Cartographic Visualization of Temporal Aspect of Spatial Data

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ABSTRACT: Data sets visualized by cartographic techniques have not only spatial aspects but also a temporal aspects in many cases. It means time as a fourth dimension of data. Map users like such maps because they are usually very attractive and show a development and evolution of presented feature or phenomenon. New technologies (GIS, Earth browsers, vector formats) brings a opportunity to present spatial data with temporal aspects. But they do not use the potential of cartography fully. They also break essential cartographic rules. Cartography as well as cartographers need to react to this situation. They have to support this approach but also they should evaluate, criticize as well as correct these maps and similar products.

The paper Cartographic Visualization of Temporal Aspect of Spatial Data is divided into two main parts. The first section introduces selected approaches of cartographic visualization of spatial data with temporal aspects. There are presented techniques of standard (analogue) cartography (such as comparative diagram map) as well as dynamic methods (animations in Google Earth or in Scalable Vector Graphics format). The paper offers a comparison of methods as well as selected tools. The second part is focused on research of changes of names of settlements in selected region in the Czech Republic. This area is near German border therefore there were monitored many various changes in relation to conflicts in history. To visualize the changes (temporal aspect of spatial data) in spatial context there were applied selected methods of thematic cartography. The output maps show the development of the area in global view as well as in local viewpoint in an interesting way. Such type of presentation is very useful for experts as well as for public. It can be used to popularization of cartography, too.

KEYWORDS: thematic cartography, cartographic techniques, spatial data, temporal aspect

Introduction

Data sets visualized by various cartographic techniques have not only spatial and attribute components but also a temporal aspects in many cases. Time information represents a fourth dimension of spatial data. It is connected with a period of time that could be depending on data resolution generalized to one moment (point in time). For example the Battle of Marathon could be assigned to the year 490 BC or to September 12, 490 BC. Even some scientists have stated that the battle took place a month earlier. It shows uncertainty and accuracy as the another question of temporal aspect of spatial data (but it will be not discussed and solved in this article). Time information is connected with a change of other spatial data components (geometry, thematic attributes or relations). This change could have sudden (revolutionary) character (e.g. battle or birth) or long-term (evolutionary) character (e.g. war or decrease of population during a year). All above-mentioned details of temporal information should be taken into consideration during a process of construction a visualization of such data sets.

The temporal aspects are very important to modeling of evolution processes, including planning, predictions or reconstructions. They are used in many different sciences such as geography, demography, history, archeology, geology, statistics, economy etc. Map users like such maps because they are usually very attractive and show a change, development and evolution of presented feature or phenomenon. New technologies (Geographic Information Systems /GIS/, Earth browsers, animations) brings a new opportunities how to present spatial data with temporal aspects. But they do not use the potential of cartography (techniques and methods of thematic cartography) fully. They also break or modify fundamental cartographic rules in many cases. Cartography as well as cartographers need to react to this situation. They have to support this approach but also they should evaluate, criticize as well as correct these maps and similar products.

This article tries to describe and summarize the approaches and possibilities of application of various cartographic techniques to visualization of temporal properties of spatial data. It is divided into two main parts (except Introduction and Conclusion). The first part shows some questions connected with terminology, classification and theory of cartographic visualization of temporal aspects of spatial data. The second major part introduces an application of above-mentioned cartographic methods in case of visualization changes of toponyms in west part of Czech Republic (near the border with Germany). Collected data sets (names of populated places in old maps) make possible to illustrate and evaluate opportunities of cartography to present dynamic changes. This article proceeds from the diploma thesis on topic “Cartographic Methods for Visualization of Time Changes of Spatial Data” written by Ing. Klára Brašnová (Brašnová, 2012).

Classifications of Methods and Maps Describing Temporal Aspects of Spatial Data

Cartographers have tried to presents time in their maps from the very beginning. For example 8th book of Geógrafiké hyfégésis by ancient scientist Claudius Ptolemaeus (Ptolemy) contains time data (time shift against Alexandria), but they were not plotted on map. But the possibilities to present temporal aspects in maps have grown in connection with a development of new cartographic techniques (e.g. isolines) or technologies.

