DETAILED ANALYSIS OF THE MÜLLER'S MAP OF BOHEMIA

Jiri Cajthaml
Department of Mapping and Cartography
Faculty of Civil Engineering, Czech Technical University in Prague
Thakurova 7, 166 29 Prague 6, Czech Republic
jiri.cajthaml@fsv.cvut.cz

Abstract

The Müller's map of Bohemia is an exceptional masterpiece of the Czech cartography. The map was created in 1720, firstly printed in 1723. Its author Johann Christopher Müller was an Austrian military engineer and great cartographer. After working out the map of Hungary ("Mappa regni Hungarie", 1709) and the map of Moravia ("Tabula generalis Marchionatus Moraviae in sex circulos divisea", 1712) he started to work on his most famous map of Bohemia. The map is printed on 25 separate map sheets, every 557 mm wide and 473 mm high. After joining these sections we get the image of Bohemia almost 2.5 meters high and 3 meters wide. Undoubtedly it is the largest map created by a solitary cartographer in the Czech history. Recently the original prints of map sections of the Müller's map of Bohemia were scanned in the Central Archives of Surveying, Mapping and Cadastre of the Land Survey Office in Prague. As we at the Department of Mapping and Cartography at the Czech Technical University in Prague have broad experience with early maps analysing we decided to make a thorough research on this map using digital technologies. Firstly it was necessary to create the seamless image of the whole map. Every map sheet was transformed to its original size. That was essential for reducing the paper shrinkage and distortions caused by scanning. As we wanted the map sections to precisely fit in the corner points we used projective transformation, which gives zero residuals. After merging all transformed sections we obtained the large image of the map. Notice that the non-compressed data volume of this image has exceeded 2 GB. Although the corner points fit precisely, other points on the edges were somehow distorted. The adjacent edges were slightly shifted or bended. We had experienced the same problem analysing the Müller's map of Moravia before. IDW (inverse distance weighted) transformation of the edge points had been tested to eliminate these errors. Due to minimal errors on the main part of the Müller's map of Bohemia, we finally kept the images after projective transformation. The cartometric analysis of the map consisted of determining of the cartographic projection (if there was any) and the scale of the map. As the Müller's map of Bohemia has a geographical grid marks on the map frame we used it for that purpose. We approved that the used cartographic projection could be normal aspect of cylindrical projection equidistant in meridian with two standard parallels. Questionable is the fact, that the geographical grid was added to the map at the end of the work and has no relationship with the cartographical content. The scale of the map can be determined by three basic methods: measuring the graphic scale bar, measuring selected known lengths and using

transformation with GCPs (ground control points). We tested all these methods and concluded the value somewhere between 1:130 000 and 1:136 000. The most precise method of the map scale determining is surely the transformation. We tested many types of transformation and many sets of GCPs. Our recent work consisted of creation of the vector data model of the map. Once having the large dataset of the map objects we can choose the best transformation method and georeference the map into some well-defined coordinate system. The ArcGIS geodatabase has been designed and filled. The advantages of the vector data model are clear. Besides determining the map scale and the best set of GCPs vector data is much easier to manipulate with. In many environmental analyses vector data are much usable. After revising the vector data model and proper georeferencing of the map, both of these digital datasets (raster map image, vector database) will be distributed on the Internet for other researchers and general public using web map services (WMS, WFS).

Müller's map of Bohemia

The Müller’s map of Bohemia is an extraordinary masterpiece of Czech cartography. J. Ch. Müller, an author of the map, was an important Austrian military engineer and above all an exceptional cartographer. The map originated in the years 1712 till 1718 as the result of the first systematic topographic mapping of the Czech lands. Firstly it was set out in 1723, unfortunately after Müller’s death. The title of the map is „Mappa geographica regni Bohemiae“. The scale of the whole map is approx. 1 : 132,000. The size of one map section is 473 x 557 mm and the entire size of the map is 2,403 x 2,822 mm (5 x 5 map sheets).

