GEOINFORMATICS 2021

EAGE

21043

Main state topographic map: structure and principles of the creation a database

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SUMMARY

Topographic databases and geoinformation web services for their use in spatial data infrastructure have become the predominant type of final products of national cartographic and cadastral agencies of developed countries. This paper presents the results of research work on the creation of a geographic information system of the topographic database "Main State Topographic Map", the initial filling of which is carried out based on updated digital topographic maps of the scale 1:50 000. The proposed solutions comply with international standards in the field of geographic information, and their implementation provides a comprehensive application of the latest geoinformation technologies and geospatial databases to create a seamless topographic database for the entire territory of Ukraine with wide access to it by interested users on the system geoportal. The main features and innovations of the topographic database being created include: completeness of classes of topographic features and their attributes; an integrated system for identifying topographic features in a database, in which each topographic feature is assigned a unique topographic identifier, as well as a code according to the industry classifier; integrity of geometric models of topographic features, in which features are not fragmented by the boundaries of the sheets of topographic maps on which they are reflected; topological consistency of geometric models of topographic features at the level of planar graph topology for all adjacent and intersecting features; support for metadata both for classes of topographic features, and for their specific instances and their attributes; use of an object-relational database management system for the implementation of an integrated storage of all information resources of the system; harmonization of geospatial data and metadata models, data exchange formats, methods and procedures for assessing data quality with the requirements of the series of international standards of the ISO 19100; prompt updating of data in the system based on the results of continuous topographic monitoring of the area; providing wide and open access to topographic data through the system's geoportal.

Introduction. The topographic databases are becoming the superior type of final topographic and geodetic products in modern conditions of the rapid development of digital technologies. There are following common main stages that can be identified in different countries in the 35-year evolution of the use of geographic information technologies for topographic mapping (Kent and Hopfstock, 2018; Jakobsson and Ilves, 2016; Olszewski et al., 2013; García et al., 2013): the use of GIS for automated mapping; creation databases of digital maps; creation of topographic databases; creation of geographic information services for the use of topographic data in the National Spatial Data Infrastructure (NSDI). These stages reflect the process of transfer of topographic knowledge about the Earth, which has been traditionally accumulated in paper topographic maps of various scales, to formalized knowledge in topographic databases. The content of topographic maps is transformed into topographic spatial data, which is structured into themes and feature types of topographic database (TDB). The database provides seamless object-structured spatial data that will be used in NSDI web services and GIS for spatial analysis and modelling (Kent and Hopfstock, 2018).

Back in 1987, W.A. Kainz emphasized: "When we try to create models for cartographic features, we often look at ordinary maps, that is, we create a model of reality, not reality itself. In future work, the focus should be on finding concepts and abstractions of real-world facts" (Kainz, 1987). The creation of TDBs in many countries demonstrates the transfer to the concept of real-world modelling, not just their cartographic models. It means that the new system of topographic production is appeared, and was formed based on integration of new digital technologies for capturing terrain data, their processing and organization of digital terrain models in TDB and their multipurpose use in NSDI (Kent and Hopfstock, 2018, Karpinskyi and Lazorenko-Hevel, 2018; Zaiets et al., 2011).

The set of standards "Topographic Database" (Karpinskyi et al., 2010) was developed in Ukraine in 2005-2010, which are harmonized with the series of the international standards ISO 19100 Geographic Information/Geomatics. The practical implementation of these standards and the creation of a seamless topographic database have been delayed for years throughout the country. This can be explained by the fact that the problems of TDB and NSDI were not a priority in our country during the years of complex transformations on the way to a market economy. But for the implementation of the Law of Ukraine "On National Infrastructure of Geospatial Data", which came into force on January 1, 2021, it is necessary to create conditions for the production of interoperable spatial data by all data holders based on a single mathematical basis and single digital models of features a real world in the TDB.

