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The Automated Update of Cartographic Data at a Scale of 1:50,000 in Lithuania: Problems and Solutions

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Abstract

The data of the cartographic base at a smaller scale are updated by using spatial objects at a larger scale. However, this process in Lithuania is still mostly manual, only partially automated and following generalisation parameters that are usually selected subjectively. The success of several projects on the automated update of the spatial data at smaller scales implemented by national mapping agencies in other countries opened the way for the pilot project in Lithuania in 2013. The main goal of the project was to investigate the possibilities for the process of updating data of the cartographic base at a scale of 1:50,000 in Lithuania with the help of the automated generalisation of spatial data at a scale of 1:10,000. The above mentioned spatial data usually had only abstract specifications regardless of the interoperability of the data or possibilities for the optimisation of update processes between the data at different scales. Therefore the differences of semantics, attributes and representations were detected during the analysis of the spatial data at different scales. That made the full automation of the update process more complicated. However it is important to make the compatibility of the spatial data at different scales as soon as possible to simplify the process and reduce the usage of resources. The authors analyse the possibilities of the update of cartographic base at a scale of 1:50,000 and provide recommendations for the automation of this process. The proposed solutions of the detected problems are dedicated for the spatial data of the cartographic base in Lithuania due to the fact that the mentioned data may carry the specific character. The solutions were implemented using of ArcGIS software and tested on real spatial data sets. Therefore the presented ideas how to solve the problems may be applicable for generalisation of others spatial data sets.

Keywords: cartographic data; model generalisation; automated update; model; ArcGIS.

1. Introduction

The cartographic basemap of Lithuania is called the spatial data set of the georeference base of the Republic of Lithuania. These spatial data are stored at three basic scales: 1:10,000, 1:50,000 and 1:250,000, taking into account the traditional topographic map scales and needs of the state and users. Depending on a scale, these spatial data sets in Lithuania are shortened as follows: GDR10LT, GDR50LT and GDR250LT.

The update of GDR10LT includes a variety of data sources. The main of them is orthophotographic imageries with resolution 0.5 m. The frequency of updating imageries is every 3 years. The update process also takes the information from approx. 10 other data sources (e.g., the Information System of Lithuanian Roads, the Cadastre of Rivers, Lakes and Ponds). Additionally, the information about changes in the real world (e.g. a new road) or inaccuracy in a spatial data set (e.g. a possible wrong geographical name) provided by GDR10LT users are used for updating a spatial data set. This spatial data set is updated on a regular basis. Meanwhile GDR50LT is updated on the basis of GDR10LT, though at irregular intervals of 3 to 4 years, usually after updating GDR10LT. It means that data of GDR50LT after updating are outdated for more than 1–2 years. For this reason, these spatial data sometimes fail to satisfy the needs of the users. Furthermore, GDR50LT is updated manually. During the process GDR10LT changes are visually evaluated by comparing the spatial data with GDR50LT. As a rule, spatial data are updated manually. Therefore, this process requires great time or human as well as financial resources.

The manual data update, rather than automatic, is a frequent case not only in Lithuania. The same problems arise at the national mapping agencies (NMA) of other countries as well.

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Therefore, the last decades saw several relevant projects and researches there. They attempted to effect a consequent automatic model generalisation [1–2] or cartographic generalisation [1–2] at a smaller scale using data sets of a larger scale. During the projects NMAs developed generalisation workflow solely for their purposes that used the functionality of commercial software and/or algorithms and tools designed specially by NMAs to achieve the right result.

