Perceivability of Map Information for Disaster Situations for People with Low Vision

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Abstract. Digital maps have become increasingly popular in disaster situation to provide overview of information. However, these maps have also created barriers for many people, particularly people with visual impairments. Existing research on accessible maps such as tactile and acoustic maps focuses on providing solutions for blind persons to be able to perceive the information digital maps present. For people with low vision, who often rely on magnifier, good contrast and good navigation support, current digital map solutions present many challenges. In this paper we have studied two types of digital maps and their related surrounding text in the home page of disaster applications. The study focused on perceivability of the information provided by the maps. To investigate this, we have adopted a mix-method approach and performed heuristic testing combined with expert testing by a user with low vision. Based on the evaluation we have made a number of recommendations to improve the perceivability, which can further enhance the accessibility of the maps.

Keywords: Maps, Universal Design, Perceivability, Emergency Management, Low Vision

1 Introduction

Maps (both paper and digital maps) and geospatial technologies in general are very crucial for efficient and timely responses in all stages of the emergency management life cycle stages; preparedness, alert, response, relief/ recovery and mitigation. In either stage, no actions can be done without knowing the locations. In the preparedness stage, resource inventory, logistic and evacuation planning, as well as in the alert stage such as monitoring, scenario identification, early warning e.g. [1] -- all should be made with the help of geospatial technologies. In the response stage, the map is even more critical as it is used for mapping the crisis, conducting situation analysis [2], providing information of evacuation path and shelters [3], dispatching resources and performing search-rescue operations [4, 5]. While in the relief stage, again geospatial information plays a role on informing the emergency organizations on the location of logistics and delivery of the relief supply [6], as well as assessing the early damages [7]. In the recovery stage, maps can be used for spatial re-planning such as infrastructure, housing, transport, water and so on [8]. In the mitigation phase, maps are very important to support assessment activities such as risk assessment, vulnerability, hazard and threat analysis [9]. In short, the needs for geospatial information on maps in emergencies are evident, regardless of its form, as agreed by many scholarly articles.

Although the digital maps cannot fully replace the paper-based maps in emergencies, they have been adopted more and more. Even todays' paper versions of updated maps during the emergencies often are prepared and produced digitally, and can then be shared both electronically or in printed forms.

The geospatial information is not only a key point for the emergency services in the field, but also the operators and decision makers sitting and collecting data in Emergency Operation Centers (EOCs). Moreover, maps provide the quickest way to share information with public on updated information of the crisis, such as location of established posts. Besides, we also need to take into consideration the contributions of the digital volunteers in collecting information related to the emergencies [10] which would not be valuable for all without being shared quickly through digital maps. Recent trends of the involvement of the digital volunteers in emergencies, show extensive use of maps to collect and share information.

However, the accessibility of such map systems is not well evaluated, especially when it comes to the people with disabilities. Cardonha et. al. [11] share the same concern and have conducted preliminary analysis on accessible maps. However, the focus of that article is to suggest better accessible route on the map, and not about how to deliver accessible map online so that people with visual impairments, for example, can still navigate the map. Thus, there are still limited works dedicated for developing evaluation methodology of the accessibility of the digital emergency management maps, especially also by involving people with visual impairment as evaluators. Keep in mind that in the emergencies, even people without physical and cognitive barriers could experience a sort of temporary or situational disabilities [12] which would further reduce the usefulness of the emergency maps, if we have not considered universal design and especially the accessibility factor [10].

A number of techniques have been developed for making accessible maps for blind persons. For example, tactile maps [13] and acoustic maps [14]. However, for people with low vision also reply on magnifiers, good contrast and navigation support, current solutions in digital maps present many challenges [15].

The goal of this research is to study and evaluate the accessibility of selected digital map applications for people with low vision. We do not differentiate the maps based on the functions of different stages of emergency management cycles. We have selected two different digital maps with relevance for emergency management to be evaluated in terms of their accessibility. One map is used for sharing social media twitter information, and the other map is used for monitoring tsunamis and earthquake including providing alerts.

This paper is organized into seven section. Section 2 is literature review where we present some related works and highlight our contributions compared to previous works. Section 3 contains the method, where we describe the map sources for the analysis and the analysis procedures. Section 4 comprises the use cases and the tasks to analyse the accessibility of the digital maps. In Section 5 we present the results of our tests, and discuss them further in Section 6. Section 7 is our concluding remarks.

