VISUALIZATION OF TRAFFIC OFFENCES IN THE CITY OF BRNO (CZECH REPUBLIC): ACHIEVING 3D THEMATIC CARTOGRAPHY THROUGH OPEN SOURCE AND OPEN DATA

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Abstract: This paper examines 3D visualization of traffic offences based on open data sources at the city level. Most of the existing studies and applications focus on 3D visualization of qualitative data. For this reason, this paper concentrates on 3D visualization methods for quantitative data. The possibilities of creating 3D dot maps, statistical surfaces, graduated 3D symbols and prism maps and their effective use was studied. A pilot web application visualizing crime statistics was developed for verifying the applicability of selected 3D cartographic methods and the feasibility of open source technologies for crime mapping. 3D visualizations of selected traffic offences registered and solved by municipal police (different traffic offences types) are available in a pilot application for the city of Brno (Czech Republic). The design and implementation of map components, interactive functionality, limitations and opportunities for future development are also discussed.

Key words: 3D crime mapping, 3D visualizations, open data, open source thematic cartography, Three.js, traffic offence

INTRODUCTION

The 3D visualization of geospatial data is used in many fields and for numerous applications but it depends on the expansion of hardware devices and software tools enabling 3D geovisualization. 3D geovisualizations include a broad spectrum of instances from photorealistic visualizations to abstract depictions of attribute data. Exploration of the applicability or possible modification of traditional cartographic visualization methods in 3D is, therefore, a progressive topic. The feasibility of 3D visualization of crime as an example of quantitative data, purely based on open technologies and available open data, is the primary aim of this paper. Open technologies and open data were solely used for this purpose in the case study area (Brno, Czech Republic).

3D CARTOGRAPHIC VISUALIZATION

The principles of 3D cartographic visualization have been relatively rarely investigated in the past apart from, for example, Jobst and Germanchis (2007), Bleisch (2011), Gede (2016), Hájek et al. (2016), or Sieber et al. (2016).

Most of these studies focus on cartographic methods for visualizing qualitative data, especially in designing and applying 3D point symbols or textures on surfaces and objects. This paper, however, explores visualization methods for quantitative data, namely about traffic offences. The potential use of these methods and practical aspects of their creation are described. Papers with a similar focus have been published, for example, by Zsoldi (2011) or Gede (2016).

Advantages, limitations, and applications

The general and main advantages of using 3D variants of cartographic visualization methods are more space for displaying additional data variables, resolving issues related to hidden symbols, or a more familiar view of spaces (Shepherd, 2008). Traffic offences or accidents are often clustered, so it is advisable to utilize more space for visualization (for instance third dimension) and to solve the problem of overlapping symbols. The usability problems of 3D thematic maps were identified by Jobst and Germanchis (2007) and Shepherd (2008):

- occlusion of objects in a 3D scene;
- perspective distortion;
- countless scales within one view;
- incomparable geometries of objects.

3D visualization of quantitative data (thematic information) has many uses, such as in digital atlas cartography (Sieber et al., 2016), visualizing demographic and economic data (Horák et al., 2003, Ourednik, 2017), air pollution (Calvillo et al., 2008), disease (Marek et al., 2015), traffic noise (Herman and Řezník, 2013), erosion and land use changes (Svatoňová and Rybanský, 2014), results of geographical analysis in general (Lin et al., 2015) or for teaching geography (Niedomysl et al., 2013; Juřík and Šašinka, 2016). 3D thematic cartography has already been employed to visualize statistics on crime and crime mapping (Lodha and Verma, 1999; Wolff and Asche, 2009; McCune, 2010). But there are no fixed guidelines for making crime maps or even their 3D variants. And it is still not enough known about how 3D visualizations can be used effectively and appropriately in these areas. User studies are therefore very important. User testing of 3D visualizations has been described by several authors, for example Niedomysl et al. (2013), Popelka and Dědková (2014), Špriňarová et al. (2015), or Juřík et al. (2017).

3D variants of cartographic methods

Most traditional (2D) cartographic methods have 3D variants. This paper focuses on visualization of crime statistics as outlined above, working with:

- 3D dot maps;
- statistical surfaces (fishnet maps);
- prism maps;
- graduated 3D symbols (3D diagram maps).

A 3D dot map is mainly used to express spatial distribution, especially of discrete phenomena. The distribution of dots on a surface specifies the variable density of objects or phenomena. Dots (of different colour or shape) may also express their quality. 3D visualization also allows vertical spatial patterns to be depicted. Potential of 3D dot map for visualizing traffic offences is relatively small, unlike the 2D variant, because the height (Z axis) can be hardly used effectively. Probably the only suitable application is in space-time cube, where the Z axis represents time.