The ICC (Institut Cartogràfic de Catalunya) developed a process for automated generalisation of a spatial data set at 1:5,000 in producing a map with a scale of 1:10,000 and a spatial data set of 1:25,000 [3–5]. Still this process is being improved for even better results in the update of spatial data sets of other scales. Meanwhile the French IGN (Institut Géographique National) has, for many years already, conducted research in relation to cartographic generalisation, namely, Project Carto2001 [6] in 1999 to 2005. Furthermore, automated generalisation helped to produce Topo100 map at a scale of 1:100,000 based on reference data set BDCarto with a scale of 1:50,000 [7]. Then, the Danish KMS (Kort & Matrikel-styrelsen) uses automated generalisation for 1:50,000 maps from the national digital topographic base map Top10DK at 1:10,000 scale [8]. The Turkish HKG (Harita Genel Komutanligi) conducted KARTOGEN project, in 2002 to 2010, which resulted in a model for producing maps at scales M1:50,000 and 1:100,000 based on data of a scale of 1:25,000 [Simav *et al.* 2010]. In the meantime, Italy has undertaken, since 2006, CARGEN project, which allowed automating cartographic generalisation of GeoDBR M1:5,000 by developing DB25 M1:25,000, and DB50 1:50,000 later [9]. In addition, the period between 2006 and 2010 saw the European project "State-of-the-Art of Automated Generalisation in Commercial Software" [10]. The project focused on the analysis and testing of CPT, Clarity, Axpand and ArcGIS software that enable object generalisation. Regrettably, the research proved that none of the software can offer proper generalisation of all data.

Such an abundance of projects suggests that there is still no unique model to meet the needs of developing spatial data sets or maps in various countries. Thus taking into account the results of the said projects and with a view to modernising the GDR50LT update the National Land Service under the Ministry of Agriculture initiated, in 2013, a feasibility study on the GDR50LT update applying automated model generalisation methods. The project period was barely 5 months, therefore, the main purposes of the research were to analyse the possibilities to use automatic generalized spatial data of GDR10LT in the update of GDR50LT and to prepare the recommendations of the automatic update.

2. Stages of the analysis

There were two main preconditions for the project: the GDR50LT update using GDR10LT must be analysed with respect to their data specifications and data analysis; and the automatic update must use the ESRI software ArcGIS, which is widely used for manual updating of spatial data sets in Lithuania, including GDR10LT and GDR50LT. In this way, the analysis stage was divided into two parts, namely, the analysis of the original spatial data sets and analysis of generalization technologies in ArcGIS.

2.1. Analysis of the original spatial data sets

GDR10LT and GDR50LT are official national spatial data sets. However, the last decade witnessed them both being developed in slightly different directions. GDR10LT was developed to meet the requirements of a base map, while GDR50LT to satisfy military mapping needs. Therefore, the research focused not only on specifications of both spatial data sets, but also on the specific character of object representation at different scales. In the first case, the compatibility of the specifications was analysed, namely, comparing the structure of layers of GDR10LT and GDR50LT, descriptions and types of representation of the objects collected, also attribute information and its amount. In the second case, it was important to identify the interpretation similarities and differences of the vector data in both sets.

The analysis of the specifications identifies the main differences between GDR10LT and GDR50LT. The first of them is a different number of attributes used to describe the same object characteristics in GDR10LT and GDR50LT (Fig. 1).

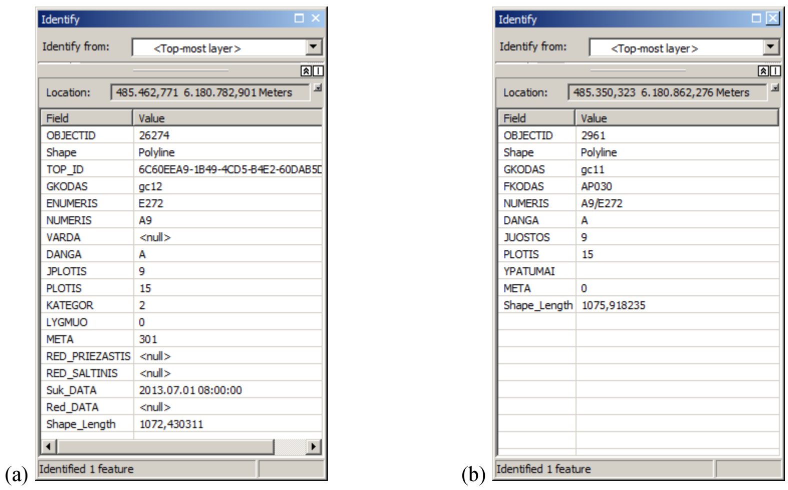

Fig. 1. Example of differences of specifying roads in (a) GDR10LT and (b) GDR50LT