2 Literature Review

As mentioned earlier, the digital maps have been used in the different stages of emergency managements and will continue to be used even more in the future as more technologies can support digital maps, and more people can access these. But many of future directions of the maps focus on the technicalities of the map itself. Bocardo [16] e.g., list some user requirements such as the ability to handle large numbers of data, interoperability, meta data, consistent and self-explanatory maps, accuracy. The requirements also consider the feature extraction algorithms for digitizing satellite imageries, visualize sensor data, and operational services such as provide users an access to data in real time. The term of access is used to refer to “a way or means to make use of the data”, instead of the accessibility in relations to the people with disabilities, as we have defined in the introduction.

Previous studies also have discussed the accessibility issues of the maps. Cardonha et. al [11] for example, point out that people with disabilities physically face challenges to find a route from A to B due to flooding, potholes and defective sidewalks. Thus, the “accessibility map” is more about outdoor accessibility map that include accessibility challenges that may be encountered in a city. It classifies and visualize the accessibility needs using voluntary citizen sensing technique which would register their reports on the map, e.g. “the regions have no side walk at all”, “sidewalk with obstructing objects” or “sidewalks with steps”. While the web accessibility is superficially discussed and is taken for granted, assuming today’s web technologies are getting better and taking into account web accessibility. Wang, et. al [17] has used tactile audio map for accessibility. They study a technology that can detect and segment text from a map image and generate a Scalable Vector Graphics file that integrate the text and graphical information as an assistive technology. The navigation function can be useful, but it requires several supporting devices (printer, touchpad, enhancer), which would be very unpractical in emergencies. The evaluation of the system in this work is done using user experience survey. Fenandes et. al [18] suggest a slightly more advanced digital map solution for navigation over smartphone intended for people with impaired vision, but the accessibility itself as we have defined was not a part of the solution.

When it comes to emergency management, accessible maps are very limitedly discussed and evaluated. Hence the contributions of this paper are to fill the gaps both in the web accessibility inspection and the evaluation method of the maps with a person with low vision.

3 Method

In the study we have chosen two maps. One is the Disaster Alert map in Pacific Disaster Center (PDC) (see **Fig. 1**) which is used for monitoring tsunamis and earthquake including providing alerts. The other one is the #onemilliontweetmap (see **Fig. 2**) which is used for visualizing social media twitter information.

In the evaluation of the two maps, we focused on the maps themselves and the surrounding text and evaluate whether the information provided by the maps and the surrounding text is perceivable for people with visual impairments.

We have used heuristic evaluation based on WAIs10 Easy Checks [18]. In addition, an automatic tool for colour contrast checking (Colour Contrast Analyser version 2.2a) was used to determine whether the colour contrast satisfied the success criteria in WCAG 2.1.

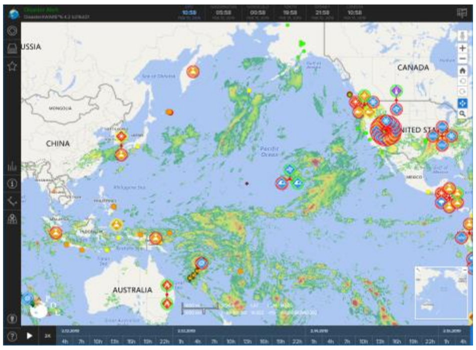


Fig. 1. PDC Disaster Alert map.

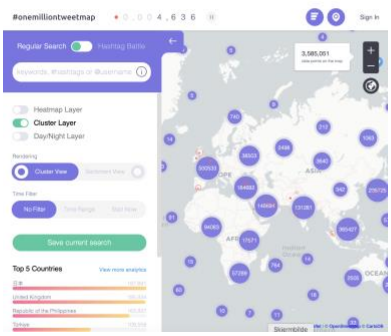


Fig. 2. #Onemilliontweetmap.