A single seamless topographic database "Main State Topographic Map" is based on updated topographic maps at a scale of 1:50 000 and is being created in Ukraine for the first time within the Ukrainian-Norwegian project "Maps for good land governance". The purpose of this publication is to discourse the structure and principles of creation a specialized geographic information system of TDB "Main State Topographic Map" (GIS TDB), the implementation of which corresponds to the purpose of TDB as a digital basis for a Core Reference Dataset of the national level of NSDI.

Methods and principles of the TDB creation. The principles of the creation of the GIS TDB "Main State Topographic Map" are determined taking into account trends in the development of geographic information technologies of topographic mapping and the key role of topographic data in the NSDI. The main principles of GIS TDB include:

- indefinitely use and operation of TDB;
- ensuring the sustainability of GIS TDB development in the conditions of constant innovations in the field of information technologies;
- classes completeness of topographic features and their attributes, which provides modeling and storage in the TDB of all features displayed on digital topographic maps;
- the complex system of identification of topographic feature in the TDB, according to which each topographic feature is assigned an unique topographic identifier, as well as a code for the relevant industry classifier, if any exists;

- the integrity of geometric models of topographic features, in which the features are not fragmented by the boundaries of the digital topographic maps sheets on which they are displayed;
- topological consistency of geometric models of topographic features should be at the level of planar graph topology for all adjacent and intersecting features;
- metadata support for both classes of topographic features and their specific instances and/or their attributes;
- the use of an object-relational database management system (ORDBMS) to implement the integrated repository of all information resources;
- the harmonization of geospatial data and metadata models, data exchange formats, data quality assessment methods and procedures following the requirements of the set of international standards of the ISO 19100 series "Geographic information/Geomatics";
- the data operational updating of in the GIS TDB based on the results of permanent topographic monitoring of the situation;
- the provision of wide and open access for the use of topographic data in the NSDI through the geoportal of the system.

GIS TDB is created as an integrated database management system, instrumental geographic information system and specialized applications that provide effective control of all technological processes of formation and use of TDB based on the input data of digital topographic maps for the implementation of these principles. There are six functional subsystems according to technological and functional features in the structure of GIS TDB (Figure 1) which provide: input control of the initial sets of digital topographic maps in scale of 1:50 000 for their compliance with the feature catalogue of digital topographic maps in scale of 1:50 000 and topological consistency of their geometry; transformation of initial digital topographic maps into datasets corresponding to the feature types catalogue of TDB; stitching geometric elements of features that area long fragmented boundaries of digital topographic map sheets; assigning unique identifiers to topographic features; the formation of primary metadata for topographic features; uploading data to the operational TDB and metadata; editing data of operational TDB and metadata based on the results of internal quality control of TDB data and topographic monitoring of the terrain; data export from operational TDB to geo-portal TDB and data sets in formats: GML, shp-files of digital map data, GeoJSON, etc.

For the initial filing of the TDB, initial sets of digital topographic maps in the scale of 1:50 000 containing layers of geometrically agreed vector models of topographic map sheets of the scale 1:50 000 in formats are used. The encoding of the types of features and their attributes of the initial sets of digital topographic maps corresponds to the current in Ukraine Classifier of the information displayed on topographic scale maps 1:10 000, 1:25 000, 1:50 000, 1:100 000, 1:200 000, 1:500 000, 1:1 000 000 and Technical Manual that was created by the authors for the creation (updating digital topographic maps of the scale 1:50 000.

Instrumental GIS is used for visualization of electronic maps and editing of topographic data of TDB based on the results of internal quality control of data in the TDB and topographic monitoring of the situation in the process of creating and operating the system. So now consider the particularities of the implementation of the most important subsystems of the GIS TDB.

