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Digital technologies in analysis of the Müller's map of Bohemia

Summary

The Müller's map of Bohemia is one of the most important maps in Czech history. It is not just beautifully and well made, but it shows many characteristics of historical landscape in surprising detail. The manuscript map was finished in 1720 by Johann Christopher Müller and is the last piece of "one-man cartography era" in Czech lands. The map was engraved on 25 copperplates by Michael Kauffer and finished in 1722. The aim of our project is thorough analysis of this map. The most important information on the old map is the spatial position of point symbols (towns, villages), line symbols (rivers, roads) and area symbols (water areas, districts). These symbols are usually compared with current situation. Using this method we can explore changes of water bodies or water network, changes of settlements (e.g. disbanded villages), changes of major travel routes. The crucial problem of this approach is georeferencing raster images into some well defined co-ordinate system. We solved this problem by creation of the full vector data model of the map. Once we have complete vector model of the map, we can test many combinations of ground control points (only towns, only roads crossings etc.) and many types of transformation.

In the first phase of the project we reconstructed the original dimensions of the map sheets. Due to the shrinkage of the paper, old maps are usually distorted. We measured original copperplate engravings and transformed the data into these dimensions. After that we merged the data of all 25 map sheets together. Then the database was designed and created. Notice that more than 15000 point symbols were digitized. Using ground control points from the database we transformed the Müller's map of Bohemia into the Czech national co-ordinate system (S-JTSK). Now the data can be joined into environmental applications as a GIS layer. Furthermore, we can perform many GIS analyses with vector data to get information about 300-year-old landscape (e.g. population density analyses were performed). Digital data of the map will be distributed via internet and web map services (WMS in the case of georeferenced raster image and WFS in the case of vector database) in the near future.

Johann Christoph Müller and his map

The Müller's map of Bohemia is one of the most famous maps depicting the Czech lands. Its author Johann Christoph Müller was born 1673 in Nürnberg, Germany. He studied mathematics and at the age of 23 he joined the Austro-Hungarian army as an astronomer. He assisted Luigi Ferdinando Marsigli, imperial colonel and geographer, who was working on the geographical work on the Danube river. In 1708 Müller was charged with creation of the map of Hungary ("Mappa regni Hungarie", finished 1709). In 1708-1712 Müller was mapping other part of Austro-Hungarian empire – Moravia (today part of the Czech Republic). After finishing this map in 1712 he began to work on his most famous map of Bohemia. Manuscript of the map was finished in 1720, unfortunately Müller died only one year later. His map was engraved on 25 copperplates by Michael Kauffer and finished in 1722.

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Müller's map of Bohemia

Müller was mapping Bohemia district by district. After 6 years (in 1718) original maps of all districts of Bohemia were finished. His mapping methods were based on measurement of distances (measuring wheel behind a chariot) and measurement of directions by compass. Questionable is the fact, if some co-ordinates were measured astronomically. Probably he didn't measure positions astronomically due to the lack of time (Čada, 2006).

In 1720 the manuscript of the whole map in the scale 1:132 000 covering 25 map sheets was finished. During following two years the map was engraved onto 25 copperplates by Michael Kauffer. In 1722 the map was prepared for print.

Figure 1. Detail of the Müller's map of Bohemia

Digital data of the map

At the beginning of our project, we needed to get the digital data of the map. As the Müller's map of Bohemia was printed relatively often, original printed maps can be found in archives or libraries easily. In last 10 years digital technologies influenced map archiving methods and so many archives are digitizing their documents. For our purposes we found two relevant sources: The Institute of History of Czech Academy of Sciences and Central Archives of Surveying, Mapping and Cadastre. Digital data from both institutions were scanned in 300dpi resolution. Nevertheless, the original prints archived by The Institute of History were quartered and that led us to use the other source. In our research we are using the data stored in Central Archives of Surveying, Mapping and Cadastre in Prague. Another solution could be creation of new digital data – the new scanning. We studied digital data thoroughly and concluded that current digital data are satisfactory for our purposes. All 25 map sheets are stored as JPEG files, together with amount over 2GB.

Original map dimensions reconstruction

Before we started analyzing the map we wanted to detect the shrinkage of the map sheets. In the first phase we used dimensions of the map sheets published in (Kuchař 1951), (Kuchař 1961). Professor Kuchař probably measured original copperplate engravings and identified the original dimensions. These numbers are 557 by 473 mm per map sheet. Later during our project we found out that original copperplates of the Müller's map of Bohemia are stored at the National Technical Museum in Prague. We tried to measure the copperplates as accurate as possible. All 25 map sheets were measured and we identified following dimensions: 559.2 by 473.1 mm. These numbers should be used in future research instead of values published by professor Kuchař.

