Investigating Accessibility on Web-based Maps

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ABSTRACT
This paper presents results of an accessibility evaluation carried out with web-based map applications. Three points of view were considered: experts on accessibility, evaluation tools and final users (partially or totally blind people). The document WCAG 2.0 (Web Content Accessibility Guidelines) provided us with guidelines for evaluation and GQM (Goal, Question and Metric) approach was used to define and set measurable goals. A number of problems was identified and none of the evaluated applications entirely meet the analyzed criteria. [1]

Categories and Subject Descriptors
D.2.0 [**Software Engineering**]: General – *Standards.*

General Terms
Design.

Keywords
Web Accessibility, WCAG 2.0, Accessibility Evaluation, Web-based Maps.

1. INTRODUCTION
According to W3C (World Wide Web Consortium) [1], web accessibility is related to the fact that people with different degrees of ability or disability can perceive, understand, navigate and interact with the web. Web accessibility promotes integration and social inclusion for disabled people, providing the use and development of computational tools through pre-established guidelines. Considering the large number of people who have some degree of disability worldwide, W3C, along with their initiative for web accessibility WAI (Accessibility Initiative) created WCAG (Web Content Accessibility Guidelines), which is a set of guidelines that support the development of accessible web content, aiming to support the social inclusion of people with disabilities [2].

There are several initiatives involving the development and research in the domain of web-based maps for blind people [3, 4, 5, 6]. Sound components, tactile maps and haptic technologies are being integrated with navigation systems in order to help the visually impaired. However, we did not find in the literature works about accessibility evaluations in this domain. Therefore, this paper aims to contribute in this area, since evaluations are essential to detect problems and possible improvements to be implemented. Our main objective is evaluating web accessibility on the maps domain based on different points of view.

This paper is organized as follows. Section 2 discusses related work; Section 3 presents the evaluations performed, the methods utilized and their findings and Section 4 presents Conclusion and Future Work.

2. RELATED WORK
Moreno [3] reports web accessibility is characterized by "developing web resources so that all people can use it, regardless of technical, physical or cognitive limitations".

In this context, Höckner et al. [4] discuss about the project AccessibleMap, an initiative of the Ministry of Transport, Innovation and Technology of Austria on making maps more accessible for people with visual impairments. The main objective of the project is to develop methods for designing web-based maps, so people with limited vision, color blindness or total blindness can use them. According to the authors, AccessibleMap presents textual description of the map providing geometric and spatial information in written format, so screen readers and Braille displays can access it. The visual optimization of the map gives options for changing colors, size of objects, and the disposal of information according to user needs. The features implemented allow to: a) configure the map, for example, selecting a specific cartographic design, depending on user preference; b) access visual descriptions of the map and c) proceed with actions on the map, such as search and zoom.

Schneider [5] presents a system for web-based maps, where the main purpose is to assist localization in the Virginia Tech buildings complex, composed of more than 100 buildings. The author argues that finding a building or a room in the institution is a problem, thus justifying the need for a system to assist in these tasks. VTQuest [5] aims to solve these problems. In addition, the system aims to help people with special needs, whereas it implements accessibility via a user interface with audio interaction. The system provides a multimodal user interface, with voice, mouse and keyboard, and the user can choose which way best fits his or her needs [5].

Kaklanis [6] discusses about HapticRiaMaps, an application of accessible maps for web adapted for the visually impaired. The application uses map representations based on data from OpenStreetMap. Thus, all data from a specific area requested by the user, such as roads, street names, markers and other items, are imported in XML format. A 2D map is then created according to the information received with the structure of the streets and finally a pseudo-3D map is generated [6]. The user interaction with the application HapticRiaMaps is via assistive technologies of the haptic type, i.e., those that integrate the user to the

application through touch. Therefore, it is necessary to handle the 3D map generated.

3. EVALUATION OF WEB ACCESSIBILITY ON THE MAPS DOMAIN

According to Aizpurua et al. [7], accessibility guidelines usually present generic accessibility tests, such as: automated tests, manual tests and semi-automatic tests or involving generic problems. The authors define the tests as: a) automated testing: a validation test that usually does not need or require to be done by a person and can be performed by a tool; b) manual or semi-automatic testing: requires the human component. These evaluations search for problems associated with code fragments that implement the website and c) generic problems: human presence required for evaluation because the item being evaluated cannot be associated with any code fragment. Brajnik [8] performs a comparative test of different evaluation methods for web accessibility, highlighting the importance of using more than one form of assessment during the accessibility evaluation process.