The Input Quality Control subsystem of the initial sets of digital topographic maps in the scale of 1:50 000 (IQC subsystem) ensure the internal quality control of each initial set of digital topographic maps for the following elements of the geospatial data quality: conceptual consistency – compliance of the set with the conceptual schema of the set of digital topographic maps according to the set of layers (classes) of features and the set of attributes of each class; domain consistency – correspondence of all attributes values of each class to the values defined in the Technical Manual; topological consistency – the correspondence geometric elements of the vector features models of the set to the rules of the digital description and the rules of topological relations between features of the same layer and between features of different classes defined in the Technical Manual; coordinate

topological consistency of features of digital topographic maps adjacent sheets of both one set of digital topographic maps and adjacent sheets of other sets of digital topographic maps. The functions of the IQC-subsystem are implemented by GIS ArcMap.

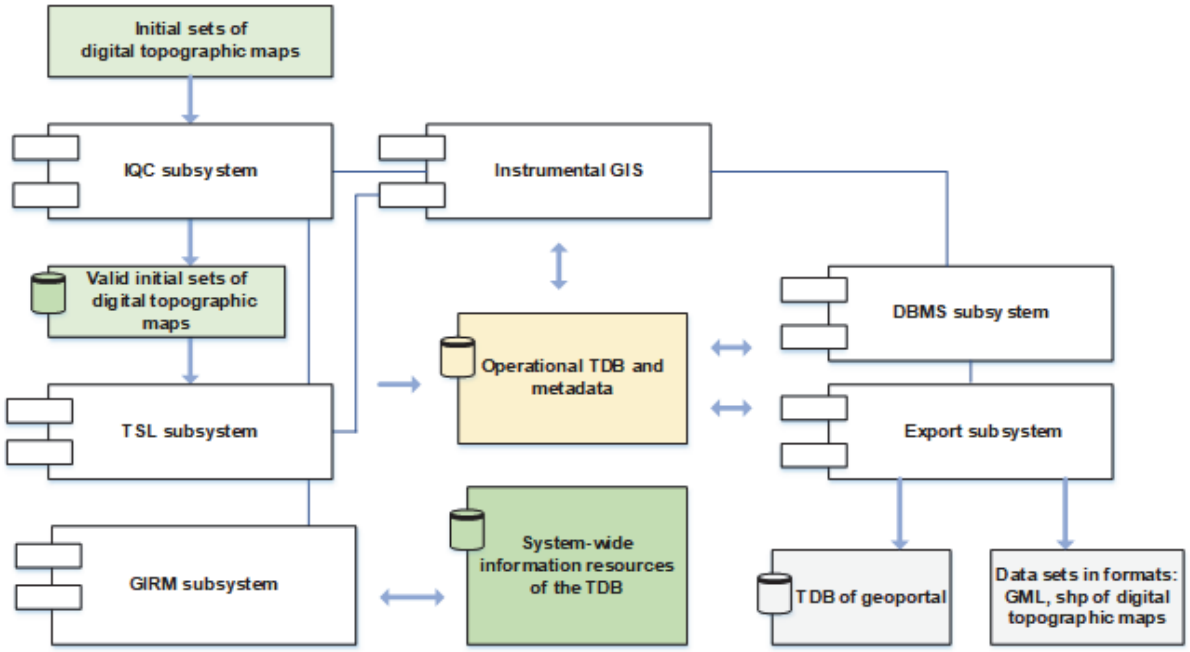

Figure 1 *The general structural schema of GIS TBD*

The subsystem for transformation and initial download of initial digital topographic maps in the scale of 1:50 000 in the TDB (TSL subsystem) ensures transforms, stitches and loads sets of valid initial digital topographic maps into the topographic database. The TSL-subsystem uses the following components of information support of the GIS TDB to implement the functions that are stored in the seamless data warehouse environment of the system ORDBMS PostgreSQL/PostGIS: valid sets of initial digital topographic maps to be converted and loaded; gateway database of geospatial data of the initial digital topographic maps; operational database of topographic data and metadata about features of TDB; a database of system-wide information resources of the TDB, in particular: feature catalogue of initial sets of digital topographic maps; a catalogue of initial metadata about the input sets of digital topographic maps sheets defined in the Technical Manual; feature catalogue of TDB; correspondence tables of catalogues of digital topographic maps and TDB features; register of geographical names of TDB features; registry of the Topographic Identifier (TOID) namespace in the topographic database.

