www.czasopisma.pan.pl www.journals.pan.pl

GEODESY AND CARTOGRAPHY
Vol. 67, No. 2, 2018, pp. 159–177

DOI: https://doi.org/10.24425/118707

Original research paper

Similarities of global web mapping services functionality in the context of responsive web design

Tymoteusz Horbiński[1], Paweł Cybulski[2*]

[1,2]Adam Mickiewicz University in Poznań
Faculty of Geographic and Geological Sciences, Department of Cartography and Geomatics
10 Krygowskiego St., 61-680 Poznań, Poland
[1]e-mail: tymoteusz.horbinski@amu.edu.pl, ORCID: http://orcid.org/0000-0002-9681-6762
[2]e-mail: p.cybulski@amu.edu.pl, ORCID: http://orcid.org/0000-0002-5514-5720

[*]Corresponding author: Paweł Cybulski

Received: 1 June 2018 / Accepted: 27 September 2018

Abstract: The graphical user interface (GUI) and the functionality of various global map services in the context of responsive web design were compared in the article. The analysis included: the number and arrangement of buttons on the start screen, available map layers, waypoints and means of transport for searched routes on four screens of various sizes: the desktop computer, laptop, tablet, and smartphone screen. Having compared the interface and the functionality of eight global map services (Baidu Maps, Google Maps, Here WeGo, Bing Maps, Open Street Map, Map Quest, 2Gis, Yandex Maps), authors draw conclusions concerning responsive web design. Despite the fact that specific map services differ, there are some common features making a good example of the adaptation of the graphical user interface to the device on which the map is presented. Global map services, regardless of the display size, use the same interactive tools that are graphically similar. Among those graphic similarities, one can distinguish two or three graphical styles representing a single function. Two versions of the interface can be observed – the desktop and mobile type. Adaptation to devices such as laptops or tablets assumes that only the screen decreases but the interface and the functionality remains relatively unchanged. Real responsiveness occurs only when service is displayed on a smartphone display.

Keywords: responsive web design, graphical user interface, web mapping services, geomatics, interactive map

1. Introduction

Customization is one of the main challenges of modern cartography. The opportunity to adapt web maps to various devices constitutes a significant aspect of the attempts to customize. The variety of display screen sizes, on which the map is presented, causes yet new difficulties in designing them. Responsive web design (RWD), i.e. integrated design of a single website onto devices of different display screen sizes, is a solution used for many years (Marcott, 2010). Such an approach results from a common opinion about the popularity of web maps and their wide use (Reichenbacher, 2001). As RWD technology makes it possible to change symbols, interface and cartographic content in real time, it is commonly utilized in online cartography (Friedmannová et al., 2006; Peterson, 2006). By combining three design techniques, i.e. fluid grid layouts, flexible images and media queries, online maps can be displayed not only on a desktop computer screen but also on a laptop, tablet, and smartphone screen (Marcott, 2010). Moreover, the GUI of a web map can adapt not only to the device but also, what is more important, to the preferences of the user (Konečný and Staněk, 2010; Roth, 2013; Roth et al., 2014). Searching for new standards of responsive map design resulted in the improvement in the quality of cartographic products, particularly in the adoption of a single format HTML5 (Dukaczewski, 2014; Cybulski and Medyńska, 2018). What is highly recommended in RWD is to first prepare the layout for the device with the smallest display screen and then adapt it to devices with larger screens (Frain, 2015). Hence, the same web map service has a slightly different interface on different display screens. Guidelines on responsive map design are general. Designing for specific devices is discussed in the sourced literature (Muehlenhaus, 2013, p. 61), however, due to lack of strict principles web maps offer diverse solutions concerning the adaptation of the interface to the context of the user and the device. Intuitiveness is an important factor taken into consideration in the design process, as it helps one to lay out buttons in the right way and secures their graphic style (Krug, 2005). Well matched icons allow the user to localize the searched button faster and interpret it correctly. The three-click rule, according to which, if users cannot quickly find the desired information, they will leave the website, constitutes one of the unofficial rules of RWD and web map design (Zeldman, 2001; Weinschenk, 2011). Thus, GUI organization plays a significant part in the process of web map design. The research mentioned above confirms that if the user cannot easily find the right button, the map will be no longer effective. Such observations can be verified on the basis of various map services, such as Google Maps that make it possible to display responsive maps. Confronting interfaces of specific map services with guidelines on design derived from the literature, one can determine what arrangement, number and graphic style of buttons is preferred by responsive map creators and what solutions are the most popular. In a search for the rules of responsive map design, a question arises: do responsive map creators follow any principles concerning the number, arrangement and graphic style of GUI buttons?

Rules on GUI design prevent creators from overwhelming users with, for instance, too many buttons, as that affects not only the functionality but also intuitiveness of a map service (Nivala et al., 2008; Baranowski et al. 2010). The way responsive maps are utilized depends heavily on the devices offered. Apart from the object search function, there are also other buttons: Measure distance, Layer, Geolocation, Waypoints. Many of those services also have buttons for various means of transport by which users can go on their chosen route (Peterson, 2008; Socharoentum and Karimi, 2015). It is also important that the interface of a responsive map displayed on the smaller device adjusts to the size of the display screen. It is thus necessary to reduce the number of buttons to the most vital ones and to lay them out properly on the smaller display (Carroll, 1985). When displaying the responsive map on the mobile device, one needs to consider the way the map is utilized. Hence and Hoober (2015) suggests that buttons are placed in the lower part of the map interface, as they are then closer to the thumb, a finger usually used for pushing them. Even though map services differ, they have many common elements, the analysis of which may help one identify the most frequently used map buttons and their arrangement (Alaçam and Dalci, 2009).

The main objective of our research was to compare GUI and the functionality of popular map services and analyze it in the context of responsiveness. It was important to check how the interface of the same website changed on the desktop computer, laptop, tablet and smartphone display screen and which functions were available on different display size. The comparison included the following data: the number of buttons on the start screen, the number of map layers, the number of waypoints on the searched route and the number of means of transport for the searched route. These numbers are supposed to help one characterize any changes in button arrangement and the functionality level of map services, depending on the display screen size. Additionally, we have checked the features on which the responsiveness of the map service depends, such as day/night mode, the largest scale and the generalization of map content. We have analyzed 8 online global map services of the similar functionality: Baidu Maps, Google Maps, Here WeGo, Bing Maps, Open Street Map, Map Quest, 2Gis and Yandex Maps.

