Gábor Molnár[*], Gábor Timár[**], Előd Biszak[3***]

Can the First Military Survey maps of the Habsburg Empire (1763-1790) be georeferenced by an accuracy of 200 meters?

Keywords: georeference; historic maps; Habsburg Empire; First Military Survey; 18th century

Summary: The First Military Survey of the Habsburg Empire was made after the order of Empress Maria Theresia, issued after the seven-year war (end of 18th Century). The scale of the survey sheets is 1:28,800. According to the processed literature, the survey has neither triangulation basis, nor clearly defined projection. Earlier, during the geo-referencing projects of the Hungarian SME Arcanum, the sheets were rectified in virtual mosaics for each mapped province. Some tens of the ground control points (GCPs) were defined by their mosaic image coordinates and the UTM coordinates of the respective zone. Twelve coefficients of a quadratic formula were estimated using these coordinates for each province. Using the quadratic transformation, the RMS errors occurred as high as several hundred meters, in case of larger provinces, even 1-2 kilometers.

A new method is introduced now, consisting of two consequent steps, using cca. 200-500 GCPs per province. (1) Parameters of the best-fitting Cassini projection are estimated from the GCP coordinates. (2) The non-systematic RMS error (up to one kilometer) is handled by a NTv2 format correction grid (GSB), compiled again on the basis of the GCP coordinates. The still remaining error is in the magnitude of 100-200 meters, however it can be further refined in important areas, using a more dense GCP network.

Introduction

The topographic surveys of the Habsburg Empire have been a main target of digitizing, georeferring and nowadays also the web-publishing activity concerning the whole cartographic heritage of the world (Timár et al., 2011; Biszak et al., this volume). The Second Military Survey (1806-1869) was geo-referred by providing a mathematical model of its native projection and locate the map sheets in that, using their corner coordinates in this grid (Timár et al., 2006), the very same method that is described in the present volume concerning the Cassini maps of France (Timár et al. A, this volume).

This method cannot be applied to the First Military Survey (1863-1887) of the Habsburg Empire. First, the Austrian literature agrees on that the survey has no geodetic and therefore projection background (Hofstätter, 1989; Kretschmer et al., 2004). We argue this point, however without knowing or estimating at least the projection parameters, it should be accepted as a starting point. In the Vienna military archives we haven't found so far any description of any geodetic survey connected to the first topographic survey. At the beginning of this study, we can only state that the surprising accuracy of the map sheet content cannot be a result of any work without geodesy.

[*] MTA-ELTE Geological, Geophysical and Space Science Research Group, Hungarian Academy of Sciences at Eötvös University, Budapest, Hungary [molnar@sas.elte.hu]

[**] Department of Geophysics and Space Science, Budapest, Hungary [timar@caesar.elte.hu]

[***] ARCANUM Database Ltd., Budapest, Hungary [biszakelod@gmail.com]

In our earlier version of the First Military Survey georeference, we selected several tens of control points per a region of the Empire. Using the image coordinates and the UTM coordinates of these points we estimated the 12 parameters of the best-fitting quadratic transformation between the coordinate system of the scanned image and the UTM grid coordinates. This transformation was applied to the whole virtual mosaic of the sheets covering the given region. The accuracy of the horizontal control was quite low: from several hundred meters (in case of smaller provinces) to even almost two kilometers (in the extremities of the larger ones). However, this solution was the first working one for this nice piece of cartography (Timár et al., 2011).

The technology of the correction grids (grid shift binary: GSB, aka. NTv2; for details, see Timár et al. B, this volume) offers a remarkable tool for refining the georeference of historic maps (Molnár & Timár, 2011). In this method, we use again ground control points (GCPs), identified terrain objects that can be found in the old map (giving their image pixel coordinates) and also in modern cartographic products (providing their location in e.g. WGS84). In the present study, we show the difficult example of the First Military Survey, where there is no initial information about the native coordinate system of the map sheets.

Data and method

At the time of submitting this paper, processing of map sheets of two Habsburg provinces (Lower and Upper Austria) have been finished and published, another one (Bohemia) is ready, while processing of Croatia and Galicia have been started. For all of these provinces, a 'province image mosaic' was made, using the scanned images of the map sheets. We collected several GCPs (minimum 3 per sheet, usually identified town or village center objects) in these mosaics. For all GCPs, we record two coordinate pairs:

1. Their pixel position in a 'province image mosaic', and
2. Their geographic (WGS84) coordinates, according to Google Earth.

As we had no hints for the initial coordinate system of the maps, we used a classic engineering method: define one somehow and provide a correction procedure that refines it to acceptable level. The input dataset for both steps was the GCP set.

