOT500. The road parcel defined in the BDOT500 model is joined to the road parcel from EGiB (The Lands and Buildings Register) model. Integration of spatial data in MRDB is based on two major types of schemas: ”topology of buildings” and ”topology of regions”, which are essential in the process of generalization. This schema element is temporary and dynamic, but, nevertheless, it can be the source of attribute values in derivative database or the subject of generalization tools [8, 9, 15].

Currently, the database schema structure of BDOT500 does not provide for one important type of objects, which are the edges of linear objects (according to theory of graphs). This problem can be solved by the skeletonization (Fig. 3.). The most popular algorithms of skeletonization are the methods of computational geometry, such as: Delaunay triangulation, Voronoi diagrams, Straight Skeletons, Medial Axis Transform [14, 12, 13, 6, 23].

One of the key operations of generalization is the data segmentation. The segmentation is achieved by construction of regions, basing on the linear objects. This process is a great illustration of the integration of two dato one database structure for generalization. The segmentation consists of following steps:

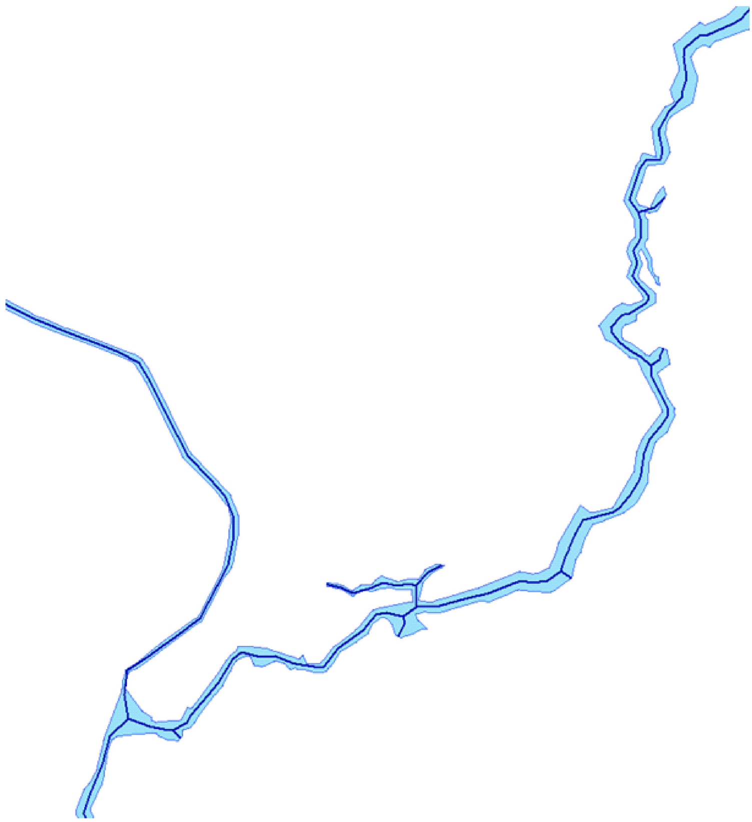

Fig. 3. Examples of the river polygon skeletonization

- generation of the elementary regions,
- classification of the streets into four groups, according to their attribute - class, which is determined by the category of its management (for example, class 1 - national roads),
- the construction of the regions, basing on a prior classification.

As a result of this process, the database is fed by five new classes of objects - elementary regions and four classes of other, component regions (Fig. 5.).

Creation of the regions is a process, in which the edges of the different classes roads are combined in a linear closed chain. The start and end nodes of the roads are joined in the way to form a closed figure, which will be a region of the planar graph. To perform this process properly, the planar graph should have a correct topology for the network objects (roads, railways, rivers). What is more, the performed classification of the structural regions, formed from the road network, will allow the automatic elimination of the less important elements (regions classified below). Nevertheless, it is important to clarify the decisive factor in

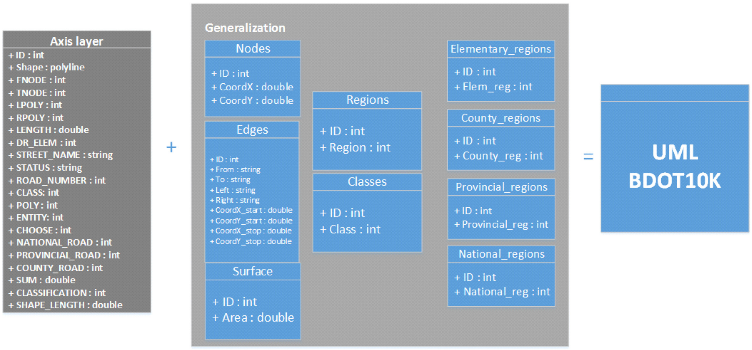

Fig. 4. Structure of the topological database in relation to the structure of communication network edges

Fig. 5. An example of building objects clustering at different levels of the network hierarchy

the removal of the considered region. Elimination of the regions removes its all internal objects.

5 Conclusions

Solution is based on a segmentation of objects from spatial database is not a new issue, and it has been applied in practice. However, there are no tools for applying segmentation on the geographical objects. It is due to the necessity of using value of their descriptive attributes which often differ between databases. Standardization of BDOT base allows the use of predefined attributes in segmentation of processed regions. Automatic grouping of objects is one of the key components in the generalization process of data for small scales.

As a result, costly, repeated acquisition of the same data for the individual scales of BDOT can be avoided. The lack of topology in geographical data of BDOT standard is still the main concern. The topology is a key element in the process of linear segmentation. It is impossible create consistent levels of hierarchy of extracted data regions without correct topology. The authors also defined a structure of database which allows to process spatial data in the process of segmentation.

The proposed solution allows, (in the future) the segmentation of geographic features to be used as a service network processing WPS (Web Processing Service). This application, due to its nature, is called the network service generalization WGS (Web Generalization Service) also.

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