2. Related work

Despite a significant interest in the topic of responsive map design, there have been relatively few studies devoted to GUI of popular map services. The article by Nivala et al. (2008), in which Google Maps, MSN Maps & Directions, MapQuest, and Multimap are juxtaposed, is one of the articles on the subject. Analyzing the functionality of these four maps, researchers drew conclusions that were supposed to serve as guidelines for designing future web maps. Guidelines were conceived on the basis of problems that users, both professional and public, dealt with during the research. It was observed that the identification of errors of online maps allows one to make some recommendations that can boost both their use and attractiveness for different target groups. Another conclusion was that certain website flaws can be overshadowed by the popularity of the websites, their long-term use and habits resulting from such use. As far as facts about the GUI of the analyzed maps are concerned, the authors of this article highlight lack of aesthetics and start interface overload. They also observe that these factors may frustrate users and cause some negative feelings in them at the very beginning of utilizing online maps. Another observation that researchers make on online maps is that the layer change button is not used.

The article by Wang (2014) is another publication that analyzes online map services. He juxtaposes four online maps, comparing their functionality and attempts to conceive recommendations for future map services. In the article, the author confronts Google Maps, Bing Maps, Map Quest and Yahoo Maps. Guidelines suggested by the researcher result from the errors that research participants had to deal with. The author also emphasizes the issue of the start screen transparency. The fewer information at the beginning, the higher the evaluation of the map by users, which directly translates into the effectiveness of their work. He recommends that in the process of interface creation designers follow the rule of simplicity and transparency. He suggests that key buttons, such as the Search or Geolocation, are located in the areas of interest or in significant spots of the website layout. In his observations, came to the conclusion that the visualization of web maps was complex for designers and the dispute between designers and users over colors or trends in design would remain unsolved, as the usefulness of websites was the much more significant factor.

The article by Maiellaro and Varasano (2017) is another source literature publication. It is devoted to one-page interactive maps of three countries: Cyprus, Malta, and Japan. Apart from the information concerning technical aspects of the analyzed maps, in conclusion, there is also a recommendation that their authors should follow. Namely, for a map service to be useful, it needs to be highly functional (the functionality is confirmed by users) and adjusted technically (fast performance and display resolution).

3. Methodology

3.1. Selection and characteristics of web map services and display devices

In the research, we focused on global map services, whose functionality makes it possible to search for spatial objects, choose a map layer, use geolocation or select a route for different means of transport. As these services use the geolocation function, they are referred to as location-based services (LBS) (Meng and Reichenbacher, 2005). The opportunity to adapt the GUI of a specific service to smaller display screens was an additional choice criterion. One of two basic ways of utilizing mobile map services is to search for a route to the desired destination on the basis of one's location (Meng, 2008). The adaptation of interface to smaller display screens is considered as an element of egocentric, user-oriented map design (Meng, 2005). On that ground, we selected 8 global map services that allow one to search for objects and routes thanks to geolocation and with the function of adapting the GUI to smaller display screens: Baidu Maps, Google Maps, Here WeGo, Bing Maps, Open Street Map, Map Quest, 2Gis and Yandex Maps. Selected maps fulfill four conditions specified by Meng's (2008) classification: "you-will-go", "you-are-here", "find next" and "wayfinding".

Each of the map services mentioned above was tested on four display screens to check how interface responsiveness functioned and how the number of buttons altered. The 21.8″ desktop computer monitor was the largest, the second largest display screen was the 15.6″ laptop screen, then tablet screen of 12″ and the 5.1″ smartphone screen was the smallest. The selection of map services and display screens is demonstrated in Figure 1. The two bigger screens were in the horizontal orientation, while the two smaller screens were in both vertical and horizontal orientation. Both types of the display were available only on the smaller devices.

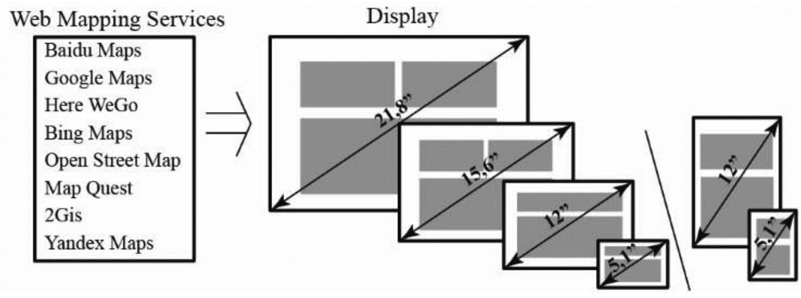

Fig. 1. Selection of web mapping services and devices display size

3.2. Analysis of graphical user interface and the functionality of web mapping services

The analysis of the GUI of web map services was based on the number of buttons visible on the start screen, map layers, waypoints on the searched route and means of transport available to the searched route. We also analyzed the arrangement of specific buttons and their popularity. We compared the graphical design of some of the buttons on selected web map services.

Among the analyzed buttons, there were: the Panning Hand, Zoom In, Place Search, Route Search, Geolocation, Map Layer button but also buttons connected with displaying traffic density or creating an individual map with the information from logged in users. Some tools do not have buttons assigned to them and are based on the knowledge and intuition of the user, e.g. panning. Many web map services do not use panning arrows anymore but panning is based on click-and-drag or touch-and-drag on mobile devices (Muehlenhaus, 2013). Even though some other tools, such as zooming in, are equally intuitive and function through a scroll wheel on the mouse, finger dragging or double clicking on the mobile device screen, they still have their buttons on the GUI. Zoom bar and plus and minus buttons are the most popular. Nevertheless, many would think zooming in through a scroll wheel or double click is the most practical solution (Roth and Harrower, 2008; You et al., 2007).

On the one hand, the number of means of transport available for a specific route depends on what routing algorithms are used by the mapping service and on the other, whether it uses timetables offered by public transportation agencies in the form of General Transit Feed Specification (GTFS) (Sinha and Prabhakar, 2015). The number of available waypoints depends on used algorithms and is usually limited, e.g. Google Maps for premium users offers more waypoints (Zhang et al., 2016). Thus, depending on API, which is the basis for a specific online mapping service, the target user receives more or fewer waypoints on the searched route (Roth et al., 2014).

Various map layers are displayed usually in the form of a button that opens a drop-down list. Symbols of buttons are not unified and are gradually changing. However, using non-standard symbols or too long button names may be unclear to the user (Muehlenhaus, 2013, p. 48; Halik and Medyńska-Gulij, 2016). It applies also to the Geolocation button which differs, depending on the map service. Its graphical style usually fits in the

GUI of the entire website. Buttons on the start screen are most frequently laid out in one of the corners of the map. Maps on mobile devices are often designed to have all the buttons at the top of the page (Takeuchi and Kennelly, 2010). Among the elements analyzed there were also the so-called widgets, for instance Share, Menu, Log In or Hotels, Restaurants etc.