On the other hand, the same values of attributes may have different descriptions. Usually Lithuanian official spatial data sets use the specification of Integrated Geographic Information System (InGIS) [11]. Therefore, the objects of GDR10LT are specified as they are described in InGIS. Meanwhile, the objects of two layers of GDR50LT used changed InGIS code value descriptions. For example, the value "gc12" means "road with pavement" in InGIS and GDR10LT, while the same denotes "primary route in national roads network" in GDR50LT. A similar problem was found in descriptions of hydrographic objects. Of course, this is not a problem for automatic creating or updating of GDR50LT, since the harmonization (transformation) of spatial data may be used. But such inconsistency of the specifications of GDR10LT and GDR50LT may confuse the users. Therefore, it is important to unify them. It allows generalising GDR10LT without attributing transformations either. The analysis of the specifications and spatial data in GDR10LT and GDR50LT found that GDR10LT does not include certain spatial data and information currently necessary for GDR50LT. For example, there is no spatial data representing dams, protected areas and ferry lines or information about the main rails in railway stations and technical parameters of bridges in GDR10LT. Nevertheless, some spatial data may be delivered from primary data sources: protected territories from the State Cadaster of Protected Areas, dams from the spatial data set represented by the inventory data of dams in Lithuania. Besides, GDR10LT has a lot of spatial data that may be used in GDR50LT as well, for example, spatial data of buildings, territories of airports, agricultural areas, route of pipelines, etc.

The specification and identity analysis of spatial data of GDR50LT and GDR10LT presented the following:

- 13 layers of the GDR50LT may be automatically updated without any corrections in GDR50LT and/or GDR10LT specifications. However, in view of compatibility between specifications corrections of specifications of 7 layers are proposed;
- 6 layers of the GDR50LT may be automatically updated by rejecting certain GDR50LT object types or their attributes, recoding them or supplementing respectively the GDR10LT specification with new objects or attributes;
- 1 layer of the GDR50LT may be updated only in part automatically, i.e. a visual revision and, if necessary, manual corrections are required;
- 5 layers of the GDR50LT cannot be updated on the basis of GDR10LT, as GDR10LT contains no such data to enable the creation of the necessary data for GDR50LT, however 2 of the layers can be automatically created using other data sources;
- 1 the update of the GDR50LT layer is unnecessary, as it is not changing;
- 1 it is suggested to omit the GDR50LT layer as excessive;
- Additionally 6 layers can be created for GDR50LT using GDR10LT.

With respect to the analysis results, further development of GDR50LT update models in future would require beforehand:

- To harmonise the specifications of both spatial data sets,
- To evaluate the necessity of current or lack of new GDR50LT data,
- To provide for additional original data sources,
- To decide as to the collection of new data in GDR10LT, this would allow a maximum automated update of GDR50LT.

2.2. Analysis of generalization technologies in ArcGIS

The analysis of ArcGIS generalization methods, algorithms and parameters checked the functionality provided by ArcGIS Version 10.2 Advanced licence. ArcGIS has a set of different tools that can be used in the creation of spatial data of a smaller scale, when the process includes objects of a larger scale. ArcGIS has 13 specialised tools for the object generalisation, such as Aggregate Points, Aggregate Polygons, Collapse Dual Lines To Centerline, Collapse Road Detail, Merge Divided Roads, Thin Road Network, Simplify Building, Simplify Lines, Simplify Polygons, Dissolve, Eliminate [12]. Nevertheless, the modelling of algorithms of the object update requires employing also other ArcGIS tools, such as object Selection by Attribute, Selection by Location, Merge, etc.