Menno-Jan Kraak and Alan M. MacEachren (in Kraak, M.-J. and MacEachren, 1994) distinguish two types of maps dealing with time information contained in spatial data. Non-temporal maps present time implicitly, but they do not provide any information about change of a feature. Temporal maps explicitly portray temporal aspects. These maps could be defined as “a representation or abstraction of changes in geographical reality: a tool (that is visual, digital or tactile) for presenting geographical information whose locational and/or attribute components change over time” (Kraak, M.-J. and MacEachren, 1994).

Czech cartographer Jaromír Kaňok distinguishes two basic ways describing dynamics of spatial phenomenons – static methods and dynamic methods (Voženílek and Kaňok, 2011). Static methods cover single and multiple maps as well as graphs, tables and other

features placed out of the map. Dynamic methods are equivalent above all to types of animations, but there are also blinking map symbols and similar techniques.

Slovak cartographer Ján Pravda worked with syntactic types of map symbols (Pravda, 2006). Each map symbol is described by various criteria such as geometry or character of visualized feature. There are two basic properties important from the point of view of representing of temporal aspects of spatial data – dynamic (moving) symbols and course symbols (arrows). Both belong mainly to static methods according to previous paragraph, but they are usable in dynamic maps as well.

Mark Monmonier has offered a conceptual framework for the visualization of geographic time-series data (published in Monmonier, 1990). He has distinguished four categories of maps:

- single static maps (e.g. temporal symbols, temporal aggregations, maps representing movements and changes by rates or absolute values),
- multiple static maps (e.g. interconnection of maps and statistical graphics),
- single dynamic maps (e.g. sequence of symbols or views, pulsing symbols),
- multiple dynamic maps (e.g. animations, interactive graphic analyses).

The similar classification is provided in the book (Kraak and Ormeling, 2010). It just join the last two items of Monmonier's systems. The classification works with terms – single map, multiple map and animation (animated maps). First two groups can cover static as well as dynamic maps (e.g. blinking map symbols).

Muehrcke (1978) provides an another view on temporal map. He discusses a content dependent classification of temporal maps: Maps that show qualitative change, maps displaying quantitative change, maps depicting composite change, maps that show space-time ratios.. This classification arises from an implementation of different types of visual variables.

But many cartographic publications have not singled out partial techniques or methods focused on time aspects of spatial data. The possibilities of such visualization are mentioned in traditional division of cartographic techniques. Of course there are some methods such as animations or flow maps emphasized.

This paper and above all in the parts focused on changes of toponyms authors deal with the “temporal maps” (or spatial-temporal) in general. Dynamic maps (often connected with interactive elements) represent just one part of large set of temporal maps that arise from an application of dynamic methods according to Voženílek and Kaňok (2011). This type of map imply action: symbols will flash, bubble, sparkle, throb, erupt, sink, explode, rotate, shake on screen (Kraak, M.-J. and MacEachren, 1994).

The second group of temporal maps is constituted by static maps. Their role used to be to underestimate to the detriment of animations and another modern visualization tools.

Static maps are able to find out more particular information but users lose an effect of movement. Static temporal maps are based on application of traditional graphic variables. Temporal aspect could be visualized by a single value (e.g. change of land use in year 2012) or rate of change (e.g. growth of population) represented by map symbol or labels. There are another cartographic techniques suitable for static temporal maps such as using of arrows, flow maps, two (or more) map or diagram symbols (e.g. comparative diagram maps) or sequence of maps (multiple static maps, strip map). In the case of sequences of maps digital cartographic products enable to use interactivity to select suitable map (e.g. changing layers representing features in various times). Sequences of maps could represent a transitional stage between static and dynamic temporal maps (because animations can be developed from multiple static maps).

Case Study – Changes of toponyms in old maps

The second part of this paper is dedicated to the research connected with temporal spatial data that was realized in the University of West Bohemia during years 2009 and 2012. The research has been focused on a cartographic visualization of changes of toponyms (geographical names of towns, villages and another populated places) on the old maps.

The area around the small city Poběžovice (called Poběžovicko) was selected as a field of study. Poběžovicko is found in the west part of Czech Republic near the border with Germany. There were two main reason why this area was chosen:

1. Nearness of Germany - because of various conflicts between Czech and German, state borders as well as boundaries between both communities were changing.

2. In the second half of 20th century the western part of Poběžovicko was displaced because of removal of Germans after the Second World War and setting up “Iron Curtain” between east a west European countries.