Thematic layer of the online map is frequently understood as a business or operational layer (Muehlenhaus, 2013, p. 143–172). In global online mapping services that layer denotes e.g. restaurants, hotels etc. that show on the base map. The change in the base map may also be treated as the layer change, which was observed by Brynard (2013). He divided layers into operational layers and base map layers. The display of information about traffic is treated by Schmidt and Weiser (2012) as a thematic layer. Kajikawa and Nagayama (2008) demonstrate a different view, dividing layers into raster and vector layers. Hence, such base maps as an orthophotomap, an elevation map or a land cover can be mentioned as examples of raster layers, whereas a road map constitutes the example of a vector layer. Thus, one lacks clear-cut criteria that define what a layer in online mapping services is, particularly considering the fact that specific options mentioned above usually have separate buttons assigned to them (López-Ornelas et al., 2013). Obviously, the number of layers results from the range of information included in a specific mapping service and therefore, we have decided to select comparable services on the basis of the classification by Meng (2008). Due to the lack of standards clearly defining what is considered a layer in a global mapping service we assumed that the button changing the base map is a component of the layer change. It is a popular approach described in handbooks dealing with online mapping service design (e.g. Muehlenhaus, 2013, p. 53). It is, obviously, the research assumption that can be completed or corrected in other circumstances.

The functionality of a mapping service depends not only on GUI but also on the opportunities of the map content to adjust to the current working mode (van Tonder and Wesson, 2009). The range of the scale displayed is a highly important element of the functionality. The adjustment to the size of a mobile device sometimes imposes on mapping services the generalization of content and the range of the scale displayed (Nivala and Sarjakoski, 2007; Dillemuth, 2013). Depending on lighting conditions in which the map is displayed, responsive map design should also consider the day/night mode. When it is dark, such mode makes the map display in different, more contrasting colors (Sarjakoski and Nivala, 2005). What is more, the mapping service may also adjust to the current activity of the user. User's activity may be connected with doing a specific task in the system in which the mapping service works but may also depend on external activity (van Tonder and Wesson, 2009).

4. Results

4.1. The number of buttons on different display screen types

Specific web map services differ in terms of the number of buttons visible on the start screen on the largest display size (Figure 2). 2Gis and Map Quest constitute map services with the greatest number of buttons on the largest analyzed display screen, with over 25 buttons. Besides basic navigation buttons, namely the Zoom, Geolocation, Object Search and Route Search button, they also have tools such as Layer, Traffic, quick searching for objects such as Hotels and Restaurants, Print, Measure Distance or tools connected with web community: Save My Place, Share, Add Pictures. Open Street Map stands out with 20 buttons on the start screen. Apart from standard navigation buttons, it also has buttons that make it possible to save, follow and export changes that take place on the map. The other 5 websites do not have more than 15 buttons. Baidu Maps and Here WeGo have the smallest number of buttons. On the start screen, there are only the Route Search and Place Search, Geolocation, Zoom, Layer, and Menu buttons. Moreover, instead of widgets, Baidu Maps has buttons for displaying, for instance, traffic density.

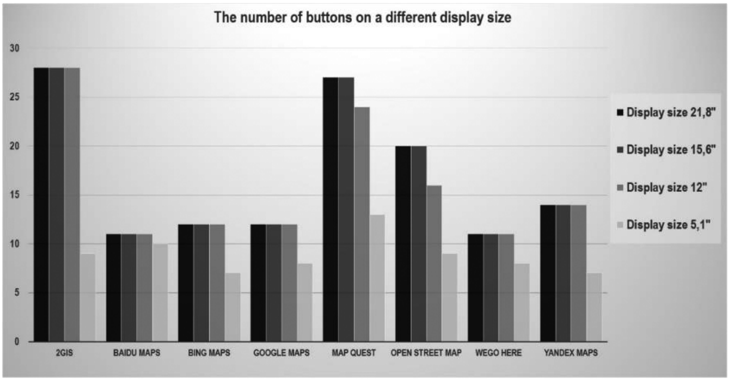

Fig. 2. The number of buttons on a different display size on the start screen

On the smaller display screen (15,6″) the number of buttons remained unchanged in all the analyzed map services. Only on the 12″ display screen the number of buttons altered in some of them. In Map Quest the number of available thematic layers, such as hotels and restaurants etc., decreased, however, only when the map service was displayed vertically on the tablet. In Open Street Map there were no buttons related to following and exporting changes, as well as information and logging in.

The greatest change in the number of buttons took place on the 5.1″ smartphone display screen. Only in one map service the number of buttons exceeded 10 and that was Map Quest. The other services had between 7 and 10 buttons on the start screen and those were mainly the Zoom, Geolocation, Layer or Route/Place Search buttons. Solely in one case the number of buttons altered, depending on the orientation of the display screen. In horizontal orientation there were no Zoom and Geolocation buttons.

4.2. The arrangement of map tools on the start screen of web map services

The analysis of button arrangement of a web map service GUI was made on the basis of those buttons that repeat in most of compared map services. The Geolocation, Layer, Search, Zoom, Route, Share, Log In and Menu button are available in all the services. There are 8 main windows in which interface buttons are located: the top left, middle top, top right, middle right, bottom right, middle bottom, bottom left and middle left. Figure 3 presents the main location of buttons in both vertical and horizontal orientation.

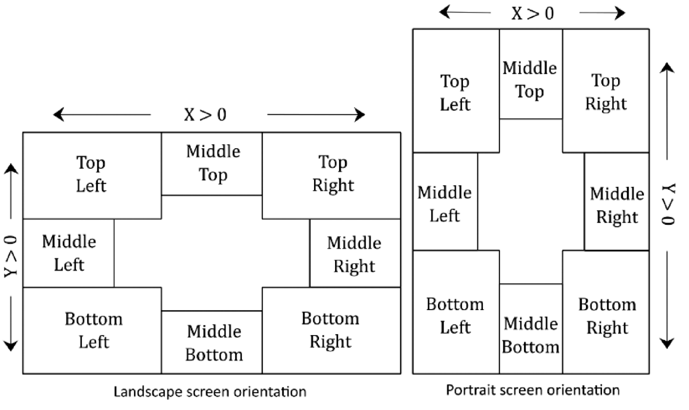

Fig. 3. Main areas of buttons arrangement on the start screen of web mapping service

In Figure 4 one can observe the most frequent arrangement of web map interface buttons on 21.8″ and 12″ display screens. As demonstrated, some buttons are placed in the same window on a few map services. It applies to the Geolocation, whose button is placed in the top right corner of the start screen in 4 map services, and in the bottom right corner of the start screen in 3 other services. What is interesting is that in all the analyzed map services the Geolocation button is placed on the right side of the screen. The situation looks similar to the Layer button, which is located in the top right corner in 4 map services, and in the bottom right corner in 3 other services. It can be clearly seen that most map services place the Layer button on the right sight of the screen. The right