In the first step, we estimated the parameters of the best-fit Cassini projection, providing the connection between the image and the geographic coordinates of the GCPs. The estimated parameters were the following:

- Cassini-grid easting and northing of the upper left (NW) corner of the province image mosaic
- E-W and N-S extents of an image pixel of the province image mosaic
- longitude of the best-fit projection origin
- Cassini-grid easting and northing of the best-fit projection origin

One can immediately observe that the latitude of the best-fit projection origin was not estimated. It was not indeed, as this estimation is invariant to this value. In case of a Cassini-projected map, the latitude of projection center can be set to anywhere, if the false northings (the northing position of the projection center) are altered together with it. In the present procedure, we provided a pre-selected latitude for the projection center, and during the estimation, we get the northings of it (the last element of the above list) according to this value.

Using these figures, we can geo-refer the province mosaic by a single linear fit to a Cassini grid with the estimated projection, interpreted on the WGS84 base surface. The horizontal accuracy of this fitting is the same we had earlier by the quadratic fit to the UTM coordinate system. Interestingly enough, for Lower Austria, the estimated central meridian (longitude of the projec-

tion center) crosses the Stephansdom tower in Vienna (with a few hundred meters of reliability), which may indicate that the survey has some cartographic background anyway.
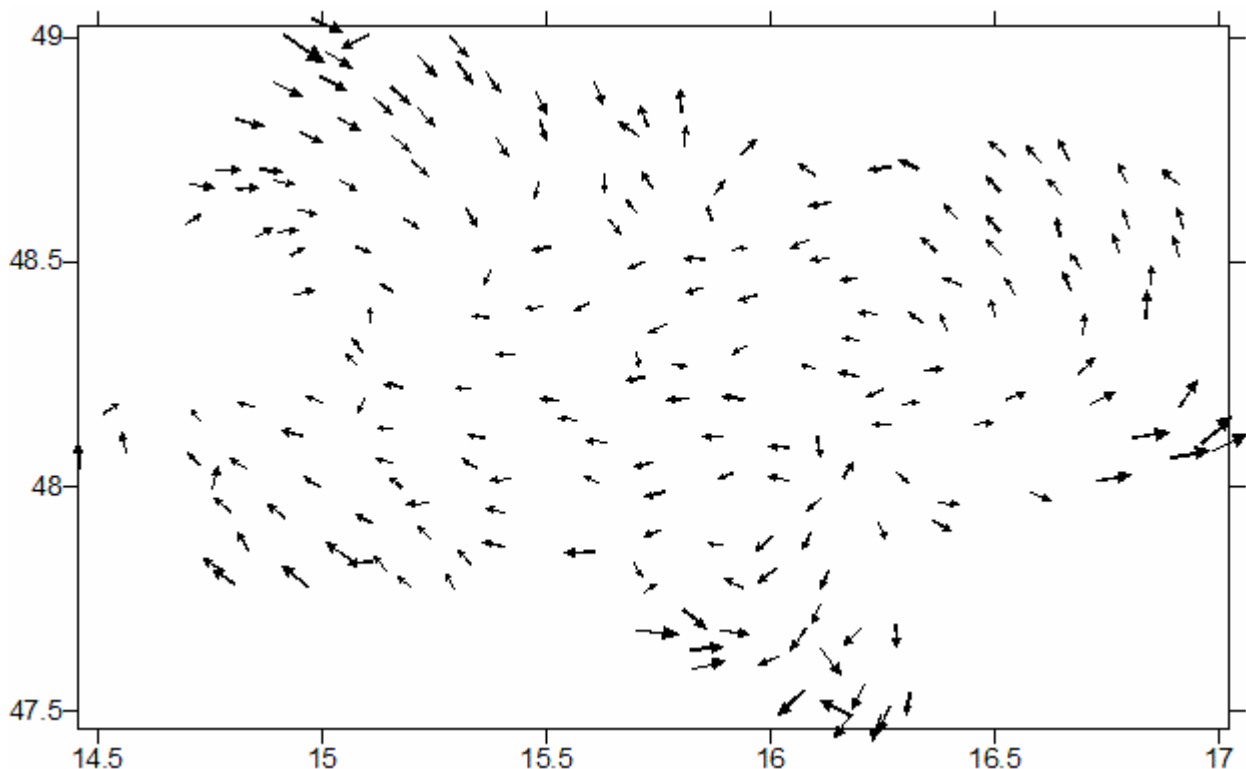

Figure 1. Correction vectors at the ground control points in Lower Austria, used for the correction grid compilation: The length of the longest vector is 80 arc seconds (cca. 2400 meters).