This paper presents in the next subsections the following accessibility evaluations: automated evaluation of accessibility by making use of evaluative tools; non-automatic accessibility evaluation with experts and non-automatic accessibility evaluation with end users.

The following evaluations analyzed items from WCAG 2.0 – Level A, the most basic level of the document (AA and AAA levels are composed of more complex accessibility guidelines). Level A presents itself in four different layers of guidance: principles, guidelines, success criteria and sufficient and advisory techniques. The principles provide the foundation for web accessibility: perceivable, operable, understandable, and robust. There are twelve guidelines under these principles, providing the basic goals that authors should work toward in order to make content more accessible.

For each guideline, WCAG 2.0 provides testable Success Criteria, in twenty-five items on its Level A. These Success Criteria are the ones used in the following evaluations. To facilitate implementation of guidelines it was also documented a wide variety of techniques.

3.1 Expert-Based Evaluation

The expert-based evaluation is a way to manually determine the existence of accessibility in an application [8].

According to Brajnik [8], the evaluation based on experts is one of the most used methods of assessment, being characterized as "an analytical method based on the opinions of evaluators, producing failures (in terms of checkpoints and success criteria violated) and pointing out defects and solutions".

3.1.1 GQM Approach: Goal-Question-Metric

There are several mechanisms known in the literature that can help define and set measurable goals in a particular process or activity, such as the Goals - Questions - Metrics (GQM) paradigm that proposes the definition, implementation, analysis and improvement of the processes [9]. According to Basili [9], measurements must be defined according to some specific objectives, in order to achieve effectiveness.

For this assessment based on experts, the following goals, questions and metrics were proposed:

• **Goal1**: Analyze web-based mapping systems, in terms of accessibility, from the point of view of experts in web accessibility.

• **Question1**: Which Success Criteria from WCAG 2.0 - Level A - are implemented by the web systems evaluated?

• **Question2**: What level of compliance in WCAG 2.0 each web system can be classified?

• **Metric1**: Sum of Success Criteria that are not implemented by the systems, whereas the option given by experts in the questionnaire is “It does not meet”. This metric serves the Question1 and shall be applied in each one of the analyzed systems.

3.1.2 ISO/IEC 25040

The ISO/IEC 25040 [10] standard provides a guide and a reference model in software evaluation, in order to provide generic requirements for specifications and reviews of software quality. Also, according to the standard, the assessment process is the basis for evaluation of software product quality for different purposes and approaches. Thus, the process can be used to assess the quality of software already in use, development, or even in a pre-development stage.

The following steps, defined in ISO/IEC 25040 [10], were used: establish evaluation requirements, specify the evaluation, design the evaluation, execute the evaluation and conclude the evaluation.

Nielsen and Landauer [12] proposed that usability evaluation should not occur on systems making use of elaborated tests or even involving a large amount of test users. Rather, the authors demonstrated in their study that the majority of usability problems found on tests require just a few users. The authors also demonstrated that an ideal test case is based on applying the highest possible number of simple tests, involving an average of five to eight users. Thus, based on ISO/IEC 25040 and Nielsen and Landauer statements, the accessibility evaluation based on experts considered eight experts.

The selection of the experts was based on their background, knowledge and experience in the subject of Web Accessibility. At first, it was created a list of possible candidates and, after that, the selection proceeded based on the following criteria: academic degree, experience with web accessibility and development experience. At the end of the process, eight experts were selected. All of them with some experience or knowledge on web accessibility and three or more years working with software development; one expert about to finish college; two finishing Master’s degree; three with Master’s degree and one with doctoral degree. The selection of websites to be analyzed was based on: web applications belonging to the domain of maps, since they were widely used. Five web systems belonging to the domain of maps were chosen for evaluation with experts:

- Google Maps - https://maps.google.com.br/
- OpenStreetMap - http://www.openstreetmap.org/
- Yahoo! Maps - http://maps.yahoo.com/
- Bing Maps - http://br.bing.com/maps/
- MapRequest - http://www.mapquest.com/

The form applied presented the twenty-five success criteria from WCAG 2.0 Level A, so that the answer to each question

consisted of an alternative to be chosen among: a) fully meets; b) does not meet; c) does not apply to the site and d) partially meets.