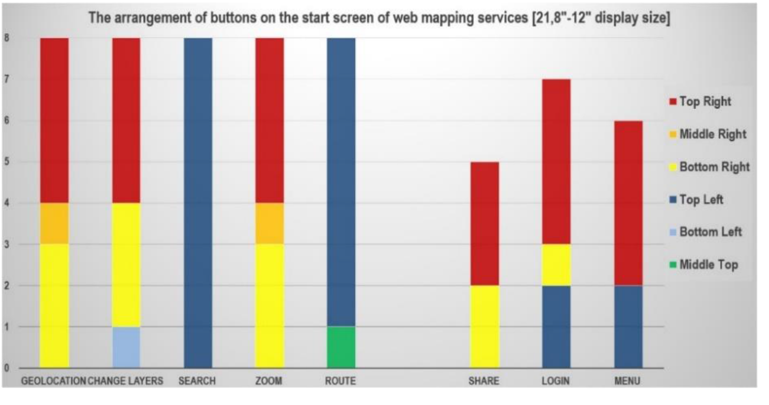

Fig. 4. The arrangement of buttons on the start screen of web mapping services [21,8″–12″ display size]

corner location is also typical for the Zoom button, which is situated in the top right corner in 4 map services and in the bottom right corner in 3 other services. Similarly, the Share button, which occurred only in 5 map services, was also placed on the right side, in two of them being in the bottom right corner and in other three in the top right corner.

The Search button was in the top left corner of the start screen in all the analyzed map services, the same as the Route button, directly connected with the previous one, placed in the top left corner in 7 map services. Moreover, the Log In and Menu buttons were also in the top left corner, however, they were situated in the top right corner much more frequently. In one of the services, the Layer button was in the bottom left corner. As demonstrated in Figure 4, most of GUI buttons of web map services, presented on 21.8″ to 12″ display screens, are located on the right side, predominantly in the top right corner. Only the Place Search and Route Search buttons are situated in the top left corner.

Figure 5 depicts the arrangement of GUI buttons of the web map on the smartphone 5.1″ display screen. As opposed to larger display screens, neither the Share nor the Log In button occurs there. Geolocation occurs most frequently in two locations: in the bottom right or bottom left corner, thus differing from larger display screens, onto which this button appears in the top part of the screen. The Layer button occurs only in 5 map services, in 3 of them in the bottom right corner. The Search button appears in 6 analyzed map services, usually in the top left or top right corner. The Zoom button, present in 4 map services in the form of $+/-$ buttons, is located mostly in the bottom and middle part of the screen on the right. The Route Search button, occurring in all map services except for Open Street Map, is usually placed in the top right corner. Only in three services, it is situated in both corners of the bottom part. The Menu button, available in 6 map services except for Yandex and Baidu Maps, is most frequently placed in the top right corner, in the top left corner for Google Maps and Here WeGo, and in the bottom right corner only for Map Quest.

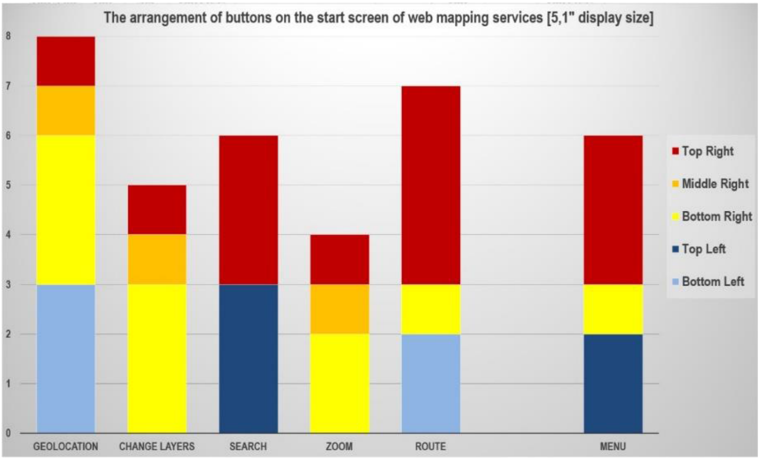

Fig. 5. The arrangement of buttons on the start screen of web mapping services [5, 1″ display size]

4.3. Graphical design of buttons in web mapping services

Figure 6 presents a graphical comparison of the design of buttons that occur most frequently in selected map services. As demonstrated, when the 5.1″ display screen is juxtaposed with other screens, there is a visible difference in the symbolism of buttons. The most uniform graphical style achieved on all the display screens is presented by Yandex

