Editorial

Modern Cartographic Forms of Expression: The Renaissance of Multimedia Cartography

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Abstract: This article summarizes the Special Issue of "Multimedia Cartography". We present three main research fields in which multimedia cartography and the study of the effectiveness of multimedia maps are currently taking place. In each of these fields, we describe how published research is embedded in the broader context of map design and user studies. The research refers to contemporary technological trends such as web HTML5 standards, virtual reality, eye tracking, or 3D printing. Efficiency, performance, and usability studies of multimedia maps were also included. The research published in this issue is interdisciplinary. They combine traditional mapping methods with new technologies. They are searching for new places for cartography in, e.g., the environment of computer games. They combine the design of the map with its perception by users.

1. Introduction

The growing volume of data that can be presented by cartographic visualization requires map makers to use different means of expression. In modern cartographic communication, they are often related to multimedia. They allow integration the map with video, sound, or animation in an interactive environment. Multimedia cartography is a research area in cartography that focuses on the utilization of various multimedia for the effective and efficient visualization and communication of spatiotemporal data. The multidimensionality of geographical data creates certain demands for mapping products, and the answer to these demands is multimedia cartography. Assessing multimedia effectiveness, efficiency, and usability is possible thanks to user studies. In this approach, actual users are involved in the overall process of map design.

2. Dynamic Spatiotemporal Data

This Special Issue focuses on the crucial features of modern maps, which are effectiveness, efficiency, and attractiveness of information communication. The issues of multimedia cartography include, among others, the study of dynamic maps. Due to its visual attractiveness, animation is eagerly used for data that change over time. It is often presented in global news websites, as well as education, entertainment, weather forecasts on the web or on television. For this reason, it is crucial to conduct research on effectiveness of animated map communication. Popular time-series animation causes some perceptual difficulties for map users. Therefore, Traun et al. [1] conducted empirical research on the effect of local outlier preserving value generalization of animated choropleth maps on the ability to detect general trends in spatiotemporal data. Such an approach results from searching for solutions to reduce the cognitive load that animated map users experience. The research experiment with the participation of users presented in this study assumed

the identification of outliers and the recognition of spatial trends. Study results show that, based on the spatial generalization of choropleth map animation, participants had higher outlier detection performance. However, it turned out that there was no significant improvement of participants' ability to correctly recognize the temporal trend. Moreover, the trend detection performance decreased with participants' age.

The effectiveness of presentation of spatiotemporal data was the main issue of the paper from Medyńska-Gulij et al. [2]. In this study, the main focus was on presentation of moveable and stationary objects in dynamic cartographic presentation. Three types of animated maps were proposed to represent people gathering at mass events. The study adopted experts' opinion and objective effectiveness evaluation. Therefore, various mapping techniques were presented of how to visualize people at a mass event. Methods proposed combined experts subjective opinion and a user study on effectiveness. The results show that the most difficult was to assess the dynamics of spatial relations (e.g., crowdedness, the number of participants). The study results showed the great importance of visually highlighting stationary objects and the need to minimize the number of map elements such as scale bar and north arrow.

Another study in this Special Issue related to cognitive aspects of spatiotemporal data was conducted by Cybulski [3]. This study takes into account two map backgrounds, which are a road map (abstract image) and a satellite map (realistic image). On these two cartographic backgrounds, participants were presented with a set of animated routes of varying difficulty (dependent on length and number of turns). The main goal of the aforementioned study is to assess the effectiveness and efficiency of route memorization based on the cartographic image. Additionally, the study adopts an eye tracking methodology to examine and explain the visual strategy that follows effective route memorization in different map-based tasks conditions. The main result shows that the effectiveness and efficiency of route memorization depends on the route difficulty. The research shows that, in this type of map-based task, the cartographic background has no impact on the memorization process nor visual strategy. The study reveals that, although the starting point of animation was the most fixated location, most errors in route memorization were related to the starting position. Additionally, the study results present the effect of subjective spatial abilities on visual strategy.

The abovementioned studies are in line with the map perception field of cartographic research. They result from the need for an objective assessment of multimedia cartographic products by the users themselves. Such results provide necessary feedback cartographers and modern map makers [4,5].

3. Maps and Interactions

Interactivity is an crucial feature of modern multimedia cartographic products [6]. Research conducted by Lorek and Horbiński [7] analyze old cartographic material in the context of usefulness in designing an interactive multimedia map of spatial development of Gliwice. The spatial development was based on vectorization spatial features from six maps: Urmesstischblätter map, Messtischblätter map, three topographical maps from different time periods, and the OpenStreetMap (OSM) database. A modern spatial database together with archival cartographic material contributed to the design of an interactive map of European freeway junction A1/A4 development. This study presented how to use old cartographic materials with a spatial database and implementation of a JavaScript Library–Leaflet. Research results focus on describing the utility of interactions such as mouse over or mouse click and implementation of W3C standards for new cartographic products.