Recently the original prints of the map sections of the Müller's map of Bohemia were scanned in the Central Archives of Surveying, Mapping and Cadastre of the Land Survey Office in Prague. In our previous work we were working with the digital data distributed by the Institute of History of Academy of Sciences of the Czech Republic. These prints of the map sheets had been quartered and a cloth had been used for mounting (Cajthaml and Krejčí, 2007). Therefore the new digital data is much better for the cartometric analysis. The quality of the digital data of both datasets is the same (24-bit colour depth and 300 DPI densities).

Merging the map sheets together

At the beginning of the research the aim was to prepare the seamless image of the whole map. All 25 map sheets were transformed into their real dimensions and into their right position in the whole image (see Figure 1.). As we knew the dimensions of the map sheet 473 x 557 mm (Kuchař, 1959), we used corner points for the map sheets transformations. Using this method we eliminated the paper shrinkage during the archiving. Although the corner points fit precisely, other points on the edges were somehow distorted. The adjacent edges were slightly shifted or bended.

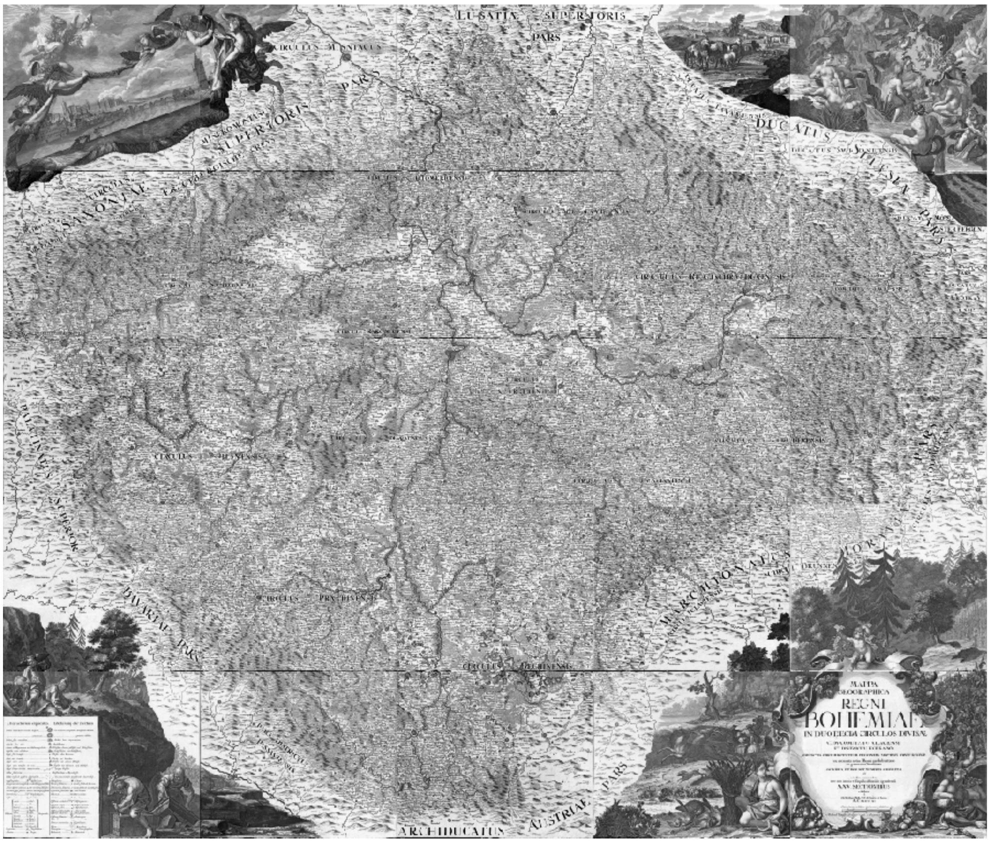

Figure 1. The image of the merged map sheets

Figure 2. The detail of the merged map sheets

We had experienced the same problem analysing the Müller's map of Moravia before (Krejčí and Cajthaml, 2009). IDW (inverse distance weighted) transformation of the edge points had been tested to eliminate these errors. Due to minimal errors on the main part of the Müller's map of Bohemia (see Figure 2.), we finally kept the images after the transformation. Another method of edge matching could be based on constrained polynomial fit (Molnár, 2010). The data volume of the image of the map exceeded 2GB.