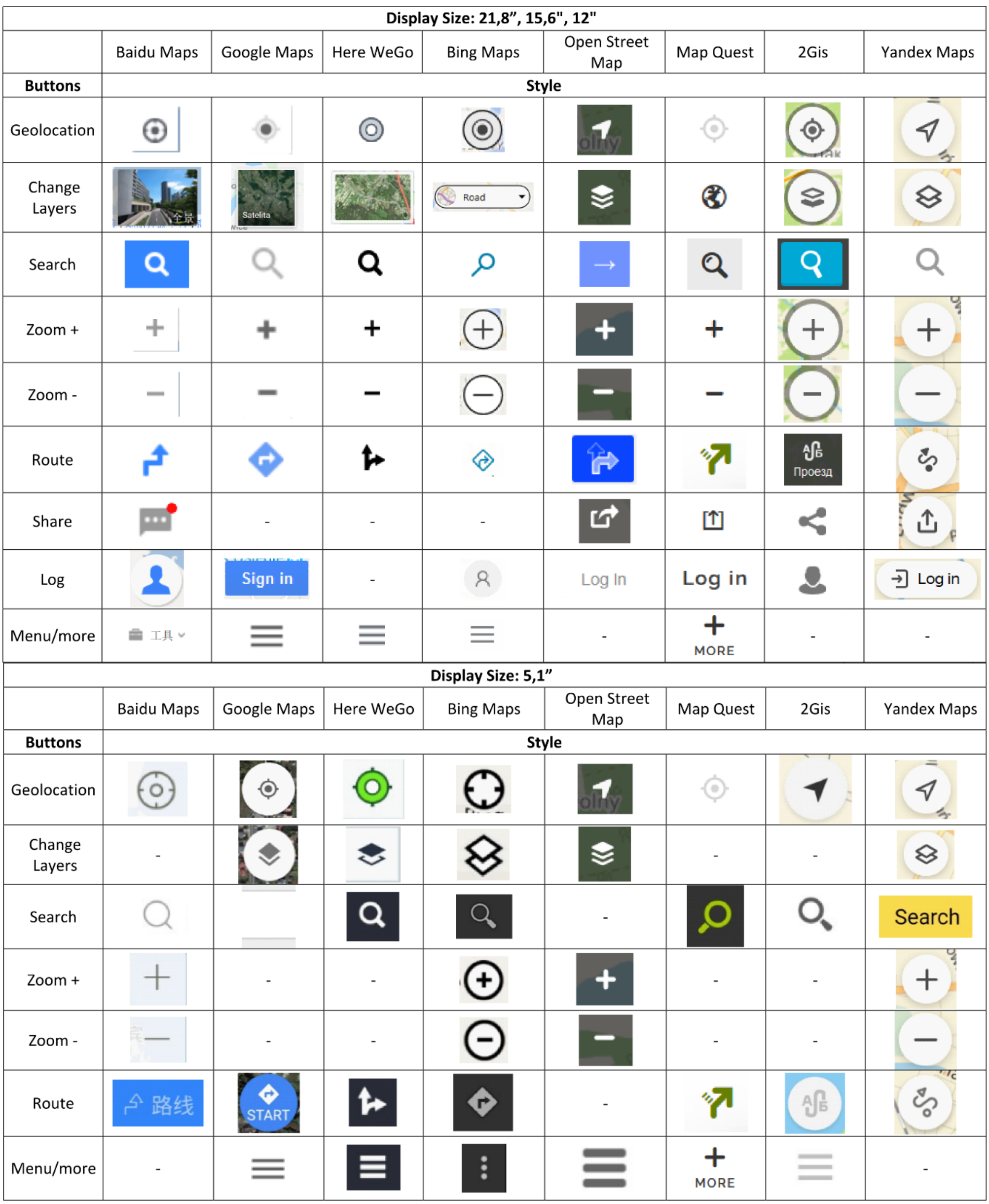

Fig. 6. The juxtaposition of graphical design of buttons in analyzed web mapping services

and Map Quest. The Geolocation button occurs in two basic forms – as a circle with a point marked inside it or as an arrow directed north-east. The Layer button also has two forms: a satellite view or overlapping rectangles. On the 5.1″ display screen the Layer button takes only the latter form in all the analyzed services. The Search button exists as a magnifying glass symbol on 21.8″–12″ screens in 7 services and only in Open Street Map, it appears as an arrow pointed to the right. Zoom buttons +/– occur in all the analyzed map services. The Route Search button on all display screens is represented by 3 types of graphic symbols in total: a symbol with an arrow pointed to the right, an arrow pointed to the right without the background and a curved arrow. The Share button occurs most frequently on 21.8″–12″ display screens in the form of a square from which an arrow comes out. The Menu button, available on screens of all sizes, has a form of horizontal lines.

4.4. Similarities in the functionality of web mapping services

The analysis of similarities between map services has been carried out on the basis of the number of buttons and functions that occur in all the analyzed map services. Four elements, namely the number of buttons on the start screen, the number of available layers, the number of waypoints and the number of available means of transport, constitute the main subject of the analysis. Figure 7 compares selected elements on line charts. The number of map layers on 21.8″–12″ display screens remains unchanged. The biggest number of layers is available in Open Street Map, three layers are in Baidu Maps, Here WeGo, Bing Maps and Yandex Maps, two layers in Google Maps and Map Quest. 2Gis offers just one layer. On the 5.1″ screen the number of layers available in specific ser-

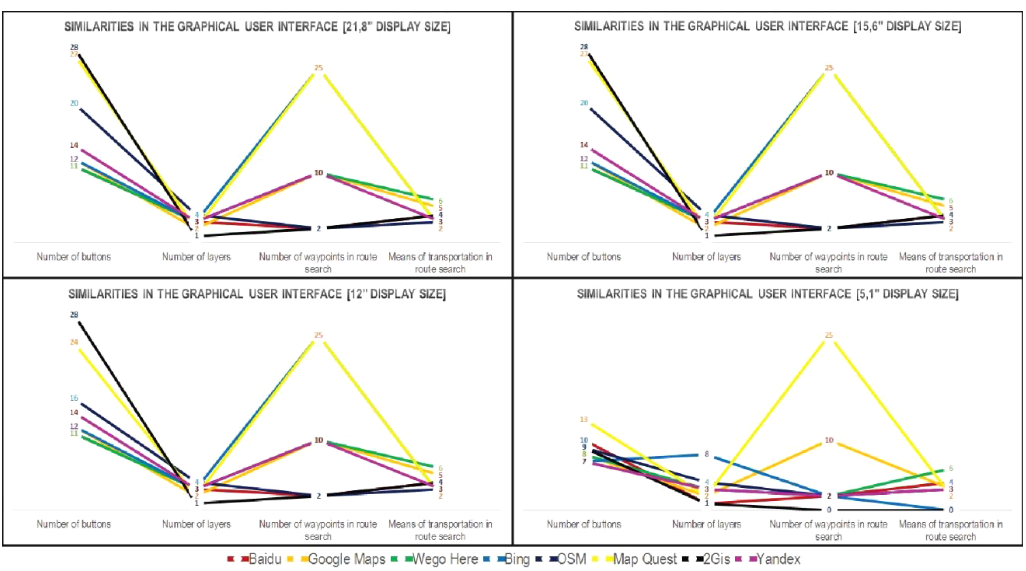

Fig. 7. Similarities in the GUI on different display size

vices differs from the number of layers shown on other display screens. Bing Maps offers the most layers, Open Street Maps – 4 layers, Here WeGo and Yandex Maps – 3 layers, Google Maps and Map Quest – 2 layers, and Baidu Maps and 2Gis offer a single layer.

When searching for a route on the 21.8″–12″ screen, one can save the most waypoints in Bing Maps and Map Quest. In Google Maps, Here WeGo and Yandex Maps it is possible to save the maximum of ten waypoints, while in other map services only two. On the 5.1″ display screen the number of waypoints on the route is different than on the other screens. Still, Map Quest offers the most waypoints. When using Google Maps, one has access to a maximum of 10 waypoints. Baidu Maps, Here WeGo, Bing Maps, Open Street Map, Yandex Maps make it possible to search for a route with just one waypoint. 2Gis is the only website that does not allow route searching on the smartphone screen.

Map services differ also in terms of available means of transport that can be selected for the route. On the 21.8″–12″ display screen Here WeGo offers the most, namely 6, means of transport, Google Maps 5, Baidu Maps and 2Gis 4, Open Street Map and Yandex Maps 3, and Bing Maps and Map Quest 2. The situation is different for the 5.1″ screen. Here 2Gis becomes the odd one out, as it is impossible to search for a route in this service. Bing Maps does not offer any means of transport to choose from, while Google Maps, Open Street Map and Yandex, Maps offer three.

A comparative analysis of similarities between map services indicates that on 21.8″ – 12″ display screens Baidu Maps, Google Maps, Here WeGo, Bing Maps and Yandex Maps are the most similar in terms of the number of buttons. On the other hand, there is a similarity between Open Street Map, Map Quest, and 2Gis, three services with significantly more buttons than the other services. When it comes to map layers, all the services are quite alike. As far as the number of available waypoints is concerned, the following combinations of map services bear the greatest resemblance: Map Quest and Bing Maps, Here WeGo, Google Maps and Yandex, and Baidu Maps, Open Street Map and 2Gis. Taking into consideration the number of available means of communication, all the services are similar. Hence, on the 21.8″–12″ display screen Google Maps, Here WeGo and Yandex Maps are the most similar in terms of functionality.