The functions of the subsystem administration and maintenance of the database of topographic data and metadata (DBMS subsystem) ensure automation of all processes related to the administration and maintenance of an operational database of topographic data and metadata about topographic features during the stages of TDB creation and operation. Specific application functions of the DBMS subsystem should provide creation of topological models for topographic features including for network models for topographic features which by their origin and functions belong to natural or infrastructural networks (hydrographic network, roads and road structures, etc.); maintaining the integrity of the TDB geospatial data, taking into account the rules for both domain and reference restrictions and topological consistency rules for geometric elements of vector models of topographic features.

The data export subsystem is designed to convert and upload topographic data and metadata from operational TDB for later use in the TDB geo-portal system and/or other external geoinformation systems. There are mainly used tools with open source and free licenses for the implementation of GIS software TDB and geoportal such as PostgreSQL (https://postgesql.org);

PostGIS (https://postgis.net); Node.js (https://node.org/en/); Mapnik (https://mapnik.org); Leaflet (https://leafletjs.com).

Conclusions. The creation of the TDB of the Main State Topographic Map of the scale 1:50 000 is one of the first steps in the development of the NSDI in Ukraine with a set of Core reference Datasets at the national level. The establishment of permanent topographic monitoring of the situation and operative updating of the TDB based on its results will bring Ukrainian topographic mapping to a new technological level and satisfy the needs of all sectors of the economy in actual topographic data at the national level.

Ukrainian and foreign experience confirms the feasibility and effectiveness of using open source software platforms for spatial databases and geoportals, due not only to the free of their licenses, but also the ability to voluntarily increase their functionality by developing and easily connecting new application services.

References

García, F.J., de las Cuevas, A., Marín, A., Martin, V., Sánchez, F. and González-Matesanz, F.J. [2013] New production environment for the National Topographic Database 1:25.000 (IGN-E). Intelligence for geographic databases. In Proceedings of the 26th ICC2013, Dresden, Germany, Retrieved from https://icaci.org/files/documents/ICC2013/_extendedAbstract/415_proceeding.pdf.

Jakobsson, A. and Ilves, R. [2016] Reinventing the National Topographic Database, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. XLI-B4, 733–736. DOI: 10.5194/isprs-archives-XLI-B4-733-2016.

Karpinskyi, Yu.O., Lyashchenko, A.A., and Runets, R.M. [2010]. Reference model of topographic database. Journal of Geodesy and Cartography, 2, 28 – 36 (in Ukrainian).

Karpinskyi, Yu. and Lazorenko-Hevel, N. [2018] The methods of geospatial data collection for topographic mapping. Retrieved from https://www.researchgate.net/publication/349536793_metodi_zbiranna_geoprostorovih_danih_dla_topograficnogo_kartografuvanna (in Ukrainian).

Kainz, W.A. [1987] Classification of digital map data model. In Proceedings EURO-CARTO, IV, Brno, Czechoslovakia, 1987, April 13 – 16, 105 – 113.

Kent, A.J. and Hopfstock, A. [2018] Topographic Mapping: Past, Present and Future. The Cartographic Journal, 55:4, 305-308, DOI: 10.1080/00087041.2018.1576973.

Olszewski, R., Zieliński, J., Pillich-Kolipińska, A., Fiedukowicz, A., Głażewski, A., and Kowalski, P. [2013] Methodology of creating the new generation of official topographic maps in Poland. In Proceedings of the 26th ICC2013, Dresden, Germany, 680. Retrieved from https://icaci.org/files/documents/ICC2013/_extendedAbstract/248_proceeding.pdf.

Zaiets, I.M., Karpinskyi, Yu.O. and Lyashchenko, A.A. [2011] Ukrgeodescartography on the way from the infrastructure of cartographic production to the infrastructure of geospatial data. Journal of Geodesy and Cartography, 5, pp. 4 – 11. (in Ukrainian).