An important part of interactive multimedia maps is the Graphical User Interface (GUI). The GUI often consists of several interactive buttons which that different functionality of a web mapping service. However, each global mapping service (e.g., Google Maps, Baidu Maps, OSM) has its unique set button graphics and arrangement. Therefore, users experience interaction differently in each of these services. This user experience (UX) while performing interactive map-based tasks was a main focus in the study from Cybulski and

Horbiński [8]. The study examined subjects' experience of interaction through the several different GUI and registered eye movement during the task. The study resulted in some valuable recommendations for map designers. It turned out that it is better for effective interaction to group buttons with similar functionality in the corners of the screen.

Another vital issue related to the interface and interaction is the maps' ability to adapt to the device on which it is displayed. In this context Horbiński et al. [9] performed a study on the responsiveness of GUI and its effectiveness in information communication. The design process of the multimedia map draws from modern JavaScript libraries, external plugins and HTML5 standards. In this study interactions and responsiveness of GUI were based on Google Maps, OpenStreetMap, and additional button arrangement based on the study of Horbiński et al. [10]. Analysis of mobile and desktop map-based tasks in a user testing research experiment with recording of eye movements was possible thanks to the use of an online questionnaire and Tobii X2-60 eye tracker. Study participants used three main functions which were: geolocation, spatial search, and route find. The study presented a novel GUI effectiveness index based on three parameters: the time to the first fixation on a target button, time of identification, and the time to the first mouse click. The study results reveal that the most effective way of performing all the interactive tasks was when the GUI was designed first on the desktop application and adapted for the mobile device. This was highly related to participants preferences of using web mapping services on the desktop computer. However, the most effective way of spatial search was when the buttons were in the lower part of the mobile screen, which was closest to the thumb.

The ease of receiving spatial information can prompt users to visit popular sightseeing websites. Therefore, Kato and Yamamoto [11] proposed the development a sightseeing spot recommendation system that could be useful and efficient for tourists. In the study, they an integrated social networking service, a web-geographic information system, and a recommendation system for interactive maps. The research experiment involved users' assessment of the system according to the viewing function, submitting functions, and recommendation functions of sightseeing spots. The study urges designers to take into account users' preferences in the map design process. The significant aspect of this study is that designed system could adopt the knowledge-based recommendations with collaborative recommendations according to users' preferences.

Multimedia presentations can combine text, image, videos, charts and maps, and through the interactive dashboard enables selecting, searching, and filtering the spatial data [12]. Zuo et al. [13] designed a novel map-based interactive dashboard supporting users' spatiotemporal knowledge acquisition and analysis. In the design of the dashboard, they applied interactive maps. Initially, the experiment consisted of free exploration in which participants could interact freely with the dashboard. Subsequently, there was a tasks-solving stage in which participants explored the dashboard to check authenticity of statements being displayed. The experimental study adopted a Gazepoint GP3 eye tracker with 60 Hz frequency. For several tasks, the study revealed the visual strategy that was most common for knowledge acquisition. This resulted in significant suggestions for designers of such dashboards. First of all, the study mentions the important role of the font size and proper labelling. Secondly, the panel arrangement in the interactive dashboard should follow a logical order (e.g., panels with similar content should be placed together).

In summary, interactive maps are the basic element of interest in multimedia cartography [14]. The GUI is especially important because global mapping services such as Google Maps, Bing Maps or Baidu Maps use an interactive interface as well as StreetView photos, videos and images. Studying the user experience during human–map interaction is a source of knowledge for effective and efficient mapping solutions. It also gives you the opportunity to optimize interactions for specific mapping products.

4. New Visualization Methods

The growing number of spatial and temporal features which can be presented through a cartographic product require searching for new visualization methods. Wielebski et al. [15]

proposed a set of complementary visualizations, interactive and static, to examine issues of people's spatial behavior. The aim of this study was to examine the usefulness for data analysis and interpretation of the following track features of human movement in urban space: trajectory, correctness, length and visibility. It also considered additional aspects such as walking time, walking speed, stops, spatial context, and motivation for getting to the finish point. The study involved recording the movement of people with the use of GPS and a questionnaire about pedestrian motivations. A space-time cube (STC) was designed and modified so that trajectories of movement could be presented in pseudo 3D view along with other mentioned features. Visualization was enhanced with buildings in City GML standard. However, the route graph, proposed by Andrienko and Andrienko [16] was assessed as the most useful for differentiation of pedestrian tracks, visualizing track length, walking time, motivation of route choice and pace/stops/tempo. The STC was the most useful for visualizing spatial context, and location in geographic space.