Creating the vector data model

There are many motivation factors for creating the full vector data model of the map (Cajthaml, 2010). Having full vector data model, many ground control points (GCPs) could be used for georeferencing the map or other analyses. Of course, the vector data are much easier to handle with. The spatial analyses (e.g. overlay) are easier to be performed with the vector data. With the full vector data model the statistics of the map features can be done very quickly.

Before creating the vector data model it is necessary to design the geodatabase for storing the data. On the Müller's map of Bohemia there were found 6 types of map features: settlements and important places (point features), towns within walls (polygon features), river network (line features), water bodies (polygon features), roads (line features), and boundaries (line features). For these types 6 feature classes were designed in the geodatabase. Every map feature holds some attributes. For villages, towns or important places it is usually the historic name of the place (written on the map), current name of the place and the type of the place. Studying the legends of the map (see Figure 3.) over 40 types of point features were identified.

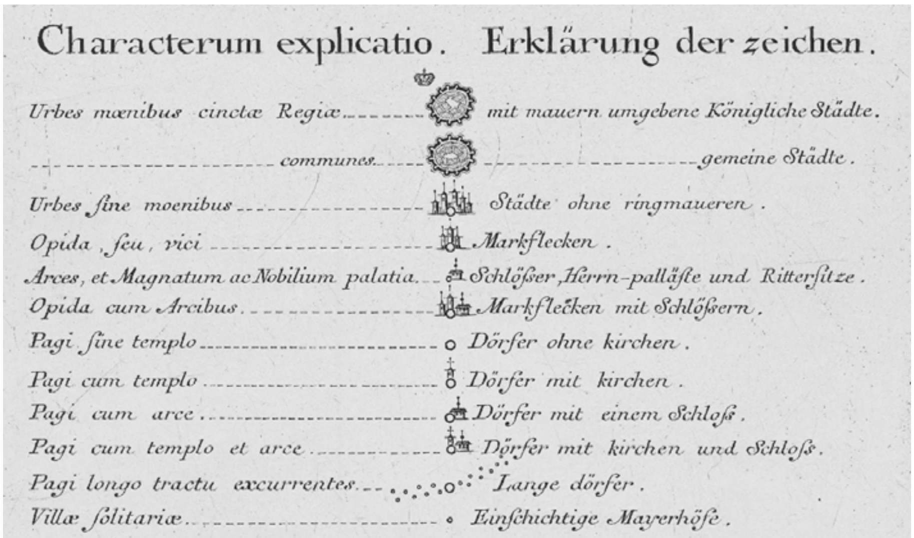

Figure 3. Part of the legends of the map

After designing the geodatabase (feature classes, attributes) the map sheets were vectorized into the designed models. Every map sheet was created in the separate database. For some analyses it is necessary to have separate databases for the map sheets. Thus these databases can be compared. For some other analyses it is better to have the merged geodatabase of the whole map. Merging of the map sheets was very difficult task. On the edges of the map sheets the topological relations had to be re-established.

Some errors occurred during the database merging. Of course, there are some problems such as evident errors made by the author. One of these errors had been published earlier (Krejčí et al., 2009). The town Kladno is on the Müller's map of Bohemia depicted twice (on two map sheets). This fact was proven and other edges were inspected to find similar errors – none was found. The second type of the author's incorrectness was the topological inconsistency. For example, the boundary or road is depicted on the other side of the river on different map sheets. The third group of errors consists of missing map features. There are some evident missing roads (not connected network) and missing boundary in the northwest Bohemia (Cajthaml, 2010). The part of the vector data model is displayed (see Figure 4.).