The evaluation process was not conducted in the presence of the researcher. A total of eight evaluations were performed. Results of each success criteria for each web system according to experts point of view are presented in Table 1.

The experts were free to choose the most convenient method to be applied in the evaluation and they were given the choice to make use of screen readers or other tools that could contribute to the evaluation. The assessment occurred during October-November 2013. A checklist form containing all the Success Criteria of WCAG 2.0 - Level A - was given to the selected experts.

The experts analyzed the five selected websites, searching for some infringement of the Success Criteria. Item by item, the experts had to answer if the Success Criteria was fulfilled on that specific website.

For this, they could just try accessing a specific functionality and see the result, or analyzing the code searching for some problem, or using a screen reader to see if a specific element couldn't be accessed.

The results were tabulated in order to identify the Success Criteria being violated. No significant troubles were reported by the experts in understanding the Success Criteria, and no mishaps of any kind or adverse situation that may compromise the results occurred.

3.1.3 Discussion

Table 1 presents the Success Criteria not met in the eight performed evaluations, and provides results to **Metric1** and **Question1**, defined in Section 3.1.1.

Figure 1 presents graphs for analysis of individual systems. It is possible to observe that in all websites analyzed there are Criteria Success not met.

Table 1. Success Criteria not met.

Success Criteria	Google Maps	OpenStreet Map	Yahoo! Maps	Bing Maps	Map Request
1.1.1	X	X		X	
1.2.1	X				
1.2.2	X				
1.2.3					
1.3.1	X	X	X	X	X
1.3.2	X				
1.3.3	X		X	X	
1.4.1	X		X	X	
1.4.2					
2.1.1	X		X		X
2.1.2	X		X		X
2.2.1					
2.2.2					
2.3.1					
2.4.1	X	X	X	X	
2.4.2	X				
2.4.3	X		X		
2.4.4	X				X
3.1.1	X			X	
3.2.1					
3.2.2	X				
3.3.1	X	X	X	X	
3.3.2	X			X	
4.1.1	X			X	
4.1.2				X	
Total	**18**	**4**	**8**	**10**	**4**

