Eötvös Loránd University

Faculty of Informatics

Department of Cartography and Geoinformatics

János Mészáros

Geodetic basis of river regulation maps

Thesis of PhD dissertation

Eötvös Loránd University

Doctorate School of Earth Sciences

Leader:

Dr. Nemes-Nagy József, professor

Doctorate Program of Cartography

Programvezető:

Dr. Zentai László, professor

Consultant:

Dr. Timár Gábor, associate professor, Habil.

Budapest, 2015

Aims

The maps representing river regulation and drainage projects are important parts of our cartographic heritage and they significantly contributed to the establishment and development of independent Hungarian geodesy. Despite this important role, only a few people have examined these maps, detailed descriptions are still absent. The used projection system (basis of the mapping) also absent part of the literature related to projection systems used in Hungary, the only exception is the article of Lajos Homoródi, published in 1953.

Because of the previous reasons, my research has had several aims: to publish the detailed description of the projection system used in river regulation projects; to search for accessible, topic-related large and medium scale maps and give their detailed description; examine these maps from the point-of-view of their geodetic basis; based on the results of previous step to georeference maps and finally to publish the created, georeferenced mosaics on the web.

Antecedents

The digital publication of georeferenced maps is not novel, several examples can be found, e.g. the products of Arcanum Ltd. publisher of map sheets of military and cadastral surveys representing territory of Hungarian Kingdom: the georeferenced version of Second and Third Military Surveys, published on DVDs.

The Danube Mappation is the most examined among the maps discussed in my essay but previously published papers and studies mostly focused on the archival description of the maps and not on the projection related or cartographic examination. One product of these researches is *The Danube Mappation – Maps of the Hungarian section of the Danube river from the Austrian border to Pétervárad* DVD disc published in cooperation of the Department of Ethnography and Cultural Anthropology - University of Pécs, National Archives of Hungary, MédiaTér Ltd. and InnoTech Ltd. in 2006. Using the software on the DVD the entire mosaic can be visualized and examined but it also has several defects which are discussed in my essay.

The projection system of the river regulation projects is less discussed in the national and foreign literature compared to other systems from the point-of-view of projections and the history of geodesy. The paper of Lajos Homoródi (1953) contains the most useful information but it highlights the definition and its uncertainties of ellipsoidal coordinates of the fundamental point established on Gellért Hill rather than a summarizing description of used projection systems. Maybe this is the reason why latter papers and descriptions failed to notice the existence of this specific projection system despite the fact that other civilian projection systems are described in detail in several paper or webpage.

Methods

Parametrization of projection system

To parameterize the projection system of river regulations we need these data:

- the parameters of ellipsoid used to the geodetic basis: half of the major axis and the flattening;
- geodetic datum parameters of the used ellipsoid compared to a reference ellipsoid (currently WGS84 ellipsoid); in case of the Molodensky–Badekas method they consist of three shifting parameters or using the Bursa–Wolf method three shifting and rotation parameters and the scale factor;
- ellipsoidal coordinates of the central point of the projection on the used ellipsoid;
- type and parameters of projection: central meridian, central latitude, false easting and false northing and the projection center scale factor.

The values of the first and third group can be revealed in related literature (e.g. previously mentioned article by Lajos Homoródi, written in 1953) and the fourth one also can be known based on record book of the horizontal fundamental points and literature. I carried out research in the Austrian State Archives, Vienna to find record books of river regulations. To compute the datum parameters I chose the less accurate Molodensky–Badekas (three parameters) method however its accuracy is sufficient to most GIS applications. The three shifting parameters can be computed, using published equations from related literature I computed the parameters based on the ellipsoidal coordinates of central point and its ellipsoidal and geoid heights.

Georeferencing of map sheets

First of all it has to create the digital version of map sheets which can be easily achievable using a roll scanner. In the next steps these digital files were the input data during processing.

Knowing the parameters of the projection system it can be define in the most frequently used GIS software and the map sheets can be georeferenced based on that. This transformation can be done one by one manually: it has to define the pixel and projection coordinates of at least four ground control points on each map sheet and using the appropriate planar transformation transform the whole map sheet from the image coordinate system into the projection one.

This previous method can be difficult and time consuming if it has to be done with ~2000 map sheets as in the case of Danube Mappation. I developed an automatic method to solve this problem: a utility program was developed which generates the PRJ file (it contains the parameters of the projection system) and JGW file (so called World file which stores the planar projection coordinates of the northwestern corner of map sheet and the actual ground extent of one pixel of digital image) formats for each prepared (clipped to its body) map sheet. The coordinate values of the latter file can be computed based on the nomenclature system, three required parameters are:

- direction of the map sheet compared to the central point on the Gellért Hill
- section of map sheet, each section contains 16 sheets
- precise location inside the section

The actual ground extent of a pixel also can be computed, another utility program imports each digital map sheet and reads its width and height given in pixel and based on the known ground extent of one map sheet (1400×1100 Viennese fathom or 2655,08×2086,12 m), the division of the two previous values (pixel width vs. actual ground width) gives us the required value. If these two files are copied into the same folder which stores the scanned and clipped sheets, they can be easily imported into GIS software without any additional steps.