Possibilities of the tools in issue were investigated by running tests with GDR10LT data. The test results showed likely inaccuracies of generalisation results that are presented in Table 1.

3. Modelling of the automated process

Taking into account the results of the original spatial data sets, the automated processes of updating (creating) current layers of GDR50LT have to involve (1) the generalisation of the source data and (2) harmonisation (transformation) of attributive information of the generalisation result regarding the requirements under the GDR50LT specification. The priority of these processes is not so important. It depends on the conception of automated updating or creation of each GDR50LT layer. Meanwhile the sequence of processes updating layers and sequence of algorithms and operations in each process is very important.

The analysis of spatial data identified what data sources were to be employed in the update. It helps for defining sequence of updating layer. Approx. 44% of the GDR50LT data update uses solely GDR10LT layers (for example, railroads, roads, geodetic points), 22% of the cases require using only the updated GDR50LT layers as original data sources (for example, generalised roads, railroads and rivers might be used for creating intersecting points representing places of bridges), and in 16% of the cases the updated GDR50LT layers are used as auxiliary data (for example, it is important to use

Table 1. Some detected inaccuracies in results of generalisation

Name of ArcGIS tool	Comments
Aggregate Polygons	The holes that are smaller than the defined minimum area of a hole are not eliminated in newly created polygon objects.
	The result may be incorrect when a barrier polygon object has common boundaries and vertexes with polygon objects that have to merge.
Collapse Dual Lines To Centerline	The result may be incorrect when all the polylines representing roads will be generalised in the same time.
Collapse Road Detail	The tool is to be used after *Merge Divided Roads* or *Thin Roads Network* will give better results.
Merge Divided Roads	The result may be incorrect when a data source includes: multipart objects, objects, which equal or are less than zero length, overlapping other objects or their parts or self-overlapping, touching the boundary of the other object, objects with elements of an arc, curve or circle.
	Only a part of the long polyline parallel to short one may be shift during generalisation.
	Long parallel or almost parallel polylines will be merged even though the distance between them in some places will be larger than the defined max value for merging.
	The result may not be parallel to source polylines.
Thin Road Network	The result may be incorrect when a data source includes: multipart objects, objects, which equal or are less than zero length, overlapping other objects or their parts or self-overlapping, touching the boundary of the other object, objects with elements of an arc, curve or circle.
	This tool uses parameters of importance expressed as a number. The results depend from the value of importance; even all the polylines have the same importance value. The road network will be rarer when the value of importance will be larger.
Dissolve	The result does not retain topology of a network.
Snap	The result will be incorrect when a number and density of vertexes of an input object are less than density and a number of vertexes of an object that is used for snapping an input object. A recommended order of snapping environment is as follows: (1) snapping to vertexes (VERTEX), (2) snapping to edges (EDGE).

newly generalised roads, railways, rivers for snapping boundaries of land cover objects). Thus, it is very important to define the right order of processes for updating (creating) each GDR50LT layers following two main rules: (1) the layers used in updating other layers must be generalised first; (2) there has to be involved an additional generalisation process for the already updated layer when another updated layer may have influence over the final result of the first one (for example, generalised land cover objects are used for the additional elimination of the roads).

The results of the analysis of technologies in ArcGIS gave knowledge about results from the data and possible inaccuracies. It helps in the selection of suitable ArcGIS tools and sequences of them as well. The processes of the automated update included various operations used for a model generalisation. The number of used ArcGIS tools for generalisation depends on the complexity of the spatial data in the layer of GDR50LT. Usually the generalisation of point objects (e.g., geodetic points, places of geographical names, towers) included only *Select* for eliminating the unnecessary data; while the generalisation of elementary line objects (e.g. pipeline) required additionally *Simplify.* Still, the generalisation of some spatial data, e.g. representing roads, railways, land cover, are complicated tasks. Therefore the automated processes cover a set of various standard generalisation tools, additional operations and specially designed sub-processes in a particular sequence. The tests of developed automated processes show that incorrectness in source data may influence the process and/or result. Regarding the test result the main requirements for source data were defined: the spatial data must be topologically correct; no multipart objects or elements of arc or curve are allowed; all necessary attribute information must be entered. It should be noted that a topologically correct object must not have overlaps or self-overlaps, intersects or self-intersects, intersect or touch the interior.