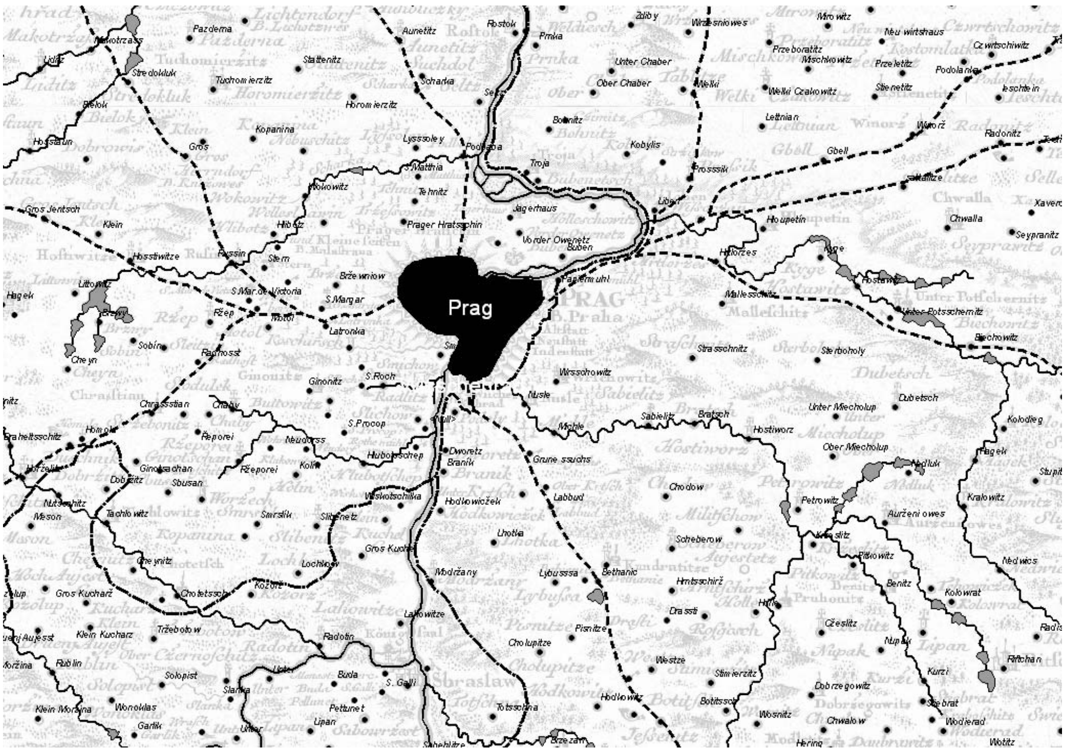

Figure 4. The part of the vector data model (Prague and its surroundings)

Statistics of the map

As we have the complete geodatabase of the Müller's map of Bohemia it is very easy to perform the statistics of the map. These numbers are very interesting when confronted with earlier published data. On the map we found: 15,215 point symbols (e.g. 11,997 villages, 677 small towns, 44 towns, 233 places of extraction and processing of natural resources, etc.). Compare this number with early published 12,495. In the polygon class we found 133 towns (45 royal towns within this class) (Cajthaml, 2010).

On the map there are 2154 water bodies with area approx. 28,300 mm^2 (490 km^2 in reality). The river network consists of approx. 185,400 mm of rivers and streams (24,400 km in reality). These data will be analysed during following research. Other two feature classes are not so interesting in the statistics field. The road network is not complete and contains only selected roads (25,950 mm on the map). Nevertheless it would be interesting to compare these main roads with today motorway and highway network. The boundaries class is very interesting. It shows the shape of Bohemia (western part of the Czech Republic) almost the same as today. That point out the fact that the boundaries has not changed through almost 300 years (see Figure 5.).