A 3D variant of an isopleth map is usually referred as a statistical surface. Statistical surfaces can be graphically represented by a regular square grid with variable height at its nodes. This representation is called a fishnet map. For instance, Wolff and Asche (2009) and McCune (2010) used this method to crime and safety mapping. Its disadvantage is superficial representation and difficulty in reading values displaying phenomenon as an expression of characteristics through height (Kraak and Ormeling, 2003; Slocum et al., 2005). Quantitative characteristics can not only be expressed as height. Colour can be used in a similar manner as it is on original (2D) variants of isopleth maps. 3D isopleth map is used only extraordinarily, but 2D isopleth maps or heat maps are used quite often. So, a surface model can be similarly coloured and the dependence of visualized phenomenon on altitude, for example, can be studied.

Prism maps show quantity by extruding the base of the polygonal area. The height of extrusion is not affected by classification; it displays raw data (Kraak and Ormeling, 2003; Slocum et al., 2005). The readability of prism maps can be affected negatively by the distribution of values, where low values may be covered by higher values. Kaňok (1999) further states that the main application for prism maps is the popularization of cartography. Prism maps are often combined with a colour scheme. The same values expressed by height can be represented by colour, or colour can represent another attribute. This second example may then be used to compare the relationship between two attributes. Colour can be expressed as a quantitative characteristic (population density) or a qualitative (administrative units). It is suitable to use this method for traffic offences visualization if they are linked to some spatial units (e.g. towed cars, penalties for bad parking). Relevant spatial units may be, for example, police districts.

Kaňok (1999) divides point and non-localized diagrams (graduated symbols), based on the number of attributes they represent on single-parameter and multi-parameter diagrams. 3D single-parameter diagrams express the characteristics of the phenomenon by its volume. The most usually employed shapes are a cube, sphere, or cone. The disadvantage of this method is that volumetric size is generally perceived as more difficult to represent than planar size (Kaňok, 1999). Multi-parameter 3D diagrams change size in different dimensions (e.g. height and width) individually. 3D diagrams may represent two or three characteristics and therefore have two or three parameters. It is suitable to use this method for traffic offences visualization if they are linked to spot-like objects (e.g. junctions – red riding), smaller sites (towed cars or penalties for parking on selected car parks) or if the offences are naturally clustered (exceeded speed limits – speed measurements points).

PILOT STUDY

The methods described above were verified in the example of the city of Brno, Czech Republic.

Input data

The following thematic data were used as input data to create 3D models:

- List of traffic offences stored as an XLS file. From this file, traffic offences of cyclists, pedestrians, and exceeded speed limits were selected.
- List of towed cars also stored as an XLS file.

Both datasets relate to the year 2015 and are catalogued according to time, place, punishment, offence. These data were provided by the Municipal Police of Brno in response to a request for information. This data is published by the City of Brno on the web (https://old.datahub.io/organization/statutarni-mesto-brno).

The following, underlying data were also used:

- City districts from the Registry of Territorial Identification, Addresses and Real Estate (RUIAN), available online as a WFS (Web Feature Service) or as off-the-shelf GML (Geography Markup Language) files. Data are compressed with the GZIP algorithm.
- Digital Landscape Model 1:25 000 (DMU 25), available as WMS (Web Map Service) by the Czech national geoportal INSPIRE
- DATA 200, available as a WMS service by the Czech Office for Surveying, Mapping, and Cadastre (CUZK).

Open data processing

These input data were processed in QGIS software (version 2.12). In this pilot study, the Qgis2threejs plug-in to create visualization in a web browser was used. Qgis2threejs exports terrain data, map canvas images, and vector data to a web browser supporting WebGL. This plug-in uses the Three.js library and so final visualization in this study was implemented through this library. Three.js is a cross-browser JavaScript library allowing 3D computer graphics to be displayed in a web browser.

Thematic data was downloaded in XLS format, and the first part of processing was therefore done in MS Excel. Specifically, it means selection by offence type, georeferencing through the Excel Geocoding Tool (http://excelgeocodingtool.com), and conversion to CSV (Comma-Separated Values*)* files. All data were then loaded into QGIS (CSV, GML files and WMS services). The QGIS program itself permits important functions for 3D data pre-processing (i.e. interpolation and other statistical surfaces creation techniques). Additional layer settings (e.g. colour scales) can be set through QGIS. Other final visualization parameters, such as final web page templates, controls, and individual layer parameters (e.g. exaggeration, display of labels, transparency, background colour, raster resampling) are defined in the Qgis2threejs plug-in.