Furthermore, we have invited an expert user with low vision to test the perceivability of the maps, based on Web Content Accessibility Guidelines (WCAG) 2.1 focusing on the Perceivable principle. The expert user is category 3 on the World Health Organization's International Classification of Disease (ICD) [19]; *severe vision impairment*. The user interacted with the web sites by keyboard and a screen reader (JAWS Professional 18). All these evaluations were conducted on browser Google Chrome version 72 on an Asus laptop. In addition, the sites were tested with the browser Safari using the VoiceOver screenreader on an iPad.

The evaluation by the expert user consisted of carrying out the following two tasks:

1. On the #onemilliontweetmap (#1Million), search for #earthquake and #tsunami in the search field [20].
2. On the Disaster Alert map (PDC), find hazards in Indonesia and details about one hazard in the list [21].

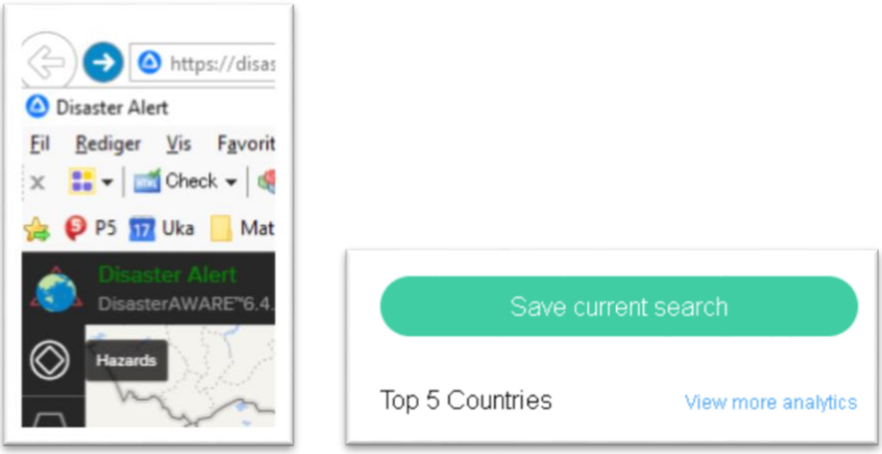
4 Results

4.1 Results from 10 Easy Checks

The 10 Easy Checks provided by the Web Accessibility Initiative at W3C [22] covers the basic accessibility barriers of main elements in a web page including page title, image description, text, interaction and general content such as multimedia and basic structure. These two web sites fail on nine out of WAI's ten checks.

Page title. The title of the application window is sufficient and briefly describes the content of the page. Both sites have well-formed page titles, but none of them reflect the last search which was done. Showing the search terms in the title could be useful to distinguish multiple simultaneous instances of the map.

Image text options. Each image should have an appropriate alternative text. There are not many images in these pages, but the main parts of the pages are graphical maps which are not accessible by screenreader. There are some image buttons, but they have no alternative text and are not coded as buttons (**Fig. 3**). The play-icon is a button and its alternative text contains the word "icon" which is unnecessary information.



(a)PDC: The Hazards button is nameless and the tooltip text is not accessible by screenreader.

(b) #1Million: The "Save current search" looks like a button or a link, but not coded as either a button or a link. It is thereby not read by screenreader.

Fig. 3. Examples of inaccessible buttons.

Headings. The heading hierarchy is important for navigating web pages. The pages evaluated have hardly any headings at all. #1Million has no headings in the main page, nor does it have headings in the pop-up windows which include many text and links (**Fig. 4**). PDC has one that looks like a heading, but it is not coded as one. This makes it very difficult to navigate in the page, you have to read the entire page top-down.

Fig. 4. #1Million: a pop-up window with a lot of details, but no heading.

Contrast ratio ("colour contrast"). Web pages should have a minimum contrast. For normal size text a contrast ration should be at least 4.5:1 (Level AA). Both sites fail WCAG 2.1 AA requirement, especially the maps. Even using high contrast configuration on the screen had no effect on the maps at all.

Contrast testing of #1Million. Nearly everything on #1Million's start page fail the WCAG requirements for colour contrasts. For example, the contrast between the sea and land is not sufficient as shown in **Error! Reference source not found.**.