The selection of above-mentioned area made sure that the changes of names of all populated places were very frequent during last centuries. Our research started by studying of the oldest maps of Bohemia (as a western part of contemporary Czech Republic). The first map was originated in 16th century (so called Klaudyjánova mapa /1518/ according to their author Klaudian or Claudianus), but there was not drawn any settlement of Poběžovicko because of low density of settlement and small size of villages. The number of named places was consecutively increasing thanks to growing details of maps and settlement of border area. Finally there were processed 24 maps from 16th to 21st century, including last generation of digital maps.

The research was divided into two stages. The first phase was focused on data acquiring (searching of old map in archives and web portals and their studying connected with building of lists of populated places in particular maps), methodology development (survey of types of changes, constructing of tables presented changes of toponymy in particular populated places) and cartographic visualization of changes (totally there were created 32 maps such as maps of current situation, maps summarized changes or maps illustrated the first /Figure 1/ or last record of places on maps). Author found 12 types of

changes of toponymy such as translation to Czech or German, change to Czech or German words, changes of particular letters or using of two names in the map.

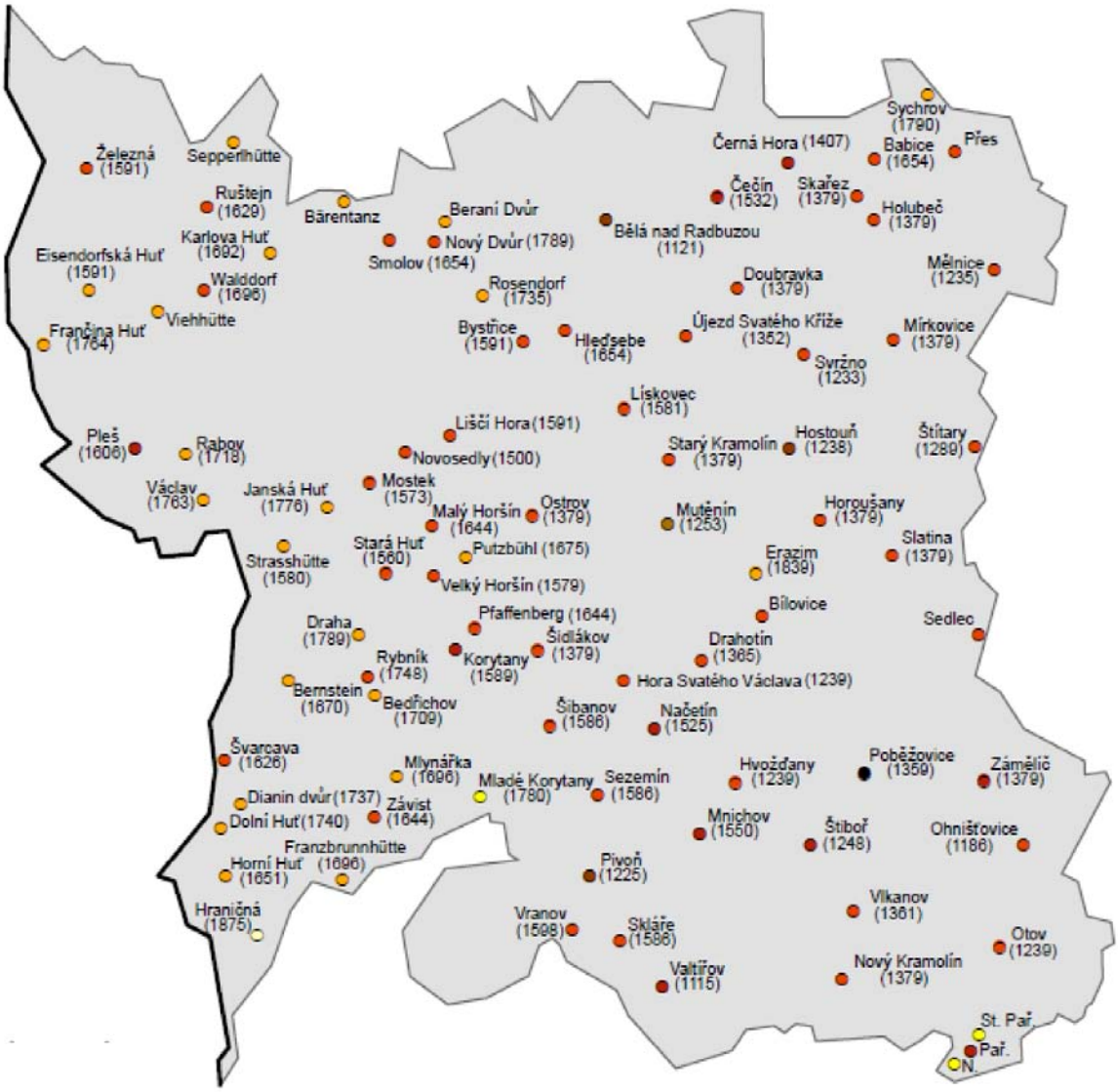

Figure 1: First record of populated places. Source: Brašnová, 2010 (modified by authors)