I also developed other utility programs for the other maps containing a few tens of sheets which help to make the manual georeferencing process quicker. In that cases unfortunately the labels outside the body of map contained the information to compute the projection coordinates of the four corner points. Using these information as input data my program generates a GCP file (it contains the pixel and projection coordinates of ground control points defined on the map sheet) which was imported into the Georeferencer tool of Global Mapper software during the manual georeferencing. In that cases the digital and georeferenced version of the map sheets were also made for each sheet.

Online publication of the georeferenced mosaic

It can be created the mosaic of the maps based on the georeferenced files where we can examine the whole map. It can be possible to share these mosaics with other people thanks to the tools of web GIS.

One of the existing tools is OpenLayers which is a function library based on JavaScript, with the help of OpenLayers we can visualize a lot of various GIS data embedded into web pages. I developed an interactive web page using the functions and methods of OpenLayers where user can view the georeferenced mosaics browsing through a list which consists them as well as it is able to set the transparency value of currently visualized layer comparing the content of the map with the historical data to the background mosaic of satellite images showing the current state.

Results

1. **I described several river regulation maps from the point-of-view of their historical background: Danube Mappation, Middle-Tisza map of Sámuel Lányi, Plan of Danube, Plan of Tisza, Duna and Tisza maps of Béla Vályi and finally maps of VITUKI (Water Management Research Institute).** It can be found detailed archival descriptions about a part of the mentioned maps but the cartographic examination is absent or insufficient in them, however I successfully clarified these missing parts and pointed out several inaccuracies.

   In my description I mentioned the editing circumstances of maps, the period of surveying, their geodetic basis, the size of map sheets and their body and the items of their legend in detail. The parameters of surveying and the description of map sheets held useful information for the latter georferencing.

2. **I clarified and described the projection system of river regulation projects in detail.** The previously mentioned surveys have had independent geodetic base, central point and coordinate system despite the existence of other period coordinate system to survey the Hungarian Kingdom. However, the primary aim of the Hungarian engineers was the establishment of an independent, Buda centered national system.

   The description and comparison to other period or latter coordinate systems of this projection system was absent in the literature as well as the analysis of related maps from the point-of-view of the used projection: which projection system was the basis of these maps. However, we can also ask the question: what is the latest map and date when the projection system of river regulations was used the last time. In this essay, I answered these questions: the Zach–Oriani combined ellipsoid was the used ellipsoid, the central point of the coordinate system was the fundamental point of the observatory built atop of Gellért Hill, Buda and the Cassini–Soldner projection is the best fit to model the original planar coordinate system. The answer for the second question is a little surprising: maps (published by VITUKI) were still made about rivers in 1984 based on the same projection system of the river regulations established in 1816.

3. **I created the parameterized definitions of projection system used in river regulation projects which can be used in GIS practice. Based on them I georeferenced the map sheets.** During practical GIS tasks we need exact parameterized definitions of the projection systems of the different datasets. Several standards are still exist, I define the river regulation projection system in the most frequently used formats

(PROJ.4, PRJ and MapServer Mapfile projection parameter). Using these formats the examined map sheets can be imported into GIS software.

I developed several utility programs which compute the projection coordinates of the corners or gridlines of the map sheets as well as mark the locations of these points by pixel coordinates on the digital version of maps to make the georeferencing an easier task. Because of the numerous map sheets I had to implement a fully automatic method which dramatically reduce the processing time in the case of Danube Mappation. This method uses the nomenclature system, the actual ground extent and the resolution defined in pixels of the map sheet. The only disadvantage of this method that it has to be cut the map sheets to their body of map prior to georeferencing.

4. **I created a simple, informative web page based on the georeferenced datasets, which can be used to view map mosaics using an interactive interface.** I created a provisory web page (River regulation maps in the 19th and 20th centuries; URL: http://mercator.elte.hu/~messer/folyo/) with the help of currently available web based GIS methods (OpenLayers) to browse through the mosaics as separately selectable layers. We can view and examine the river and its environment on the selected map after the download of map tiles, its transparency also can be adjustable partly or fully to compare its graphical content to the mosaic of Google Maps satellite images representing the current status of the river.

Conclusions

Unfortunately the river regulation mappings are slightly discussed in the related literature, my research tried to change this, to be a completion. The description of the projection system discussed in the first part of my essay can be a useful contribution to the history of the Hungarian, Budapest centered coordinate systems. The fact that the system established by engineers in the 19th century was still in use during the surveys of 1980s has to be highlighted.

My research on the history of the maps decreased the ‘grey zones’ or gave completely new descriptions of the discussed maps. The magnitude of the river regulation projects can be uncovered through these maps as well as the change of rivers and their environment can be trackable. Because of the latter fact the georeferenced and published mosaics can be useful for other researchers with different topics as physical or social geography, ethnography or archaeology.

The methods discussed in the latter application focused and practical problems and their solutions oriented chapters can be used to other maps, they are partly universal solutions. The developed utility programs can be used to georeferenced the map sheets what they made for, their source can be used freely if somebody would like to develop own versions written in different programming language or on different platform. Based on the given definitions of the projection system anybody can integrate it into GIS software, import and compare the map sheets to other datasets.