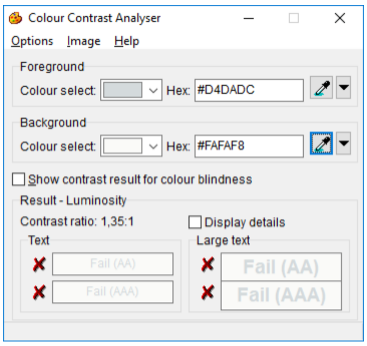


Fig. 5. The contrast between the sea- and land colour fail.

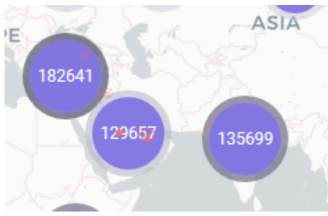


Fig. 6. Icons showing an active event.

The icons shown in **Error! Reference source not found.** are the main information carriers on the page. They are continually changing, showing that something is going on. The size of the icon, the number in the icon and the red dots all carry information. The contrast between icon and red dots fails to comply to the requirement, and the number in the icon only pass the AA requirement if a particularly big font size is used.

Contrast testing of PDC. There is a lot of information given by colour in this map and the details are quite tiny, like the icons shown in **Error! Reference source not found.**. The icons contain much orange and red colours and fail the contrast check, although the thin white frame helps a bit to distinguish these. Notice also the white text on the coloured map shown in **Error! Reference source not found.**, here the contract obviously fails. In fact, most colour checks fail at WCAG AA-level, including contrast between water and land, and also between sea/land and colours indicating weather conditions.

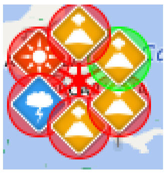


Fig. 7. Example of a mess of different icons with colour information.

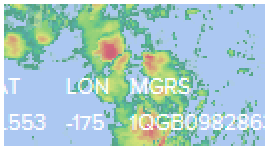


Fig. 8. Map with white text and weather information.

Magnification of the page. Both pages have separate zooming functionality in the maps. But if you have a pop-up window on the screen when zooming you lose it or the pop-up window was opening up outside the screen. Horizontal and vertical scrolling is done by dragging (click, hold and move the cursor) in the maps. Zooming in the browser affect the whole page. None of the pages can handle 200% magnification. Not all buttons, form fields and other controls are visible and usable at that zoom level. If zooming more than 200% in the #1Million page, the content will wrap, but scrolling to see all content is not possible.

Keyboard access and visual focus. We checked if the keyboard focus was visible and if it did follow a logical sequence through page elements. No keyboard traps were experienced, but the tabbing order was not always correct. It was not possible to tab to all elements on the screen. The active element did not have any visual focus. Visual focus (the blinking circles) were only used to show ongoing events/tweets in the map. The size of the map-pins (bullets) are too small according to WCAG 2.5.5 Target Size (Level AAA): The size of the target for pointer inputs should be at least 44 by 44 CSS pixels.

Forms, labels, and errors. There are no input forms in these pages except the search input. So, no error handling is necessary in these pages.

Multimedia (video, audio) options. The weather time progress is playable as a video. The buttons are not labelled correctly and there are no alternative text telling what is happening if you push the play button.

The basic structure. The requirements for checking the basic structure, are to look at the application window's images, styles and layout. On these sites use of high contrast colours on the screen didn't have any effect at all. The information was not read in the order in which they are displayed. The alternative texts on some icons/buttons do not provide sufficient information to the models. There were no clear headings at all, navigating content by using headings is not possible.

4.2 Results from Expert Testing

Navigation. The maps are only accessible by mouse, it is difficult to point at and click on the map pins (bullets), because of their small size. The maps would be easier to use if the focus was on the search functionality and not on the map. The first tab should be to the search field. The map and navigating in it by clicking in the map would make more sense to a low vision user as an extra bonus functionality, not the main functionality.

Dynamic features. The use of blinking icons or running numbers are other issues. Dynamically changing details on the pages can be confusing, and it steals attention.

Colour contrast. The contrasts are too low, the two sites do not even pass WCAG's AA. This is in particular a problem on the maps themselves. Some persons with stronger visual impairments might not even see that it is a map and be able to see the difference between sea and land. To investigate this further, we have performed automatic contrast testing with Colour Contrast Analyzer against *WCAG 1.4.3 Contrast (minimum) - level AA* and *1.4.6 Contrast (Enhanced) - level AAA*, for both of the sites. We also tried the page with high contrasts and it did not have any effect. The map is the main information-carrying part of the screen and thereby also representing a major barrier.