Figure 2. One of the original copperplates of the Müller's map of Bohemia

Using identified dimensions of the map sheets we transformed the digital data into these right dimensions. During this process we discovered that the shrinkage of the original prints (in comparison with copperplates) is up to 4% (over 20 mm in the length of the map sheet). In the next step we wanted to create the image of the whole map. As all map sheets have the same dimensions we created regular grid (see Figure 3.) using identified dimensions of one map sheet. Into this grid all 25 map sheets were inserted. Then 25 images were merged together. The merged image can be seen on Figure 4. Note that volume of this image exceeded 2GB. Such image can be used for visual analysis of the map or can be viewed on internet via specialized applications. Because we wanted to analyze the map more thoroughly, we created the full vector data model of the map.
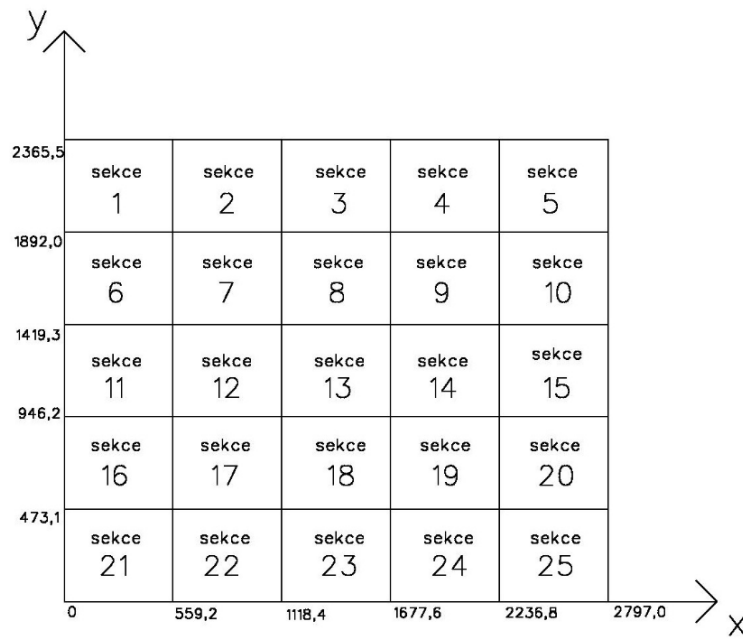
Figure 3. Regular grid for creating the merged image of the whole map

Figure 4. Merged image of all 25 map sheets

Creation of the vector data model of the map

Creation of the full vector data model of the map has many advantages. Vector data are much easier to handle with; they can be used for GIS analysis etc. Furthermore, vectorized point symbols can be used as ground control points (GCPs) for georeferencing the map. Due to these factors we designed and completed the vector database of the Müller's map of Bohemia.

Legend

Firstly, we deeply studied the legend of the map. Over 40 symbols were identified. Legend labels are written in Latin and German also. Part of the legend is depicted on Figure 5.
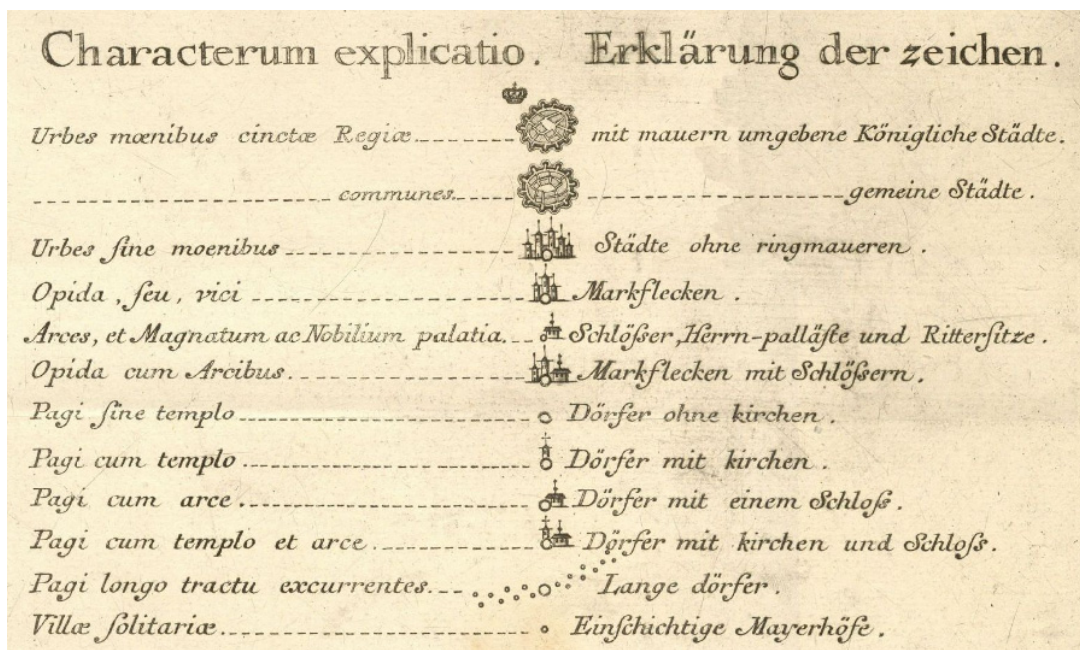