The second part tried to find the most useful methods how to present partially processed data collected in previous part. It was composed of theoretical section (dynamics of spatial data, approaches to time and dynamics processing in thematic cartography, examples of study of cartographic methods visualizing dynamic data), practical part (building of large portfolio of thematic maps) and conclusion (comparison of usability of tested cartographic techniques to visualize and present selected data).

During the whole research author went through all stages of MacEachren's and Kraak's approach (MacEachren and Kraak, 1997) to spatial data visualization (goals of map use). In the final part they were concentrated to the fourth part – data presentation. The

presentation of above-mentioned data has several groups of audience – scientist interesting in local history or linguistic (evolution of geographical names) or public (citizen of processed settlements or tourists). The authors tried to find appropriate methods how to transform the input data to a form suitable to above-mentioned target groups. They work with spatial data with specific properties – data dealing with changes of toponyms has qualitative character but the quantity of changes is visualized in many cases.

The expression of dynamic is based on traditional graphic variables in case of static cartographic methods. Dynamic methods (above all animation) are dealing also with other types of parameters described in texts of Hayward (1984), DiBiase (1991) and MacEachren (1994), Kraak and Klomp (1995). The set of dynamic graphic variables (and effects) used to composed of items such as moment of display, order of display, duration, frequency, synchronization and rate of change (Köbben and Yaman, 1995).

The techniques classification of static maps got along the works of Czech and Slovak cartographers Pravda (2006), Voženílek and Kaňok (2011). This classifications are very detailed and well implemented in Czech cartographic community. Following methods were described and evaluated from the view of presentation of dynamic in general as well as in specific case limited by above-mentioned data:

- Qualitative figure symbols
- Qualitative line symbols
- Qualitative areal symbols
- Choropleth mehod
- Diagram maps (including specific types such as structured, comparing or dynamic diagram maps)
- Dot maps
- Dasymetric method
- Izolines
- Cartographic anamorphosis
- Statistical surfaces
- 3D and pseudo-3D (2.5D) methods

All of above-mentioned methods are able to present dynamics of geographical features and processes individually as particular maps. But they can be a part of sequence of maps (as was defined in Monmonier, 1990 – multiple static maps). The sequence of maps represents an universal tools how to express dynamics.

Except cartographic methods there are also other possibilities how to add an element presenting dynamics that is not a part of proper map but is connected with the map layout. There are mentioned various tables, schemes or graphs. The focus is given to chronograms (Figure 2) as an interesting variant of scheme that is able to present temporal information. A interconnection of chronogram a topogram (localized scheme) could be placed into map as a specific and attractive map symbol.

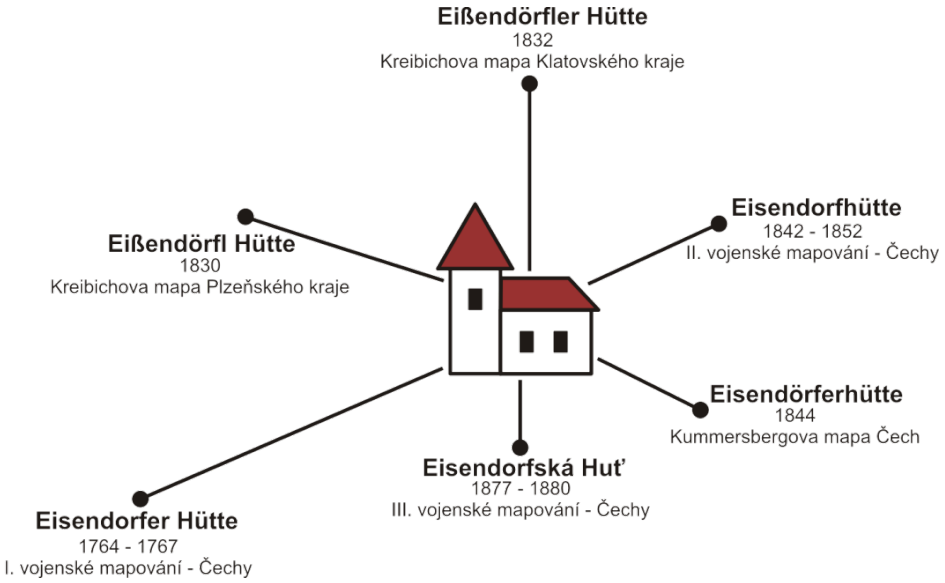

Figure 2: First record of populated places. Source: Brašnová, 2012.