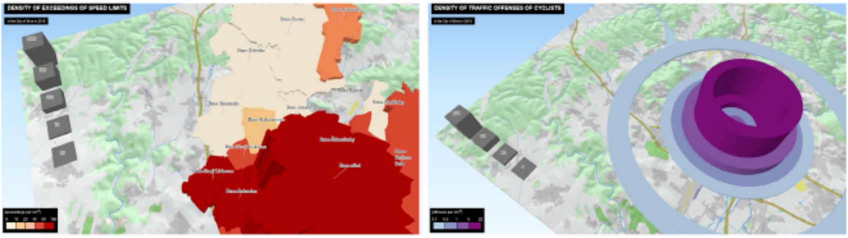

Fig. 1. Examples of prism maps (left – city districts; right - belts of distance from the city center).

RESULTS

Examples of 3D thematic maps are shown in Fig. 1, 2, 3 and 4; all interactive 3D maps are available online at http://web3dvis.esy.es/3d_traffic_offences. Three.js in final 3D visualization enables the basic functionality usually available in web map portals. Users can switch between layers or set their own transparency. Transparency avoids the occlusion of features or layers. The attributes of a selected feature (e.g. a city district) are available after clicking on it in the pop-up window (see Fig. 3 – right). The coordinates of the selected point may also be displayed.

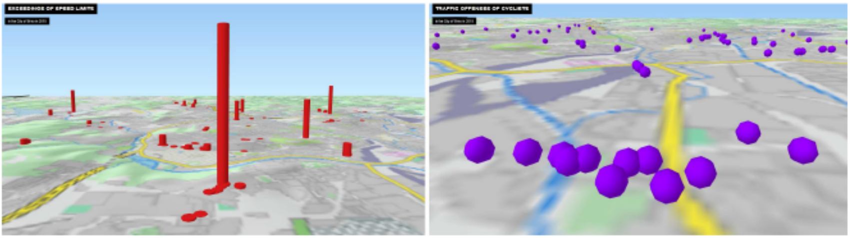

Fig. 2. 3D diagram map (left) and 3D dot map (right).

Users can also create their own *cutting plane* (Fig. 3 – left). A *cutting plane* allows easier comparison between map features (their heights) or with a 3D legend. A north arrow and labels facilitate orientation in the 3D scene. How labels are depicted can be set in the Qgis2threejs plug-in. Names of city districts were used in this case. A north arrow was created manually as a new layer (Shapefile) and extruded at a fixed value. Two different methods to implement a legend were used. A legend for the colour scale was created with HTML (see Fig. 4 – left), while legends located directly in 3D scenes were used to explain the heights of map features or the scales of map diagrams (see Fig. 4 – right).

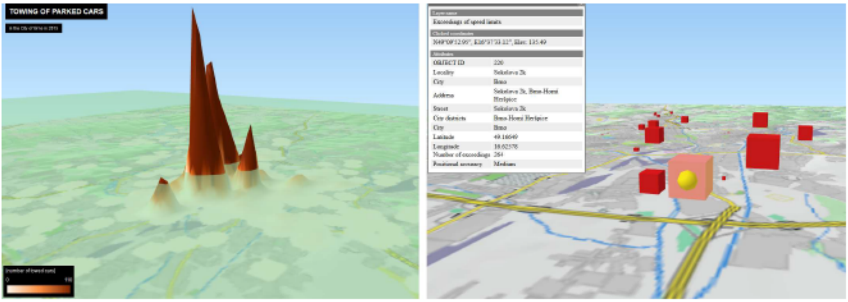

Fig. 3. Statistical surface with cutting plane and 3D diagram map with displayed attributes in pop-up window.

DISCUSSION

3D visualization, in general, has significant potential for application, but it is affected by its properties, for example the cartographic visualization method or the UI (*User Interface*). In terms of cartographic visualization, the approach in this study is not directly dependent on the visualization(s) of underlying data. In this case, cartographic visualization is not directly redistributable since it is stored in the Three.js code. Cartographic visualization should be designed, developed, and ideally also verified by user testing for each application separately.

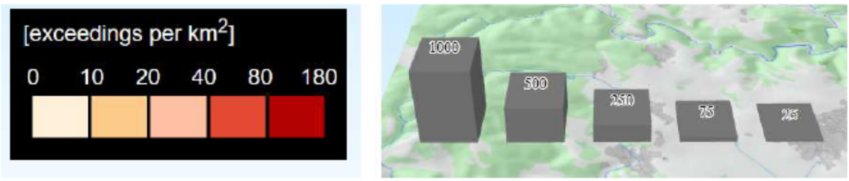

Fig. 4. Map legend variants (left – 2D, right – 3D).