The similarity of GUI on the 5.1″ display screen is different than on the other screens. The number of buttons is similar for all map services except for Map Quest that has 13 buttons. All the services but Bing Maps are also very much alike in terms of the number of map layers. As far as the number of available waypoints is considered, Map Quest and Google Maps clearly stand out. Other web map services, excluding 2Gis, in which there is no route search tool, are similar. There is a visible similarity between Baidu Maps, Google Maps, Open Street Map and Yandex Maps in terms of the number of available means of transport for selected routes. Here WeGo stands out with the largest number of them.

The functionality of global mapping services to the great extent depends on the adjustment to environment conditions. The day/night mode is one of the basic functions. Responsiveness of the online mapping service requires the map to display in more bright color in case of poor lighting. The adjustment of the map to the device may in some cases change the largest scale due to the size of the display screen. The content of the map should also adjust to the smaller display screen. The Table no 1 below demonstrates features of the map that also adjust. The content of the mapping service on the PC screen was the starting point for generalization. The largest presented scale is approximate as some services do not display scale in the graphic form.

Table 1. Additional features which characterize responsiveness of global web mapping services

display: 21.8″	Baidu Maps	Google Maps	Here WeGo	Bing Maps	Open Street Map	Map Quest	2Gis	Yandex Maps
day/night mode	No	No	No	No	No	No	No	No
max scale	1:300	1:200	1:750	1:400	1:800	1:1500	1:650	1:800
generalization	NA	NA	NA	NA	NA	NA	NA	NA
display: 15.6″	Baidu Maps	Google Maps	Here WeGo	Bing Maps	Open Street Map	Map Quest	2Gis	Yandex Maps
day/night mode	No	No	No	No	No	No	No	No
max scale	1:450	1:250	1:1000	1:500	1:1000	1:2000	1:900	1:1000
generalization	No	No	No	No	No	No	No	No
display: 12″	Baidu Maps	Google Maps	Here WeGo	Bing Maps	Open Street Map	Map Quest	2Gis	Yandex Maps
day/night mode	No	Yes	Yes	No	No	No	No	No
max scale	1:500	1:250	1:1500	1:500	1:1000	1:2000	1:900	1:1000
generalization	No	No	No	No	No	No	No	No
display: 5.1″	Baidu Maps	Google Maps	Here WeGo	Bing Maps	Open Street Map	Map Quest	2Gis	Yandex Maps
day/night mode	No	Yes	Yes	No	No	No	No	No
max scale	1:3000	1:250	1:1500	1:1 500	1:1 500	1:2000	1:900	1:1000
generalization	No	Yes	Yes	Yes	No	Yes	Yes	No

Comparing additional features that determine the functionality in the context of responsiveness of global mapping services, one can observe similarity between some services. In terms of the PC screen Google Maps, Here WeGo and Bing Maps were similar. The maximum available scale was smaller than 1:500. The other group of services had the scale larger than 1:500 but smaller than 1:1 000. Only Map Quest offered the largest scale, i.e. approximately 1:1 500, on the 21.8″ display screen. The display on the 15.6″ screen does not cause significant responsiveness of the service apart from the fact that the largest available scale slightly decreases in all services. The day/night mode occurs neither on the PC nor on the laptop screen. The mode is available on tablets and only in two mapping services. There is no generalization of content for the 12″ display screen, compared to the 21.8″ screen. In Baidu Maps and Here WeGo the maximum scale slightly decreases, compared to the 15.6″ scale. On the 5.6″ display screen the day/night mode is available only in two mapping services. The maximum scale significantly decreases for Baidu Maps and Bing Maps. Most of mapping services adjust map content, generalizing roads, names, rivers, lakes or point signs. Maps on smartphone display screens have clearly simplified content. Only for Baidu Maps, Open Street Map and Yandex Map the map content remains unchanged, compared to the display on the 21.8″ screen.

5. Discussion

Analyses of GUI of various map services, both global and local, made it possible to formulate conclusions about the interface. First and foremost, it was demonstrated that the web map user frequently deals with interface overload (Nivala et al., 2008; Wang, 2014). Indeed, for 21.8″–12″ display screens some map services offer users highly extended GUI with plenty of buttons. On the other hand, there are some global map services, whose creators do not overwhelm users with too many interactive tools. These could be referred to as the balanced interfaces. The analysis of the same services on smaller display screens allows one to draw conclusions on responsive web map design. Adaptation to the smaller device is a fundamental assumption of responsive design, according to which, as the device gets smaller, the number of buttons is reduced to the most crucial ones (Carroll, 1985; Chittaro, 2006). Indeed, this applies to global map services, as their number of buttons decreased, with creators finding the following buttons the most important: the Geolocation, Layer, Place Search, Zoom, Route and Menu button.

The layout of GUI buttons in the context of responsiveness is supposed to adjust to the needs of the user, thus, the proper arrangement on the smartphone screen was the subject of interest of researchers (Hoober, 2015). It is suggested that buttons on the small display screen are placed in the bottom part, as such devices are usually operated with a thumb. It is hence natural to use buttons located close to the bottom part of the screen. As the research shows, it is not a popular solution in the analyzed map services. On the 5.1″ display screen there was indeed a group of buttons placed in its bottom corners but other buttons were predominantly in top corners. The corner button layout, which dominated on the smartphone screen, may be justified when the map is displayed horizontally on the screen.

The fact that specific buttons differ in terms of graphic style is another issue touched upon during the GUI analysis (Muehlenhaus, 2013, p. 48). It does hold true for the Geolocation button, which has two symbols or for the Route button that has three different graphical styles. However, some similarities can be observed for e.g. the Zoom button or the Menu button in all the services. The Layer button was the most unified on the 5.1″ display screen (one symbol for all the services), compared to the 21.8″–12″ display screens (three different symbols).

The responsiveness of GUI assumes that the interface adapts to the device on which the map is displayed (Fairbairn and Erharuyi, 2003). In practice, however, on global map services two interface versions can be observed: the desktop type and the mobile type.

Adaptation to devices such as laptops or tablets assumes that only the screen decreases but the interface remains relatively unchanged. Only when the service is displayed on the 5.1″ screen, can real responsiveness occur, as the change in the number of buttons and their arrangement takes place and the functionality of the service in terms of the number of available map layers and thematic layers alters as well. What's more, the change of the screen's orientation from vertical to horizontal does not result in a change in the number or arrangement of interface buttons.