Figure 5. Part of the legend of the map

Geodatabase design

Based on the legend study we designed ArcGIS geodatabase for storing the vector data of the map. There were identified 6 categories of features on the map available for vectorizing. The most represented category contains over 15000 symbols of settlements, instead of 12495 mentioned in (Kuchař, 1959). Every point feature was vectorized and relevant attributes were stored (e.g. type of settlement, original name on the map, current name). Other vectorized features were rivers, water bodies, main roads, boundaries and bigger towns depicted by polygon shape. This part of the project was very time consuming. But, after all we have the full vector database and now it is much easier to analyze the data in many different ways.

Analysis of the map

There are two main groups of analyzing an old map. First group consists of analyzing spatial accuracy of the map (including finding the best method of georeferencing), in other words cartometric analyses. The second group contains geographical analyses of particular map features. Topo-

logical or topographical analyses can be done. These analyses describe spatial characteristics of the map.

Georeferencing

The Müller's map of Bohemia was probably created in a normal aspect of cylindrical projection with undistorted parallel of 50°04' (Krejčí and Cajthaml, 2009). But we don't exactly know which reference sphere was used. Therefore the best solution how to display the map in current co-ordinate systems is to georeference it. As we have the full vector data model, it is very easy to use all point symbols as GCPs (if they exist till today and have identifiable position). After statistical testing we eliminated some points and obtained set of 3906 GCPs. Using similarity transformation we georeferenced the map into the Czech national co-ordinate system (S-JTSK) with following parameters: standard error of position 1.74 km (13.2 mm on the map) and the mean scale of the map 1:131 580. More about cartometric analysis can be found in (Cajthaml, 2009).

Geographical analyses

Our plans for the future are geographical analyses of the map. There can be analyzed density of specific features, topology of line features and areas, spatial accuracy with respect to some spatial characteristics (e.g. accuracy of towns lying on the main roads). Now we are standing at the start line of this research. The first performed analyses compared the density of settlements on the map and today. Results can be seen on Figure 6. There are well identifiable areas with high density that resisted till today. The areas with low density on today's map are usually military restricted areas of big towns, which absorbed surrounding villages. The boundary areas of the Czech Republic are notably less settled today than before 300 years.
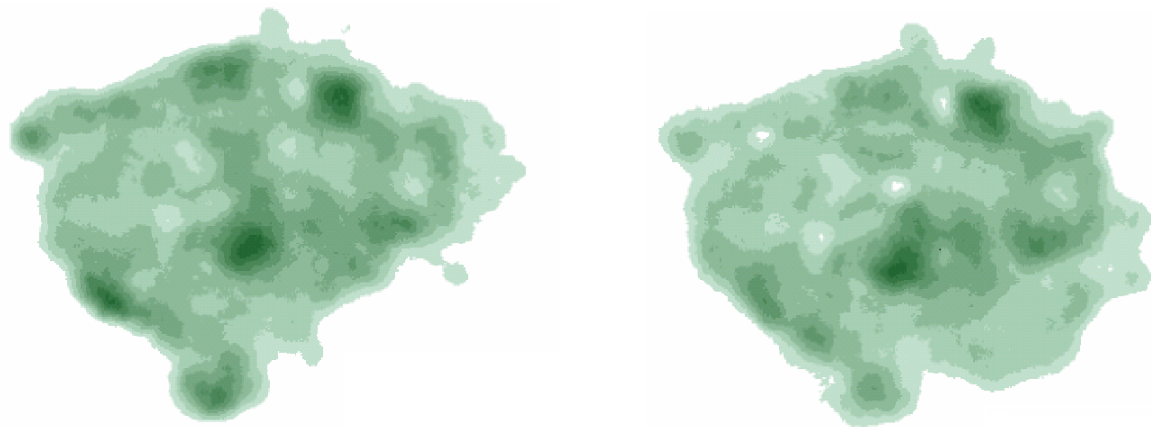