The usability aspects of the UI and effective 3D map design are therefore important topics for future research. This research could also be demanded legislatively or be the subject of standardization (Řezník, 2013). Some authors, for example (Voženílek, 2001), argue that 3D visualization can present geospatial data to wider audiences, including those with little or no cartographical or GIS experience. On the other hand, the results of other previous studies (Herman and Stachoň, 2016; Juřík et al., 2017 or Kubíček et al., 2017) suggest that interactive 3D visualization would be more useful to users with previous 3D visualization experience and for complex tasks particularly. It would be appropriate to validate a created application with user testing.

CONCLUSIONS AND FUTURE WORK

The presented proof-of-concept application was created to demonstrate the possibility of open web-based 3D visualization. It should be emphasized that its open source relies on the data and software used, as well as its final application. The proof-of-concept application is freely available to interested persons under a BSD license.

To summarize, the following major advantages of 3D visualization based on open data and the Three.js library were identified:

- it represents (in this pilot study) an example of an open data application usable in crime analysis;
- it enables user-friendly interactive 3D visualization which is accessible to a broad spectrum of users (from the general public to experts);
- it does not need any new software or plug-ins installed on the client or server sides;
- it shows that cartographic methods common in classic (2D) cartography may also be transferred to 3D visualizations;

We also identified some limitations in the procedures and technologies used. Much of a 3D thematic map's creation process takes place within the Qgis2threejs plug-in interface. Additional modifications to the UI (such as creating a legend or map title) require either new data layers in QGIS to be created or the HTML code of the final visualization to be edited. Optimizing a 3D thematic map's design is, in general, primarily based on modifying HTML code and CSS templates. Final visualizations are not yet completely responsive (optimized for display on mobile devices).

Our outputs are comparable to those of other free and open source tools (Thematicmapping.org) and commercial software (ESRI ArcScene). Thematicmapping.org creates prism maps and graduated 3D symbols, but they are placed on the Google Earth virtual globe, and comparing the height of objects is rather difficult (Popelka and Doležalová, 2016). ESRI ArcScene permits all four of the tested methods to be created (3D dot maps, statistical surfaces, prism maps, and graduated 3D symbols), but export to 3D format VRML (Virtual Reality Modelling Language), which is supported on the Web, is problematic (Herman and Řezník, 2015). Only prism maps can be exported correctly.

Our Three.js-based solution will be further modified and extended in the future. We want to implement the main principles of application of adaptive visualization and visual seeking as it is described by Štampach et al. (2015), especially map view adaptation. It may also be possible to perform advanced spatial analysis during input data processing and then present the results using 3D visualization. Russnák et al. (2016), for example, discusses the possibilities of clustering the data of traffic offences committed by cyclists or aggregating traffic offences into street segments. The different methods of 3D thematic cartography presented in this paper can be also combined into one 3D scene. However, it is necessary to consider the potential problems mentioned by Shepherd (2008), where the Z-axis is used to illustrate different variables and visualization loses clarity. Despite all these extensions and modifications, the 3D thematic cartographic methods described (3D dot maps, statistical surfaces, prism maps, and graduated 3D symbols) can be relatively quickly and easily created and subsequently used. However, it is necessary to take into account the spatial character of the offences and to consider both the dimensionality of visualization and the cartographic visualization method.

Acknowledgements: This research was created in scope projects "Influence of cartographic visualization methods on the success of solving practical and educational spatial tasks" (Grant No. MUNI/M/0846/2015) and "Dynamic mapping methods focused on disaster and risk management in the era of big data" (Grant No. LTACH-17002) and funded by project "Integrated research on environmental changes in the landscape sphere of Earth III" (Grant No. MUNI/A/1251/2017).

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Shrnutí

Příspěvek se věnuje 3D vizualizaci prostorových dat o dopravních přestupcích, které jsou dostupné jako otevřená data v měřítku města. Většina existujících studií se zaměřuje na trojrozměrnou vizualizaci kvalitativních dat. Z tohoto důvodu se chceme v tomto příspěvku zaměřit na 3D kartografické metody pro znázornění kvantitativních (statistických) dat, jakými jsou například data o kriminalitě či právě o rozložení dopravních přestupků. Analyzovali jsme možnosti tvorby a efektivního použití 3D variant tečkové metody, izopletových map, kartodiagramů a metody objemových kartogramů. Byla vytvořena pilotní webová aplikace pro praktické ověření výše popsaných kartografických metod a možností aplikace open source technologií při mapování a vizualizaci dopravních přestupků. Vizualizovány jsou dopravní přestupky zaznamenané a řešené městskou policí v městě Brně (konkrétně přestupky chodců, cyklistů, překročení povolené rychlosti a odtahy zaparkovaných vozidel). V závěru jsou diskutovány různé aspekty návrhu a implementace jednotlivých kompozičních prvků (např. legendy 3D map), interaktivní funkcionality, jejich limitů a možností dalších úprav a rozvoje.