The main aspects of the proposed solutions in more complicated cases during the automation of the GDR50LT update/creation are presented below.

Eliminating dangles. A set of polylines connected to the consistent network (e.g. spatial data representing roads, rivers, electrical-power transmissions, etc) may have short dangles that have to be eliminated during the generalisation. It is a simple task when polylines representing objects with the same characteristic(s) (for example road with no. A1) may intersect or touch other polylines. The polylines less than the defined minimal length have to be deleted in this case. Otherwise the task of eliminating dangles is complicated, since an object with the same characteristic(s) may be divided to the segments in the places where the object may touch or intersect another object. This problem may be solved in such a way: (1) segments based on the specified attributes are aggregated (use ArcGIS tool "Dissolve"; option "Create multipart features" has to be unchecked and "Unsplit lines" checked); (2) features from the result with a length less than the defined minimum length are selected; (3) the selected features are used for the selection of source features that are identical to the first ones ("Select Layer by Location"); (4) the selected source features are deleted. The process for eliminating dangles has to be performed in several iterations with selecting different values of length.

Eliminating short linear features adjacent to other linear features with a value of higher importance and likely to form a small closed area together with them (e.g. branches of an old river bed). These objects may be eliminated following such procedure: (1) create a new attribute field for assigning values of road hierarchy (importance), define the values; (2) select linear features with values of lower importance that are inside the defined distance from the features of higher importance including its boundaries (“Select Layer by Location”; use option “apply search distance”). The process has to be involved in several iterations by selecting different values of length depending on the importance of a feature.

Generalisation of a road network. A network of roads is represented as a set of polyline objects in GDR50LT. Apart from the simplification of the object it was important to merge parallel roadways into one centre line of roads and to eliminate short streets. The process of road network generalisation has to include these steps: (1) the elimination of the dangles using the solution described above; (2) creation of a new attribute field for assigning values of road hierarchy (importance), defining the values; (3) thinning a network of the roads/streets (“Thin road network”) in territories of the cities using values of road/street hierarchy; (4) splitting features at vertices (“Split lines at Vertices”). It will give better results in the next step; (5) merging parallel features into centre lines (“Merge divided roads”); (6) thinning a network of roads (“Thin road network”) in other territories using values of road hierarchy; (7) collapse and simplification of small, open configurations of road segments, such as traffic circles (“Collapse Road Detail”); (8) aggregation of features with the same characteristics (“Dissolve”); (9) simplification of the features (“Simplify Line”); (10) creation of a geometric network (“Create Geometric Network”).

Generalisation of a railway network. A network of railways is represented as a set of polyline objects in GDR50LT. The generalisation of this network is similar to the generalisation of roads. It has to be performed in steps in the following sequence: (1) create a new attribute field for assigning values of railway importance, define the values; (2) split features at vertices (“Split lines at Vertices”); (3) merge parallel features into centre lines (“Merge divided roads”); (4) eliminate the dangles using the solution described above (values of length and importance have to be used); (5) eliminate features with lower importance values that fall into the territory between features with a higher value of importance and have common start/end points with them; (6) aggregate the features with the same characteristics (“Dissolve”); (7) simplify the features (“Simplify Line”); (8) create a geometric network (“Create Geometric Network”).

Generalisation of a hydrography network. A network of hydrography is represented as a set of polyline objects in GDR50LT. The process of generalisation has to include these steps: (1) creation of a new attribute field for assigning values of road hierarchy (importance), defining the values; (2) elimination of the dangles using the solution described above; (3) elimination, following the description above, of the short linear features that are adjacent to other linear features; (4) simplification and smoothing of the features (“Simplify Line”, “Smooth Line”).