Responsiveness is not only the adjustment of the interface but also of the map content. It is particularly important in the context of functionality of global mapping services (Reichenbacher, 2001; Medyńska-Gulij, 2010). Indeed, analyzed global mapping services adjust their GUI and map content. As a result, the maximum scale of the display decreases on smaller display screens. It applies to most of the analyzed mapping services. It is a deliberate solution as a large zoom results in highly limited map readability on a small screen, especially from a short distance (Weakliam et al., 2008). Thus, the map content needs to be generalized to limit information it conveys so that it remains readable and clear even on the small display screen (Konečný and Staněk, 2010). As far as global mapping services are concerned, generalization of the map content occurs only on smartphone screens. The number of names and point signs on maps is reduced. In most cases, the network of roads and rivers is also generalized so that it can be easily readable on the 5.1″ display screen. It as a useful practice that allows one to display the content of the global mapping service on the mobile device screen (Dillemuth, 2005).

6. Conclusions

Mobile devices have significantly altered the way web maps are designed. Smaller sizes of display screens have imposed limitations not only on creators but also users. Responsive web design, which assumes the adaptation of not only the web map content but also its GUI to the smaller device, has become a solution to these problems.

The analysis makes it possible to notice that interface adaptation applies mainly to the device on which a map is displayed. The entire context of how the device is used is of secondary importance. It can be concluded from the arrangement of buttons on the start screen. The arrangement in the bottom part of the screen is partial or marginal. Furthermore, the location of buttons remains unchanged, irrespective of the orientation in which the user is looking at the map. It questions the effectiveness of such solutions. However, it may transpire that the user's habit of using buttons located in the top part of the screen is so strong that a facilitation in the form of buttons placed closer to the thumb may fail to bring expected results. Moreover, very few services adjust maps to environment conditions, e.g. to work in day/night mode. The analysis conducted shows also that responsiveness in the terms of lighting conditions occurs only on tablets and smartphones. Laptops, also treated as mobile devices, lack such responsiveness.

Certain rules can be observed that apply to all the analyzed map services. On the 21.8″–12″ display screens interactive buttons are placed in the corners of the start screen, mainly in the top left or right corner. Such layout is justified for tablets and mobile phones in landscape position due to their way of use. Decreasing the display screen to 5.1″ makes the number of buttons smaller and changes arrangement. The corner arrangement still dominates but the contribution of buttons located in the bottom left or right corner significantly rises. Global map services, regardless of the display size, use the same interactive tools in the form of the following buttons: the Geolocation, Layer, Place, and Route Search and Menu. Buttons for specific functions are graphically similar. Among those graphic similarities, one can distinguish two or three graphical styles representing a single function. As far as the functionality is concerned, on the 21.8″−12″ display screens it usually remains at the same level, however, it drops in some cases on the 5.1″ display screen, e.g. the number of available means of transport or layers drops. Similarity of 21.8″−12″ display screens can be observed also in terms of the map content. Proper responsiveness of that element is visible on the 5.6" screen on which the content adjusts to the size of the display screen, which is connected with significant generalization and selection of the most significant elements of the map. Generalization usually includes the removal of some point signs and reduction of some roads and physio-geographical objects such as lakes and rivers, sometimes also geographical names. Generalization of the content is linked with the maximum scale of display. Obviously, services displayed on the largest screen will have the largest scale. The decrease of the maximum display scale takes place for most of the analyzed mapping services.

The authors of this analysis believe that GUI of global map services constitutes a good example of responsive web design. The interface adapts to the context of the device and, to some extent, also to the context of the user. However, there is a need to ask questions about the effectiveness of specific solutions concerning the type, number and arrangement of buttons. A small part of the features that have been analyzed indicates that not only the size of the screen but also the equipment of the mobile device (GPS, light sensor, accelerator) should be included when designing responsiveness of mapping services. The fact that in this analysis we included only touchscreens of tablets and smartphones is one of the limitations of the research. We hope that our comparative analysis will allow one to make a critical evaluation of web cartography products, directing map creators even more towards the user-oriented design.

Acknowledgments

The paper is the result of research on designing effective adaptive graphical user interface carried out within statutory research in the Department of Cartography and Geomatics, Adam Mickiewicz University in Poznan, in Poland.

References

Alaçam, Ö. and Dalci, M. (2009). A Usability Study of WebMaps with Eye Tracking Tool: The Effects of Iconic Representation of Information. *Human-Computer Interaction*, 1, 12–21. DOI: 10.1007/978-3-642-02574-7_2.

Baranowski, M., Bielecka, E. and Dukaczewski, D. (2010). Methods of portraying spatial data used in official geoinformation services in Poland – a comparative study. In: G. Gartner, F. Ortag (ed.), *Lecture Notes in Geoinformation and Cartography. Cartography in Central and Eastern Europe*. Springer, Berlin, Heidelberg, pp. 41–62. DOI: 10.1007/978-3-642-03294-3_3.

Brynard, H. (2013). Best practices for the development and serving of web map services. *Proceedings of the South Africa Surveying + Geomatics Indaba (SASGI)*, Kempton Park: South Africa.

Carroll, J.M. (1985). Minimalist design for active users. In: *Human Computer Interaction – INTERACT'84*. B. Shackel (ed.). Amsterdam: Elsevier Science, 621–626.

Chittaro, L. (2006). Visualizing Information on Mobile Devices. *IEEE Computer*, 39 (3), 40–45. DOI: 10.1109/MC.2006.109.

Cybulski, P. and Medyńska-Guli, B. (2018). Cartographic Redundancy in Reducing Change Blindness in Detecting Extreme Values in Spatio-Temporal Maps. *ISPRS International Journal of Geo-Information*, 7 (1), 8. DOI: 10.3390/ijgi7010008.

Dillemuth, J. (2005). Map Design Evaluation for Mobile Display. *Cartography and Geographic Information Science*, 32 (4), 285–301. DOI: 10.1559/152304005775194773.

Dukaczewski, D. (2014). Designing simple and complex animated maps for users from different age groups, employing the appropriate selection of static and dynamic visual and sound variables. In: *Lecture Notes in Geoinformation and Cartography. Thematic Cartography for the Society*. T. Bandrova, M. Konecny, S. Zlatanova (ed.), Springer, Cham, 47–60. DOI: 10.1007/978-3-319-08180-9_5.

Fairbairn, D. and Erharuyi, N. (2003). Adaptive Technique for Delivery of Spatial Data Technique for Mobile Devices. In: *2nd Symposium on Location Based Services and Telecartography, ICA Commision on Maps and the Internet*. G. Gartner (ed.), 28th–29th January, Vienna, Austria.

Frain, B. (2015). *Responsive Web Design with HTML5 and CSS*. Birmingham, UK: Packt Publishing.

Friedmannová, L., Konečný, M. and Staněk, K. (2006). An adaptive cartographic visualization for support of the crisis management. *Proceedings of the AutoCarto*, pp. 100–105.

Halik, Ł. and Medyńska-Gulij, B. (2016). The Differentiation of Point Symbols using Selected Visual Variables in the Mobile Augmented Reality System. *The Cartographic Journal*, 54 (2), 147–156. DOI: 10.1080/00087041.2016.1253144.

Hoober, S. (2015). Lessons learned: Fingers, thumbs, and people. *Interactions*, 22 (3), 48–51. DOI: 10.1145/2745957.