Figure 6. Density of settlements on the Müller's map of Bohemia (left) and on current maps (right)

There are some analyses we made especially for checking up the vector data model. We tested topological rules for boundaries, rivers and roads. Using this method we identified several errors made probably by the author of the map (e.g. missing boundary, bad topology of river network). We also tested the edges of map sheets if some settlement symbols are not doubled. We proved only one appearance of this error. This case was published earlier in (Krejčí et al., 2009). The town Kladno is depicted twice on two adjacent map sheets. See this error on Figure 7.
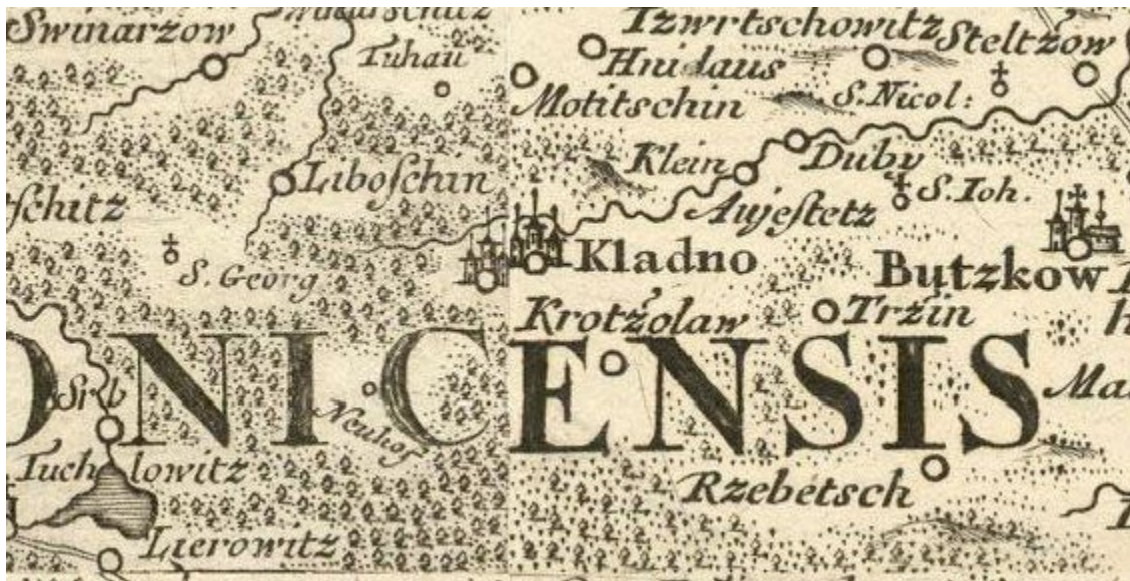
Figure 7. The town Kladno depicted twice

Plans for on-line accessibility

Old maps are very popular both for specialists (e.g. historians) and for public. We have some experience with publishing maps on the Internet (Cajthaml and Krejčí, 2007) and so we are prepared to distribute the data of the Müller's map of Bohemia via internet. Müller's maps of Czech lands are accessible through the Internet since 2006 by "oldmaps.geolab.cz" project (Brůna and Křováková, 2006), but in this case, only separate map sheets are accessible. We would like to exhibit the merged image of the whole map, see Figure 4.

From our point of view, it is important to distribute georeferenced data as well. We would like to use standards of OGC as WMS or WFS service. The image of the map will be accessible by WMS service and anyone would be able to join this map to his GIS application. The vector data will be available through WFS service in GML data format. These services will be launched at the end of 2010.

Conclusion

Our project is focused on the famous Müller's map of Bohemia from 1720. This map was analyzed very thoroughly. Original copperplate engravings were measured; new corrected dimensions of map sheets were published. The digital data of the map were transformed with respect to these dimensions. All 25 map sheets were merged together and seamless image of the map was created. The legend of the map was studied deeply. Based on this study the vector geodatabase in ArcGIS was designed. This data model was filled with vectorized data. Now we have the full vector data model with over 15000 point symbols and over 4000 lines. The vector data are analyzed in two ways: for cartometric purposes and for geographical analyses. From the cartometric analysis we determined the mean scale of the map (1:131 580) and the standard error of position on the map (13.2 mm). Geographical analyses will help us understand historical landscape and its changes through last 300 years. The digital data of the map (both raster and vector) will be accessible via internet using OGC standards WMS and WFS.

Acknowledgements

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