In the second step, we use the GCP set again, to define a geodetic datum instead of the WGS84 used in the first step to reduce the horizontal errors. A five arc minute correction grid was compiled by simple bilinear interpolation. The latitude and longitude shifts at the GCPs were computed from their WGS84 coordinates (as starting points of the vectors) and the geographic coordinates computed from the mosaic pixel coordinates and the above listed parameters of the Cassini grid and its location (as endpoints of the vectors). The correction vectors for Lower Austria are shown in Fig. 1. It is obvious that these corrected error is not systematic, they cannot be modelled by simple mathematic methods available in GIS packages. Therefore the correction grid is the best and so far the only available method to handle these errors.

Results

The result for each province is (1) the coordinate system of the mosaic, characterized by the Cassini projection with its estimated parameters and the datum defined by the correction grid (GSB) and (2) the province image mosaic fit to (resampled into) this coordinate system.
The horizontal control of the geo-referred mosaic is considerably better than it is without the correction grid. With the five arc minute grid, the error can be decreased to 100-200 meters (Fig. 2). However, the method has an option to increase the accuracy not in the all mapped region (by defining more GCPs and compiling a denser grid) but also in smaller parts of it (e.g. for the city of Vienna) by defining a high-resolution local grid for the more important parts of the area. The

data input (GCPs) can also be obtained from the users of the published database, making a new, interesting application area of the social-web database building.
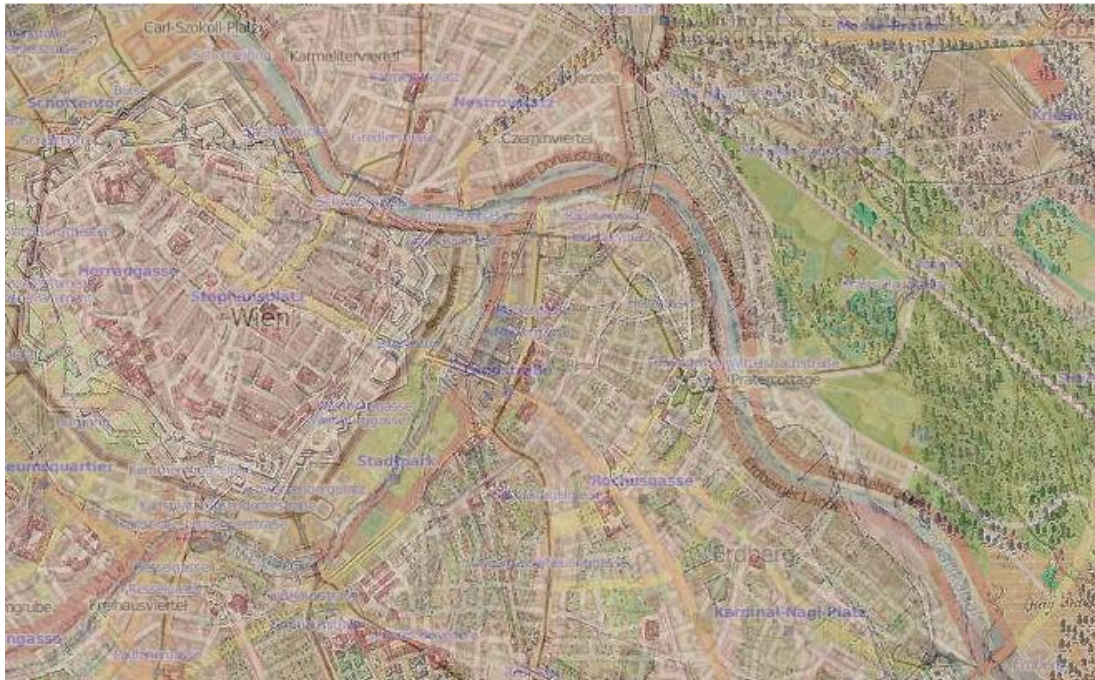

Figure 2. Overlay of the First Military Survey mosaic on the modern OpenStreetMap layer of Vienna.

The boundary problem

As it was mentioned earlier, the error vectors of the correction grid are compiled by bilinear interpolation of the ones at the GCP locations. It is an important experience that they should be interpolated indeed: extrapolation could result unacceptable errors. It is the typical case occurring at the boundaries of the regional mosaics (Fig. 3).

To avoid the extrapolation errors, we have to define GCPs along the boundaries of the mapped area/mosaic. If we do so, even at the boundaries, we have accurate results, and the zone of extrapolation is shifted to beyond the area of our interest, which is represented by white, blank area in the map sheets. This is the only way to make fit the mosaics of two neighboring provinces seamlessly.

Figure 3. The Wolfgangsee is in wrong position at the western margin of Upper Austria, because of the lack of the control points on the province boundary.