Kajikawa, S. and Nagayama, T. (2008). Considering Standards for Specifications of Global Map Version 2. *Workshops ISO/TC 211*. Tsukuba International Congress Center, December 3, Tsukuba, Japan.

Konečný, M. and Staněk, K. (2010). Adaptive cartography and geographical education. *International Research in Geographical and Environmental Education*, 19 (1), 75–78. DOI: 10.1080/ 10382041003602977.

Krug, S. (2005). *Don't make me think: a common sense approach to Web usability*. Berkeley, CA: New Riders.

López-Ornelas, R., Abascal-Mena, R. and Zapeda-Hernández, S.J. (2013). Geospatial Web Interfaces. Why Are They So "Complicated"?. In: *DUXU/HCII, Part IV, LNCS 8015*. A. Marcus (ed.), Berlin, Heidelberg: Springer-Verlag, 231–237. DOI: 10.1007/978-3-642-39253-5_2.

Maiellaro, N. and Varasano, A. (2017). One-Page Multimedia Interactive Map. *ISPRS International Journal of Geo-Information*, 6 (2), 34. DOI: 10.3390/ijgi6020034.

Medyńska-Gulij, B. (2010). Map compiling, map reading and cartographic design in "Pragmatic pyramid of thematic mapping". *Quaestiones Geographicae*, 29 (1), 57–63. DOI: 10.2478/v10117-010-0006-5.

Meng, L. and Reichenbacher, T. (2005). Map-based mobile services. In: *Map-based Mobile Services*. L. Meng, T. Reichenbacher, A. Zipf (ed.), Berlin, Heidelberg: Springer, 1–10.

Meng, L. (2005). Ego centres of mobile users and egocentric map design. In: *Map-based Mobile Services*. L. Meng, T. Reichenbacher, A. Zipf (ed.), Berlin, Heidelberg: Springer, 87–105.

Meng, L. (2008). The State of the Art of Map-Based Mobile Services. In: *Map-based Mobile Services*. L. Meng, A. Zipf, S. Winter (ed.), Berlin, Heidelberg: Springer, 1–12.

Muehlenhaus, I. (2013). *Web Cartography: Map Design for Interactive and Mobile Devices*. Boca Raton: CRC Press.

Nivala, A.M., Brewster, S. and Sarjakoski, L.T. (2008). Usability Evaluation of Web Mapping Sites. *The Cartographic Journal*, 45 (2), 129–138. DOI: 10.1179/174327708X305120.

Nivala, A.M. and Sarjakoski, L.T. (2007). User Aspects of Adaptive Visualization for Mobile Maps. *Cartography and Geographic Information Science*, 34 (4), 275–284. DOI: 10.1559/152304007782382954.

Peterson, M.P. (2006). The Transition from Internet to Mobile Mapping. In: *Location Based Services and TeleCartography*. G. Gartner, W. Cartwright, M.P. Peterson (ed.), Berlin, Heidelberg: Springer, 73–88.

Peterson, M.P. (2008). Maps and the Internet: What a Mess It Is and How To Fix It. *Cartographic Perspectives*, 59, 4–11. DOI: 10.14714/CP59.244.

Reichenbacher, T. (2001). Adaptive concepts for a mobile cartography. *Journal of Geographical Sciences*, 11, 43–53. DOI: 10.1007/BF02837443.

Roth, R. and Harrower, M. (2008). Addressing map interface usability: learning from the Lakeshore Nature Preserve interactive map. *Cartographic Perspectives*, 2 (60), 46–66.

Roth, R. (2013). Interactive maps: What we know and what we need to know. *Journal of Spatial Information Science*, 6, 59–115. DOI: 10.5311/JOSIS.2013.6.105.

Roth, R., Donohue, R., Sack, C., Wallace, T. and Buckingham, T. (2014). A Process for Keeping Pace with Evolving Web Mapping Technologies. *Cartographic Perspectives*, 78, 25–52. DOI: 10.14714/CP78.1273.

Sarjakoski, L.T. and Nivala, A.M. (2005). Adaptation to Context – A Way to Improve the Usability of Mobile Maps. In: *Map-based Mobile Services, Theories, Methods and Implementations*. L. Meng, A. Zipf and T. Reichenbacher (ed.), New York: Springer, 107–123. DOI: 10.1007/3-540-26982-7_8.

Schmidt, M. and Weiser, P. (2012). Web Mapping Services: Development and Trends. In: *Online Maps with APIs and WebServices*. M.P. Peterson (ed.), Berlin, Heidelberg: Springer-Verlag, 13–21. DOI: 10.1007/978-3-642-27485-5_2.

Sinha, S. and Prabhakar, S. (2015). Integrating Traffic Data Stream with Public Route Planning Algorithm and Personalizing it for the End User. Boston University: Department of Computer Science.

Socharoentum, M. and Karimi, H. (2015). A comparative analysis of routes generated by Web Mapping APIs. *Cartography and Geographic Information Science*, 42 (1), 33–43. DOI: 10.1080/15230406.2014.976656.

Takeuchi, K. and Kennelly, P. (2010). Creating Mapping Application for the iPhone. *Cartographic Perspectives*, 66, 71–84. DOI: 10.14714/CP66.100.

van Tonder, B. and Wesson, J. (2009). Design and Evaluation of an Adaptive Mobile Map-Based Visualization System. In: *Human-Computer Interatcion – INTERACT 2009. Lecture Notes in Computer Science*. T. Gross (ed.), Berlin, Heidelberg: Springer, 5726. DOI: 10.1007/978-3-642-03655-2_92.

Wang, C. (2014). Usability evaluation of public web mapping sites. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 60 (4), 285–289. DOI: 10.1179/ 174327708X305120.

Weakliam, J., Wilson, D. and Bertolotto, M. (2008). Personalizing Map Feature Content for Mobile Map Users. In: *Map-based Mobile Services: Design, Interaction and Usability*. L. Meng, A. Zipf and S. Winter (ed.), Berlin, Heidelberg: Springer-Verlag, 125–145.

Weinschenk, S.M. (2011). *100 thing every designer needs to know about people*. Berkeley, CA: New Riders.

You, M., Chen, C., Liu, H. and Lin, H. (2007). A usability evaluation of web map zoom and pan functions. *International Journal of Design*, 1 (1), 15–25.

Zeldman, J. (2001). *Taking Your Talent to the Web: Making the Transition from Graphic Design to Web Design*. Berkeley, CA: New Riders.

Zhang, D., Chow, C-Y., Li, Q., Liu, A., Zhang, X., Ding, Q. and Li, Q. (2016). Efficient evaluation of shortest travel-time path queries in road networks by optimizing waypoint in route request through spatial mashups. *GeoInformatica*, 22 (1), 3–28. DOI: 10.1007/978-3-319-45814-4_9.