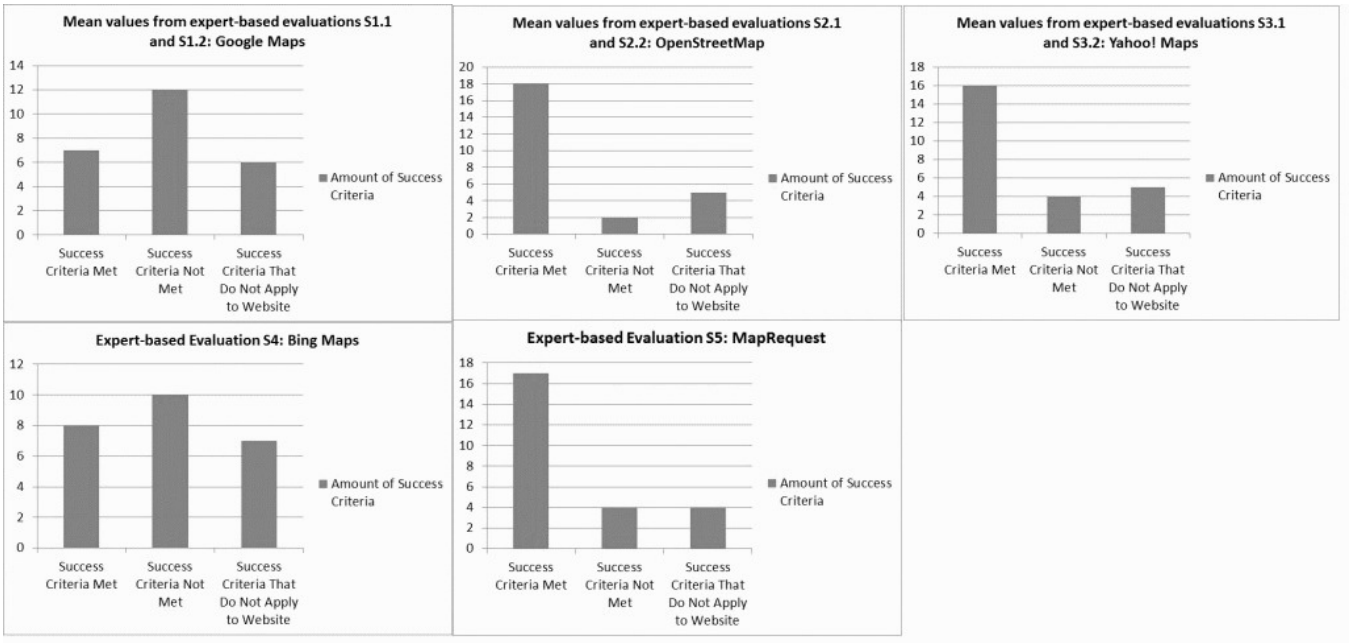

Figure 1. Individual Analysis Results of Websites.

According to Table 1, on success criterion 1.3.1, no evaluation returned positive results, indicating that information regarding the content visually presented in the applications is not available to users. That is, the information is not accessible in a way that it reaches different users with different needs.

Four out of five websites analyzed had problems in criteria 2.4.1 and 3.3.1. According to Criterion 2.4.1, a mechanism should be available to bypass blocks of content that are repeated on multiple web pages; when this Success Criterion is not satisfied, it may be difficult for people with some disabilities to quickly and easily reach the main content of a web page [2]. Criterion 3.3.1 deals with textual corrections of errors in user inputs: in this kind of error, simple typos, for example, can preclude the user from accessing correctly the functionality. These results illustrate the need to implement mechanisms that meet the Success Criteria that weren't fulfilled.

In order to answer **Question2** in Section 3.1.1, it is possible to say that, according to this evaluation by experts, none of the assessed websites implement Level A defined by WCAG 2.0, since several Success Criteria at this level are not contemplated.

3.2 Tool-Based Evaluation

Bach, Leal and Silveira [13] emphasize the importance of using automatic tools on web accessibility assessment, although they discuss that assessments should not be limited to such, since automated assessment tools do not consider aspects of human interaction. Next subsections present more details about the tool-based evaluation.

3.2.1 Tools

Five tools were used in this evaluation. The AChecker tool [14] evaluates different sets of guidelines. The Total Validator tool [15] performs validation tests in HTML files in various WCAG guidelines and check for broken links and spelling problems in different languages. The CynthiaSays tool [16] also makes automated website analysis, including the three levels of WCAG 2.0 and Section 508. The TAW tool [17] provides the WCAG 2.0 Analyzer tool, which also makes the analysis of accessibility items provided by WCAG 2.0 in its three different levels. Finally, the AccessMonitor tool [18], which provides analysis on three levels of WCAG 2.0, was also used in this evaluation. The tool selection was based on the following criteria: to perform analysis on WCAG 2.0 - Level A and provide detailed analysis report.

3.2.2 GQM Approach: Goal-Question-Metric

For this tool-based assessment, the following goals, questions and metrics were proposed:

• **Goal1**: Analyze web-based mapping systems, in terms of accessibility by making use of automatic evaluation tools.

• **Question1**: What compliance level of WCAG 2.0 accessibility each site can be classified, according to automatic evaluation tools?

• **Metric1**: Sum of Success Criteria that are not implemented by systems which analysis returns as result "not implemented", "not met", or any similar nomenclature, which expresses that the success criterion has not been met. This metric helps to answer the Question1, defined in this section.

3.2.3 ISO/IEC 25040 Standard

This tool-based evaluation also used the ISO/IEC 25040 standard in order to support the activities of the evaluation. Thus, analogous to the experts' evaluation, steps in conducting the evaluation were defined following ISO/IEC 25040 standards [10], such as establish evaluation requirements, specify the evaluation, design the evaluation, execute the evaluation and conclude the evaluation.

The evaluation consists of an automatic analysis considering web-based mapping systems and previously selected tools. Web systems selected for the evaluation are the same ones from experts' evaluation. The tool-based evaluation was performed between November and December 2013, so that after the websites to be analyzed and the tools to be used were selected, the tools analysis was executed, generating a report for each analysis on the items investigated. The criteria used in the evaluation are the Success Criteria from WCAG 2.0 - Level A, so that each tool internally runs a checklist, checking if the Success Criteria are implemented or not by the application. Once the tools performed the tests on the selected websites, the results were tabulated and it was possible to determine which application had the biggest number of error and Success Criteria not met. Results are shown in Figure 2.