Publications

Journal articles

Mészáros, J., 2010: A Duna Mappáció szelvényeinek georeferálása. in: Geodézia és Kartográfia, 2010/7, pp. 30-32. Budapest

Petrovszki, J., - Mészáros, J., 2010: The Great Hungarian Plain in the sheets of the Habsburg Military surveys and some historical maps – A case study of the Körös/Criş Drainage Basin. in: Acta Geodaetica et Geophysica Hungarica, 2010/45, pp. 56-63., Akadémiai Kiadó, Budapest

Mészáros, J., 2012: The georeferencing method of the 1:5000 scale Danube maps. in: E-perimetron, 2012/1, pp. 45-49.

Conference papers

Mészáros, J., 2010: The georeferencing of Sámuel Lányi's Tisza maps. in: Gartner, G. – Livieratos E. (szerk.): Proceedings of the 5th International Workshop on Digital Approaches in Cartographic Heritage. Wien. pp. 370-374.

Mészáros, J., - Timár, G., 2010: The Danube Mappation of Hungary (1823-45) and its reprojection to modern map coordinate systems. in: Gartner, G. – Livieratos E. (szerk.): Proceedings of the 5th International Workshop on Digital Approaches in Cartographic Heritage. Wien. pp. 365-369.

Mészáros, J., 2011: The georeferencing method of the 1:5000 scale Danube maps. in: Proceedings of the 6th International Workshop on Digital Approaches in Cartographic Heritage. Den Haag. p. 27.

Mészáros, J., 2011: A Vízügyi Igazgatóság térképeinek vetületi rendszere és GIS integrációja. in: Lóki, J.: Az elmélet és a gyakorlat találkozása a térinformatikában: II. Térinformatikai Konferencia és Szakkiállítás. Debrecen. pp. 265-270.

Mészáros, J., 2011: The Danube map of Béla Vályi and its georeferencing method. in: Ruas, A.: Proceedings of the XXV International Cartographic Conference: Enlightened view on Cartography and GIS. Paris. p. 316.

Mészáros, J., 2012: Vályi Béla vízrajzi térképei és geoinformatikai rendszerbe integrálásuk. in: Lóki, J.: Az elmélet és gyakorlat találkozása a térinformatikában III. - Térinformatikai konferencia és szakkiállítás. Debrecen. pp. 253-258.

Posters and presentations

Mészáros, J., 2009: The Tisza maps of Samuel Lanyi and their geodetic basis. Poster. European Geosciences Union General Assembly, Wien, 2009. április 19-24.

Timár, G. – Mészáros, J., 2009: High-resolution digital elevation model and historical topographic maps of the Tisza River floodplain, the Great Hungarian Plain. Poster. European Geosciences Union General Assembly, Wien, 2009. április 19-24.

Mészáros, J., 2009: Duna Mappáció szelvényeinek georeferálása. Presentation. Fény-Tér-Kép, Dobogókő, 2009. november 12-13.

Mészáros, J., 2010: The georeferencing of Sámuel Lányi's Tisza maps. Presentation. 5th International Workshop on Digital Approaches in Cartographic Heritage, Wien, 2010. február 22-24.

Mészáros, J., - Timár, G., 2010: The Danube Mappation of Hungary (1823-45) and its reprojection to modern map coordinate systems. Presentation. 5th International Workshop on Digital Approaches in Cartographic Heritage, Wien, 2010. február 22-24.

Mészáros, J., 2010: The Danube Mappation of Hungary (1823-45) and its georeferencing method. Presentation. European Geosciences Union General Assembly, Wien, 2010. május 2-7.

Mészáros, J., 2011: The Danube Cadastre map system and its georeferencing method. Poster. European Geosciences Union General Assembly, Wien, 2011. április 3-8.

Mészáros, J., 2011: The georeferencing method of the 1:5000 scale Danube maps. Presentation. 6th International Workshop on Digital Approaches in Cartographic Heritage, Den Haag, 2011. április 7-8.

Mészáros, J., 2011: A Vízügyi Igazgatóság térképeinek vetületi rendszere és GIS integrációja. Presentation. Az elmélet és a gyakorlat találkozása a térinformatikában: II. Térinformatikai Konferencia és Szakkiállítás, Debrecen, 2011. május 19-20.

Mészáros, J., 2011: The Danube map of Béla Vályi and its georeferencing method. Presentation. XXV International Cartographic Conference: Enlightened view on Cartography and GIS, Paris, 2011. július 3-8.

Mészáros, J., 2012: Vályi Béla vízrajzi térképei és geoinformatikai rendszerbe integrálásuk. Presentation. Az elmélet és gyakorlat találkozása a térinformatikában III. - Térinformatikai konferencia és szakkiállítás, Debrecen, 2012. május 24-25.

Mészáros, J., 2014: Historical water control maps – key to understand current challenges? Poster. European Geosciences Union General Assembly, Wien, 2014. április 27-május 2.