The online version

The result of the completed Habsburg provinces is available for the public via the MAPIRE initiative/project (Biszak et al., this volume). The geo-referred mosaics can be analyzed in a modern (OpenStreetMap or Google) cartographic background. Using the geo-reference of all historic databases in the MAPIRE, the Habsburg military topographic surveys can also be analyzed by coupling them (Fig. 4); providing a virtual time machine for natural or historical environmental and/or landscape studies. Now, with the results of the present study, with the same horizontal reliability.
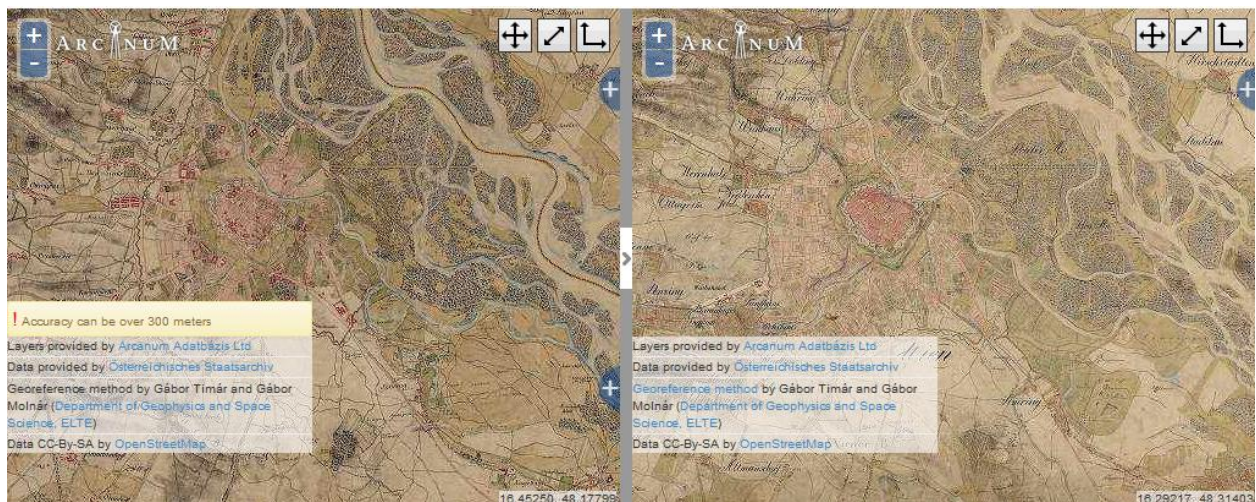

Figure 4. First Military Survey (left) vs. the Second Military Survey (right) or vicinity of Vienna: virtual time machine, a simultaneous display based on the georeference.

References

Biszak, E., Kulovich, H., Biszak, S., Timár, G., Molnár, G., Székely, B., Jankó, A. and I. Kenyeres (this volume). *Cartographic heritage of the Habsburg Empire ont he web: the MAPIRE initiative.*

Hofstätter, E. (1989). *Beiträge zur Geschichte der österreichischen Landesaufnahmen*, I. Teil, Bundesamt für Eich- und Vermessungwesen, Wien, 196 p.

Kretschmer, I., Dörflinger, J. and F. Wawrik, (2004). *Österreichische Kartographie.* Wiener Schiften zur Geographie und Kartographie, Band 15, Institut für Geographie und Regionalforschung der Universität Wien, Wien, 318 p.

Molnár G., and G. Timár (2011). Using of Grid Shift Binary (GSB) data to improve the geo-reference of the Third Military Survey of the Habsburg Empire. *Geophysical Research Abstracts* 13: 11861.

Timár G., Molnár G., Székely B., Biszak S., Varga J. and A. Jankó (2006). *Digitized maps of the Habsburg Empire – The map sheets of the second military survey and their georeferenced version.* Arcanum, Budapest, 59 p.

Timár, G., Biszak, S., Székely, B. and G. Molnár (2011). Digitized Maps of the Habsburg Military Surveys: Overview of the Project of ARCANUM Ltd. (Hungary). In: Jobst, M. (ed.): *Preservation in digital cartography*. Lecture Notes in Geoinformation and Cartography, Springer, Berlin-Heidelberg, 273-283.

Timár, G., Mészáros, J. and G. Molnár (this volume, A). *A simple solution for georeferencing the Cassini map series of France*.

Timár, G., Bartos-Elekes, Zs., Molnár, G., Imecs, Z. and Zs. Magyari-Sáska (this volume, B). *Improvement of horizontal georeferencing accuracy of the 1864 map of South Romania by correction grid (GSB) in GIS and web publishing environment*.