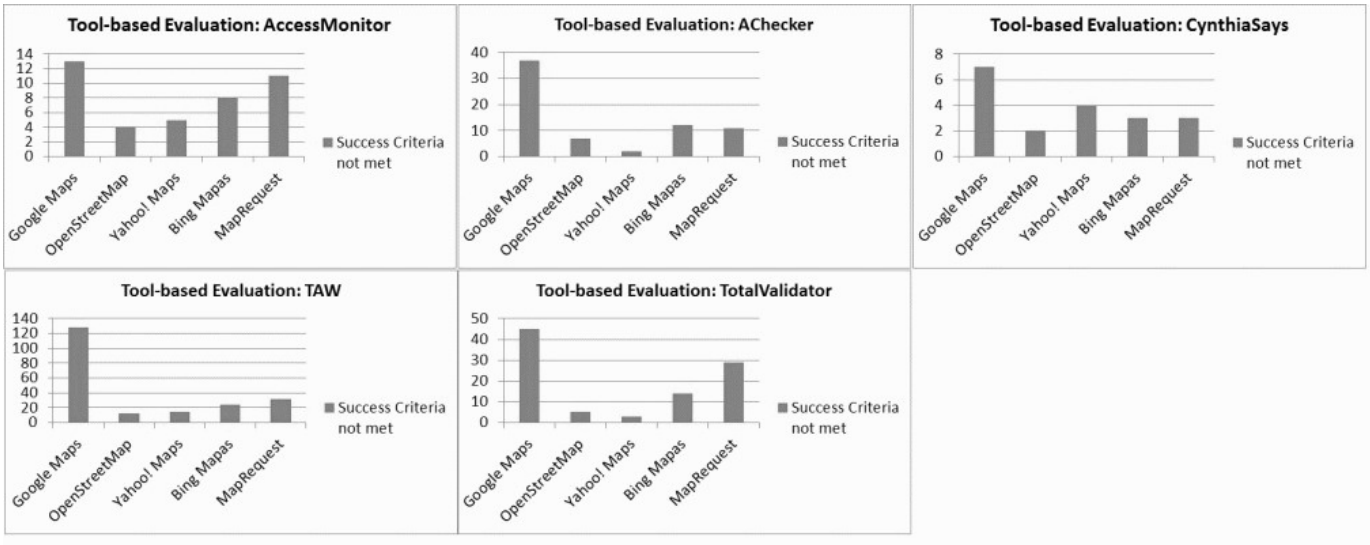

Figure 2. Tool-based evaluation results.

3.2.4 Discussion

In Figure 2 the total of errors found by the tools in web systems is presented. From these results, we observed that all the websites analyzed by the tools contain errors and Success Criteria not met, indicating accessibility problems within their elements and features. Considering that for all web systems the tools detected Success Criteria errors, it is possible to conclude, in response to the **Question1** from Section 3.2.2, that the websites are not in the Level A of the WCAG 2.0 guideline.

The tool-based evaluation aimed to identify success criteria that were not properly implemented by the analyzed websites. Five tools and five different websites were selected for the task, so that each tool selected tests performed on each of these websites, totaling twenty-five tests.

The first tool to proceed with the evaluations was AccessMonitor. It is an automatic validator that checks the implementation of accessibility guidelines in a website.

Table 2. Accessibility Evaluation from AccessMonitor tool – Success Criteria not met.

Success Criteria	Google Maps	OpenStreet Map	Yahoo! Maps	Bing Mapas	Map Request
1.1.1	X	X	X	X	X
1.3.1	X	X	X	X	X
2.1.1	X				
2.1.3	X				
2.4.1	X	X	X	X	X
2.4.4	X				X
3.1.1	X			X	
3.2.2	X				X
3.3.2	X	X		X	X
4.1.1	X	X	X	X	X
4.1.2	X	X		X	X
Total of criteria not met	11	6	4	7	8

AccessMonitor offers the options to enter a URL for analysis, load a HTML file or analyze only a fragment. It offers analyzes of WCAG 1.0 and WCAG 2.0 in the three levels of compliance and validation in CSS and HTML code.