In comparison with static methods the dynamic techniques are not well processed in Czech cartographic literature therefore a different approach was applied. There were compared three various methods how to build a animated maps – animations in ESRI ArcGIS, Google Earth and SVG (Scalable Vector Graphics). Author described (Brašnová, 2012) not only construction process (including examples of code) and its pros and cons but also possibilities of control of animations as well as accessibility of created maps.

The results of case study are summarized in following list that contains recommendations for similar projects:

- The information about time and time changes that is found in the map layout but out of proper map, could be very intelligible for readers (above all non-cartographic experts). They are also workable very easily. But the interconnection between spatial and temporal information is not explicit (and is missing very often).

- There some cartographic techniques that are very fitting for purposes mentioned in this section (changes of toponyms and their analyses):

    - Qualitative figure symbols with two graphical variables – changing of color hue according to particular centuries and a shape representing existing or extinct populated places,

- Dot maps are an other examples of appropriate techniques. Their main advantage is an ability to visualize localization and density of geographic feature.

- All types of dynamic diagram maps (e.g. comparative or summation diagram map) play very important role in visualization of collected data. But they could be very complicated for cartographers as well as map users. The complexity of map symbols makes a perception of dynamics and details very difficult (above all in cases of dynamic maps such as animations).

- It is very important and difficult to find a right moment when to divided a very complex map into a sequence of maps. This task depends on many various factors such as medium, format or type of map users.

- Even flow maps and arrow symbols are used for expression of dynamics very often, they have minimal significance in our work because of the data sets are based on point geometry.

- Animation maps are very attractive and directly designated for visualization of changes and many researchers are focused on them. Animations in cartography are in conformity with current trends of multimedia technologies. But there are still many open questions concerning perception of details or technology. Users are not often able to perceive details and to find a size of change. Such map used to be perceived as the whole and the changes are felt as a qualitative value. Also it is very difficult to synchronize reading the map and zooming to small areas. Therefore such maps are suitable above all for selected task (e.g. presentation or research). For real study purposes are more suitable traditional cartographic methods (of course selected with care).

Conclusions

The questions of cartographic visualization of temporal data represent very important part of contemporary cartographic research. There are many open questions such as general theory and terminology (that is very heterogeneous), problems of legend or user requirements and user needs. This paper is focused on implementation of cartographic techniques (above all methods of thematic cartography) in the process of cartographic processing of time aspects of spatial data.

The first section of this paper (Classifications of Methods and Maps Describing Temporal Aspects of Spatial Data) tries to summarize knowledge about above-mentioned part of cartography. It describes the fundamental terms (e.g. “dynamic map” or “temporal map”) and shows an examples of classification.

The second section is focused on a research realized in the Geomatics section of the University of West Bohemia (Czech Republic). The research deals with changes of toponyms (names of populated places) in old maps. It was divided into four stages:

1. Collection of data (toponyms, including localization).

2. Analyses & summaries of changes.

3. Simple visualization of results of research.

4. Searching of the bets methods of visualization.

The last part is strongly interconnected to research of thematic cartography. The essential information are summarized in previous part of this article. In the future (possible Ph.D. thesis of the second author or following research in the Geomatics section or final thesis of students) we would like to focus on two main topics:

1. Extension of data sources (new processed areas, studying of another old as well as actual maps) and its connection with database of settlements developed in the Geomatics section.

2. Research of usability and reliability of developed thematic maps – testing of user groups and their work and dealing with maps, including complexity, amount of acquired information and quality and accuracy of decisions and conclusions. We plan to test all aspects of the maps – colors, technology, cartographic techniques, etc. The target will be to try to find appropriate maps for particular using and users. This part is connected to a long-term cartographic research in Geomatics section of the University of West Bohemia.

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