Other hew ways of using multimedia in cartography involves virtual tours and virtual reality (VR). Some of these virtual images uses official data (e.g., topographic databases Halik [17]) and are used by leisure industries to attract tourists [18]. Lai et al. [19] performed a research about processing panoramic images for a VR environment integrated in a multimedia platform. This study contributed especially to improving panoramic photography and image stitching quality, proposed a strategy for producing high quality panoramic images, combination of information technologies, and assessing teaching effectiveness through the multimedia platform. The results show that RMSE of stitched images was below five pixels using a full-frame single-lens reflex camera equipped with an ultra-wide-angle zoom lens on a panoramic instrument (GigaPan EPIC Pro V).

User experience in VR could be different based on previous experience with this technology. Medyńska-Gulij and Zagata [20] performed an experimental study in which they asked experts and gamers to take an immersive experience in a virtual stronghold of Ostrów Lednicki (Poland). Participants had to take a virtual walk around the stronghold, visit the palatium with a chapel, then go to the viewing point. The VR environment was built in the Unity game engine. The building geometry was based on a point cloud acquired from LiDAR. The gamers group needed less time than the experts group to complete the tour. However, expert users made more comments, and their observations made references to their expertise from academic publications. It turned out that gamers were more homogenous in their comments and opinions. Based on this, the study concludes that cartographic materials could be a fundamental source of information in immersive VR for cultural objects and reconstructions.

Another project related to VR technology and cartographic context is provided by Zagata et al. [21]. They studied the effectiveness of a mini-map for navigation in a reconstructed stronghold. The research adopted eye tracking technology in order to capture the total time users gaze on the mini-map. Participants were asked to find and collect Mieszko I's coins within the stronghold, highlighted on the mini-map. One group of participants used walking, and the second used teleportation for movement in space. Study participants were gamers, playing computer games a minimum 10 h per week. The study was supported by several software packages, e.g., SketchUp, CloudCompare, Photoshop, and Unity game engine. The main hardware was HTC Vive Pro Eye googles with an in-built eye tracking device. The study reveals that participants who examined the mini-map longer needed more time to finish collecting all the coins. There was no significant difference between people walking and teleporting in mini-map examination time. However, participants who used teleportation finished the task faster.

New visualization methods draw from various data gathering methods. Another study analyzed land use mapping techniques according to pedestrian movement registration with unmanned aerial vehicle (UAV) [22]. The research aimed to develop a methodological approach for thematic maps production based on low-level aerial images with recording of pedestrian movement. The study proposed point-to-polygon transformation of pedestrian visualization. The outcome of the research was several thematic maps of

pedestrian density and land use occupied by pedestrians. The results show that formal land use classification could be changed due to the pedestrian movement behavior. The usage of point-to-polygon transformation allowed qualitative data to be obtained, therefore providing complementary information to actual land use visualization.

Visualization of spatial data is not only related to digital cartography. Harding et al. [23] proposed a web application enabling 3D printing of terrain models. This type of terrain visualization is something opposite to the VR environment, and the models that are produced are static in nature. Three-dimensional models provide the aspect of tangibility of cartographic product. Printed physical terrain models are commonly used in geography and geology teaching. The TouchTerrain application uses Google Earth Engine and can process digital 3D terrain models according to given coordinates. Additionally, it provides the possibility to import vector data such as GPS (GPS Exchange Format). In the study, Google Analytics were used to determine TouchTerrain users' characteristics. It turned out that most users are returning users, and only 21% of all users are new users (the results are based on the session between 1 July 2019 and 26 December 2020). The primary location of users, based on IP geolocation, suggests US and Western Europe.

5. Conclusions

This Special Issue on multimedia cartography highlights detailed research in specific research fields. However, the field of interest in multimedia cartography is much wider. Particularly noteworthy is the importance of the cartographic symbol and the map itself as the core of the multimedia visualization. The leading topic at present is the effectiveness of individual media in conveying information, in particular the effectiveness and efficiency of cartographic communication in multimedia presentation. In the context of changing technology, it is interesting to note the importance of new media such as VR, AR, holography and their significance for cartography. Among the research included in this Special Issue, one can also find questions about the place of maps in new technologies.

As the presented research shows, cartography plays an crucial role in the information communication process. The map is becoming an inseparable element of navigation in space, especially on mobile devices. In addition to the real world, it is part of virtual tours and allows finding specific locations in virtual space. Cartographers search for mapping methods that will be most useful and attractive for users by researching effectiveness, efficiency, and user experience implementing new research methods and technologies. Multimedia maps are used in education, storytelling, navigation, visualization and, above all, in everyday activities.

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