In this evaluation, the URL of the websites were submited on the tool and the analysis option was WCAG 2.0. The evaluation results provided by AccessMonitor tool are shown in Table 2. It presents also a field with the total of criteria not met

The second assessment used AChecker tool. This tool provides evaluations from guidelines Section 508, WCAG 2.0 in its three compliance levels, BITV 1.0 and Stanca Act. It provides the options of evaluating HTML files, code snippets, or submit an URL. The tool also provides web and downloadable reports.

The results of the analysis of AChecker tool are displayed in Table 3, which shows the success criteria not met, according to the evaluation tool. The third assessment used CynthiaSays tool. Table 4 shows the analysis results of CynthiaSays evaluations.

Table 3. Accessibility Evaluation from AChecker tool – Success Criteria not met.

Success Criteria	Google Maps	OpenStreet Map	Yahoo! Maps	Bing Mapas	Map Request
1.1.1	X			X	X
1.3.1	X	X		X	X
2.1.1	X				
2.4.4		X	X	X	X
3.1.1	X			X	
3.3.2	X	X	X	X	X
4.1.1	X				
Total of criteria not met	6	3	2	5	4

Table 4. Accessibility Evaluation from CynthiaSays tool – Success Criteria not met

Success Criteria	Google Maps	OpenStreet Map	Yahoo! Maps	Bing Mapas	Map Request
1.1.1	X	X	X	X	X
1.3.1	X	X	X	X	X
2.4.1	X				
3.1.1	X			X	
3.2.2	X				
3.3.2	X				
3.2.2					X
3.3.2			X		
4.1.2	X		X		
Total of criteria not met	7	2	4	3	3

The following evaluation was performed with TAW tool. Table 5 shows the analysis results with TAW tool.

Table 5. Accessibility Evaluation from TAW tool – Success Criteria not met.

Success Criteria	Google Maps	OpenStreet Map	Yahoo! Maps	Bing Mapas	Map Request
1.1.1	X	X	X	X	X
1.3.1	X	X	X	X	X
2.2.1	X				
2.4.4	X	X	X	X	X
3.1.1	X				
3.2.2	X				X
3.3.2	X	X	X	X	X
4.1.1	X		X	X	X
4.1.2	X	X	X	X	X
Total of criteria not met	9	5	6	6	7
Errors reported	128	12	14	24	32

The fifth and last analysis used TotalValidator tool. This tool makes the following analysis: HTML (including version 5.0), XHTML, CSS, WCAG 1.0 and 2.0 (levels A, AA and AAA), Section 508, spelling errors in six languages and broken links. It is available either as a plug-in for browsers, as in the form of downloadable local analysis of a website. Table 6 shows the evaluation results performed by TotalValidator tool.

Table 6. Accessibility Evaluation from TotalValidator tool – Success Criteria not met.

Success Criteria	Google Maps	Open StreetMap	Yahoo! Maps	Bing Mapas	Map Request
1.1.1	X	X	X	X	X
1.3.1	X	X	X	X	X
3.2.2	X				
4.1.1	X				
4.1.2	X				
Total of criteria not met	5	2	2	2	2

3.3 End-User Evaluation

According to Brajniki [8], there are many benefits of evaluation with users, such as the ability to identify usability problems that often cannot be found with automatic or expert reviews.

3.3.1 GQM Approach: Goal-Question-Metric

For this end-user assessment, the following goals, questions and metrics were proposed:

• **Goal1**: Analyze a web-based map, in terms of accessibility, utilizing end users.

• **Question1**: What features, among those offered by the application, can be accessed by visually impaired users?

• **Question2**: What features the users could find any barrier to access, precluding the use of the functionality?

• **Question3**: What level of ease of access and level of success users can develop the list of proposed activities?

• **Metric1**: Percentage of users who successfully accessed the functionalities analyzed, regardless of the degree of difficulty or degree of success in using them. This metric is applied to each proposed activity to the group of end users, and is calculated by (1):

$$S = \frac{\text{sum of successfull access in a functionality}}{\text{amount of evaluations performed}} x100 \quad (1)$$

Through analysis of Metric1, it is possible to answer **Question1** and **Question2** from this section.

• **Metric2**: Necessary time to complete the proposed activities. This metric consists of the measured time that each user in each activity utilized to perform the asked task. The times are grouped and the average time for each activity is calculated, according to (2):

$$S = \frac{\text{sum of the time spent by each user in the activity}}{\text{amount of evaluations performed}} \quad (2)$$

This metric should be applied for each activity and aims to answer **Question3**, defined in this Section.