5 Discussion and Recommendations

As mentioned above, our main focus has been the persons who has low vision, it is interesting to see that the 10 easy checks do catch many of the barriers experienced by the expert user.

To summarise: The maps are difficult to use. The main drawbacks in these sites are the colour contrasts, the tabbing order, headings, links and size of icons, the maps not being accessible with keyboard, and the use of pop-up windows for extra information of the events.

For people with low vision, it is preferable to be able to access maps using keyboard or by voice commands rather than mouse. Navigation and zoom are two main challenges in this case. We further suggest that the map pins should be numbered so it is possible to choose them by number, or coded as links so it is possible to navigate to them by tabbing or by link lists.

Furthermore, it is essential that all information shown in the map should have text description somewhere. This is not only beneficial for people with low vision, but also for blind users who will rely on the search function, event result list and detailed information about the events when using the maps.

5.1 Search and Result List

It should be possible to do a free text search within the geographic area displayed in the map on your screen. When the search is done and the results are shown, the user should be notified. The result-lists could show a list of most important recent disasters (PDC) /events (#1Million).

It would be useful to have a list of ongoing and/or last events, for example a list of the ten most recent events. It would also be nice to have the possibility to easily choose between floods, earthquakes, volcanoes and so on. If you search for a geographical place, as an example Indonesia, both the map and disaster list should reflect this search.

An advanced search setting could be provided. For example, users should be able to search for country or disasters type within the last fifty years.

When selecting an event in the search result-list, it is important to position the cursor in the map, use a lower scale in the map if it is a small spot/town that is displayed and to show some information about the search result selected in the left sidebar.

Detailed information about the selected event should expand in the list of elements, preferably integrated in the page and not as a pop-up window, which is difficult to access with a screenreader. More detailed information could be displayed in a separate tab in the browser. In addition, a proper heading structure is also important for showing the detailed information about events.

5.2 Focus and Zoom

The application should set the focus in the middle of the map when the user is activating it, or done by positioning the cursor with a search first or by positing the cursor directly in the map. When double-clicking on the map, the entire map should be zoomed by 200% each time. Users should only zoom the map within the screen so they do not have to drag the map left or right with the cursor. Expanding the map to cover the entire screen could also be an option.

5.3 Keyboard and Voice Commands for Navigation

Users should be able to navigate in the map by addressing 3x3 named squares, by using compass directions as shortcuts such as a combination of a chosen **map key + a letter.** For example**, Map key +X** to the center square of the map and starting point for further navigation, **Map key +N** to the top row, **Map key +W** to the top left corner, **Map key +E to** the top right corner, **Map key +X** and **Map key +S** to the last row.

Another option is to navigate by using the arrow keys to tab through the squares after the user has activated the map and found the centre of it.

All navigating in the map done by the keyboard should also be available by voice commands. Users should be able to navigate by addressing it by 3x3 named squares, by using compass directions as "**go North-West**", "**go North**" and "**go North-east**" and "**go centre**".

6 Conclusion

In this paper we present the evaluation of two digital maps and the surrounding text for disaster situation focusing on the perceivability of the information to people with low vision. A mix-method approach was adopted including heuristic evaluation and expert user testing. Many accessibility barriers have been identified that can hinder users to perceive the information provided by the maps. Based on the evaluation we have made a number of recommendations to improve the perceivability, which can further enhance the accessibility of the maps.

In this paper our focus is on making maps in disaster situations accessible for people with low vision. Therefore, colour contrast, zoom, keyboard and voice commands for navigation are important. For blind users, the search function, the event result-list and detail information are more important, all information given in the map should be described by text.

Our general impression from the evaluation shows that maps used in disaster situations have not taken into considerations the accessibility principles and guidelines such as WCAG, although the accessibility of web content is covered in the discrimination laws and regulations in many countries. Access to information is essential in disaster situations and it concerns life and death. Through our study we have found that little research has focused on the evaluation of accessibility of digital maps, and in particular when it comes to maps for use in emergency management. We argue that more knowledge and research are necessary to ensure that digital maps are accessible to all users in disaster situations.

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