Generalisation of land cover. Land cover objects are represented as polygon objects. Usually this layer represents different themes of the real world features: built-up territories, lakes, rivers, forests, agricultural areas, etc. Generalisation of land cover has to be performed regarding some rules: simplification algorithm and parameters depend on a type of an object; the boundaries of the neighbouring objects in the defined distance have to (or may) be identical; the boundary of the object has to (or may) be identical to the interior of a road, railway and hydrographic objects if they are in the defined distance from them. The generalisation of land cover is carried out in the following steps: (1) select objects with important attribute information that could not be lost during the generalisation process (e.g. name of the lake); generalised selected polygons to points (“Feature to Point”); (2) select and export objects to different layers according to its theme; (3) aggregate neighbouring objects (separately in each layer), if they are in the specified distance from each other (“Aggregate Polygons”); use option “Preserve orthogonal shape” in the case of aggregating objects, which represent anthropogenic features (e.g. built-up territories, territories of airports); (4) simplify objects separately in each layer (use “Simplify Polygons”, if objects represent natural features of the real world and “Simplify Buildings” for the objects representing anthropogenic features); different generalisation parameters may be used for each layer; (5) copy attribute information from the points (the result of the 1st step) (“Spatial Join”, “Calculate Field”); (6) dissolve all layers into one (“Dissolve”); (7) add vertices along polygon features (“Densify”); it will give a better result in the next step; (8) snap simplified objects (except represented hydrographic objects) to generalised roads, railways and hydrographic objects (“Snap”); (9) eliminate small objects by merging them with neighbouring objects that have the longest shared border and after that the largest area (“Eliminate”); this step must include some iterations of elimination with different values of min area of the eliminated object.

The test results show that the automated processes of updating/creating of GDR50LT layers may significantly reduce the time resources comparing with the manual update. It gives a possibility to avoid subjectivity that may happen during manual generalisation as well. However only properly developed automated processes (models) may produce a correct result (Fig. 2).

4. Conclusions

The generalisation process itself is rather contradictory. First of all, the generalised map may show objects that are significant for the general perception of an area situation, even though it fails to comply with the minimum representation values decided by the specific scale. Secondly, a contradiction often arises between the geometric accuracy and graphic accuracy of a represented object, i.e. a spatial location is represented correctly, while a geometric one is distorted. And finally, generalisation leads not only to the elimination (simplification) of the object details and loss of information, but also causes the appearance of new generalised information.

(a) (b)

Fig. 2. Example of the GDR50LT (a) updated manually in 2011-2012 and (b) automatically in 2013

The GDR50LT update algorithms are developed based on the ArcGIS models that comprise a certain sequence of ArcGIS offered processes in order to generalise the GDR10LT data. The testing of these models suggests that the entire automation process may be carried out using ArcGIS software, still it requires selecting proper parameters. Nonetheless, in certain cases, such as matching up or snapping objects of one layer to the other, to get a proper result the generalisation process demands using, physically, vertexes of objects developed for that purpose as much as possible. At the same time it increases the loads of technical resources, while the process itself becomes time consuming. In this way, the testing of algorithms (models) prompted choosing such parameters that would require no great time and technical resources, yet it would ensure the correctness of the developed algorithm. Therefore, the GDR50LT update with proper parameters demands evaluating time resources and hardware possibilities.

The correctness of the models developed during the research was tested using the original spatial data of GDR10LT: in the first stage approx. 170 sq.km and in the second approx. 5,000 sq.km of the data covering the Lithuanian territory. The results of the second stage suggested that models had to be revised, even though the first stage results were proper as well.

The reason behind it was the specific character of the objects in different territories. Therefore, the developed models should be additionally tested using all GDR10LT data in order to develop unique models for the entire Lithuanian territory or those suitable for the data of specific territories.

The testing of the models showed inaccuracies in GDR10LT that affected the generalisation result. To avoid such problems in future individual check models for original data must be developed additionally that would enable to identify data errors affecting the final result.

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