• **Metric3**: Average level of difficulty encountered by users to complete the tasks. The following levels of difficulty were defined to classify the activities: a) fully achieved, without difficulties; b) fully achieved, with difficulties; c) partially achieved; d) not achieved. For this metric, each activity at each assessment is classified into one of the items above, so that in the end, an arithmetic average of the assessments can be made. In order to be possible to calculate this average, numerical values were assigned to each item, as follow:

a) Fully achieved, without difficulties: 50 points;

b) Fully achieved, with difficulties: 30 points;

c) Partially achieved: 10 points;

d) Not achieved: 0 points;

The **Metric3** can be calculated by (3):

$$S = \frac{\text{sum of the points from the activity in all evaluations}}{\text{amount of evaluations performed}} \quad (3)$$

The measure also seeks to assist in the resolution of **Question3**, defined in the present section.

3.3.2 ISO/IEC 25040 Standard

In a similar way to the previous two assessments, the ISO/IEC 25040 Standard [10] was used in this evaluation to define the different steps present in an evaluation.

The evaluation based on end-users took place during the period of February-March 2014, with visually impaired users from Institute for Blind Florivaldo Vargas - ISMAC, located in Campo Grande, state of Mato Grosso do Sul, Brazil.

The website selected was Google Maps (http://maps.google.com) due to its ease of use, popularity, and the fact that, among the websites analyzed in the other two evaluations, it contains the highest average number of accesses, according to TrafficEstimate tool [11]. It was created a list of activities that could evaluate the functionality in terms of accessibility.

These activities have been prepared considering all the websites analyzed in the other two evaluations presented in this paper. Thus, the activities, even if applied only to one website, are covering features that are common to this application domain.

The selection of users to participate in the evaluation was made according to the following criteria: a) at least 18 years old; b) be partially or totally blind and c) know how to operate a computer.

The evaluation took place individually, being performed by the visual impaired and accompanied only by the researcher. A total of eight participants could evaluate google maps. Each activity was timed and classified, being performed by the participant with the help of a screen reader.

The activities were classified by the users in order to be possible to identify the ones with accessibility problems. The possible classification options are: (A) fully achieved, without difficulties; (B) fully achieved, with difficulty; (C) partially achieved; and (D) not achieved. The activities description follows:

- Activity 1: lookup for an address, using the search field;
- Activity 2: find out the name of a neighborhood with a supplied address;
- Activity 3: switch between "Map" and "Satellite" views, using the website tools;
- Activity 4: access photos of a given address, and read their descriptions;
- Activity 5: find the function buttons to "get directions" and "my places";
- Activity 6: use function "get directions" with start and end addresses;
- Activity 7: use function “avoiding tolls” on a chosen path in a given address;
- Activity 8: change the path to “walking”;
- Activity 9: use the zoom feature on the map.

Table 7 presents the results obtained by the eight visually impaired users on the evaluation.

Table 7. End-user evaluation – Classification of Activities.

Activity	U1	U2	U3	U4	U5	U6	U7	U8
Activity 1	A	A	A	A	A	B	A	A
Activity 2	A	B	A	A	D	A	A	A
Activity 3	A	A	D	B	D	B	D	D
Activity 4	D	D	D	D	D	D	D	D
Activity 5	A	A	A	A	A	A	A	A
Activity 6	A	A	A	A	B	A	A	A
Activity 7	A	A	A	A	A	A	A	A
Activity 8	A	A	A	B	A	A	A	A
Activity 9	D	D	D	D	D	D	D	D

Through analysis of Table 7, is possible to obtain the percentage of users who successfully accessed the functionalities, which is **Metric1**, described in Section 3.3.1.