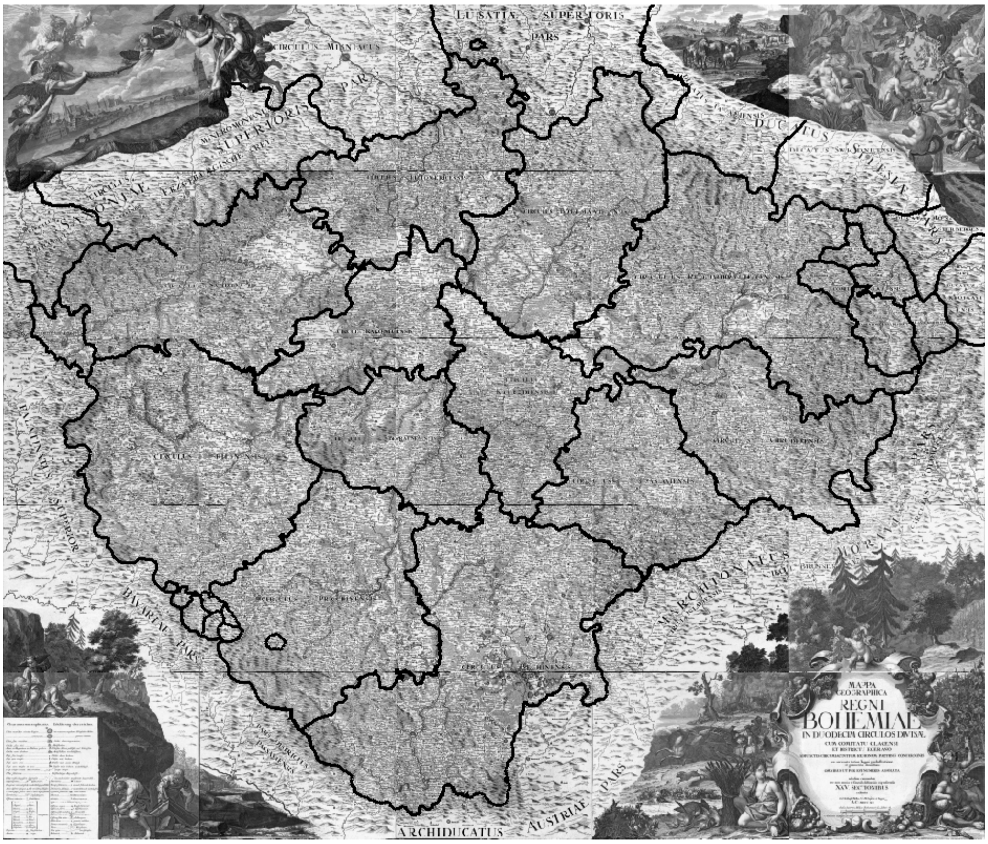

Figure 5. Boundaries on the map

Cartometric analysis of the map and georeferencing

Just like the map of Moravia, the map of Bohemia has a geographic grid scale on the map frame. The measurement of the grid scale concluded to define the map projection as a normal aspect of cylindrical projection equidistant in meridian with two standard parallels. Using the projection equations, the latitude of the standard parallel was identified as 50° 04'. This value is close to the value of Prague's parallel as well as to the rounded value of 50°. It is questionable which of them was in the author's plans. Nevertheless, the coordinate grid of the map of Bohemia is more accurate than those of the Moravian map, which is just roughly estimative (Krejčí and Cajthaml, 2009).

We determined the map scale by several methods (Cajthaml and Krejčí, 2007). The graphic scale bar on the map of Bohemia displays two Czech miles. We know that one Czech mile is 300 strands and one strand is 52 Prague ells. The most probable value of one ell is 0.5914 m. We determined the distance of 1 Czech mile as 68.8 mm in the map and the map scale as approx. 1 : 134,000 by careful measurement of scale bar (Krejčí and Cajthaml, 2009).

Another method, the measuring of distances between towns in the map was done just for a few couples of towns in a test area, which resulted in a map scale of 1: 132,000. In the next step, we used MapAnalyst software for the map scale determination by global transformation (Helmert) with 83 GCPs. The scale varies between 1 : 130,000 and 1 : 136,000. The resulted mean scale was computed as 1 : 133,000. The depiction of the local scale distortions was made as well.

The best method how to determine the scale of the map is the transformation (georeferencing) using as many GCPs as possible. After we had completed the full vector data model, the transformation with more than 4,000 points was tested. In fact we found 4,409 points with their corresponding coordinates in the current coordinate system. As the coordinates of these points were joined automatically (from the database of the Czech statistical office), many errors occurred. In the Czech Republic there are many villages with the same name and therefore joining the coordinates failed (the name of the village can't be used as a primary key of the table). Some other villages moved their centre within 300 years and the coordinates did not correspond with reality. Nevertheless we kept 3,906 GCPs for data transformation.

There are many transformation methods how to georeference old maps. Usually affine transformation is used because the shrinkage of the paper could be eliminated and the map image is not badly distorted. The better results can be achieved with polynomial transformations. Unfortunately, after polynomial transformation the image is somehow distorted and the lines are transformed into the curves. As we used the transformation (to the right dimensions of the map) at the beginning of our research, we eliminated the shrinkage of the paper earlier. Then if we don't want to damage the map image similarity transformation method should be the best. Using all 3,906 GCPs we acquired following numbers for similarity transformation: standard error of position 1.74 km and the mean scale of the map 1 : 131,580. Compare these numbers with previous research (Kuchař, 1959), (Krejčí and Cajthaml, 2007).

Conclusions

The aim of our ongoing research is to make detailed analysis of the Müller's map of Bohemia. At the beginning it was necessary to merge all 25 map sheets together. For this type of data we discovered the best solution – transformation of the map sheets into their right dimensions and position in the merged map (of course with the knowledge of the right dimensions of the map). Projective transformation using all 4 corner points provides the perfect fit of the map sheets. If the data are badly distorted (bended) other methods should be used (e.g. IDW transformation of the edge points, or the constrained polynomial fit).

If we want to analyse the map with the real functionality of GIS software the best solution is to create the full vector data model. We applied this method on the Müller's map of Bohemia and obtained the database that will be used during following research. We have vectorized over 15,000 point symbols with their classification into many categories; we have vectorized the river network or the road network with their topologies, etc. These data can be analysed using GIS software very effectively. Of course the data were transformed into well defined coordinate system (national system S-JTSK). The standard error of position of this similarity transformation was 1.74 km (13.2 mm on the map).

References:

Cajthaml J., Krejčí J. (2007): Müllerovy mapy Českých zemí, jejich digitalizace a zpracování. [Müller's maps of the Czech lands, their digitizing and processing. (in Czech with English summary)]. Kartografické listy vol. 15: pages 51-59, Kartografická spoločnosť SR a Geografický ústav SAV, Bratislava.

Cajthaml J. (2010): Vector data model of the Müller's map of Bohemia. Acta Geodaetica et Geophysica Hungarica, vol. 45: (accepted for publication), Akadémiai Kiadó, Budapest.

Krejčí J., Cajthaml J. (2009): Müller's maps of the Czech lands and their analysis. Acta Geodaetica et Geophysica Hungarica, vol. 44: pages 27-38, Akadémiai Kiadó, Budapest.

Krejčí J., Mikšovský M., Zimová R. (2009): Possible relation between the Müller's map of Bohemia and the First Military Survey — A case study of the Kladno region. Acta Geodaetica et Geophysica Hungarica, vol. 44: pages 39-48, Akadémiai Kiadó, Budapest.

Kuchař K. (1959): Vývoj mapového zobrazení Československé republiky I.- Mapy českých zemí do poloviny 18. století [Evolution of mapping of the Czechoslovak

Republic I. – Maps of Bohemia till the middle of the 18th century (in Czech)]. Praha : Ústřední správa geodézie a kartografie.
Molnár G. (2010): Making a georeferenced mosaic of historical map series using constrained polynomial fit. Acta Geodaetica et Geophysica Hungarica, vol. 45: (accepted for publication), Akadémiai Kiadó, Budapest.