- Activity 1: accessed successfully in eight out of eight evaluations: $8/8 \times 100 = 100\%$
- Activity 2: accessed successfully in seven out of eight evaluations: $7/8 \times 100 = 87.5\%$
- Activity 3: accessed successfully in four out of eight evaluations: $4/8 \times 100 = 50\%$
- Activity 4: accessed successfully in zero out of eight evaluations: $0/8 \times 100 = 0\%$
- Activity 5: accessed successfully in eight out of eight evaluations: $8/8 \times 100 = 100\%$
- Activity 6: accessed successfully in eight out of eight evaluations: $8/8 \times 100 = 100\%$
- Activity 7: accessed successfully in eight out of eight evaluations: $8/8 \times 100 = 100\%$
- Activity 8: accessed successfully in eight out of eight evaluations: $8/8 \times 100 = 100\%$
- Activity 9: accessed successfully in zero out of eight evaluations: $0/8 \times 100 = 0\%$

3.3.3 Discussion

Analyzing the previous data, it is possible to answer the questions "Question1" and "Question2", from the Section 3.3.1, as follows:

- From a list of activities involving the common features of web-based mapping systems and one application:

Question1: Which of these features visually impaired users can access?

Answer1: The features used in Activities 1, 5, 6, 7 and 8 had no problems in access, while Activity 2 could not be accessed in one evaluation. The Activity 3 presented accessibility problems in four out of eight evaluations performed.

Question2: On what activities the users have found any access barrier, precluding the use of the functionality?

Answer2: Activities 2, 3 4 and 9. These barriers prevented the users, during the evaluations performed, to use the features affected, making it impossible to them to execute the asked task.

In Activity 2, only one user was unable to proceed with the access. In Activity 3, four evaluations resulted in unsuccessful access. In Activities 4 and 9, not a single visually impaired user completed the tasks, indicating possible severe accessibility problems.

The **Metric2** presented in Section 3.3.1, addresses the time required that each user used to complete the proposed activities from the list. Since each activity is designed to be similar, it is possible to identify the activities where users had more difficulties in its execution through the analysis of the spent time. Once obtained the evaluations times, the arithmetic mean equation (2) defined in Section 3.3.1 is utilized to obtain the average time required to complete each activity individually.

Once an activity took more time than others, it is possible to say that this activity may have some element that presents accessibility issues, being necessary further analysis. For each activity, it was given a limit of ten minutes to completion. Table 8 shows the execution times of activities obtained during the evaluations.

Table 8. End-user evaluation: time spent in the execution of activities

Activity	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	Total per Activity
Activity 1	3min25s.	3min51s	3min18s	2min43s	5min19s	3min18s	4min19s	3min56s	**30min09s**
Activity 2	2min28s	4min08s	2min43s	2min33s	10min	2min19s	3min38s	3min39s	**31min28s**
Activity 3	5min33s	3min52s	10min	3min44s	10min	5min02s	10min	10min	**58min11s**
Activity 4	10min	10min	10min	10min	10min	10min	10min	10min	**01h20min**
Activity 5	2min15s	2min47s	2min23s	1min19s	2min41s	1min32s	1min21s	2min02s	**16min20s**
Activity 6	3min11s	3min55s	2min58s	2min31s	4min21s	2min49s	2min36s	5min38s	**27min59s**
Activity 7	2min13s	2min22s	1min45s	1min19s	2min19s	1min25s	1min21s	2min53s	**15min37s**
Activity 8	2min24s	1min55s	1min53s	1min32s	1min21s	1min43s	1min42	2min59s	**15min29s**
Activity 9	10min	10min	10min	10min	10min	10min	10min	10min	**1h20min**
Total per evaluation:	**41min29s**	**42min50s**	**45min00s**	**35min41s**	**56min01s**	**38min08s**	**44min57s**	**51min07s**	

The total time spent per activity was divided by eight, which is the number of evaluations performed. Table 9 shows the average time spent on activities:

Table 9. Average time spent on activities.

Activity	Average activity time
Activity 1	03min46s
Activity 2	03min56s
Activity 3	07min16s
Activity 4	10min
Activity 5	02min02s
Activity 6	03min30s
Activity 7	01min57s
Activity 8	01min56s
Activity 9	10min00s

It is possible to conclude, from the analysis on the average time presented in Table 9 that activities 4 and 9 might have accessibility problems, once the blind users that tried to accomplish the task reached the time limit – 10 minutes – and failed to fulfill them.

Activity 3 also indicates it might have accessibility problems, since the average time for its execution is high, when compared to the other activities. These detected problems are detailed previously on this Section, answering **Question2**.

Metric3, as defined in Section 3.3.1, aims to find the level of difficulty encountered by the users to complete the list of activities.

The sum of the points of each activity in the evaluations can be obtained by assigning scores to each classification, as previously presented. These values indicate and evidence which activities the users had troubles to fulfill or not. Table 10 shows the score of the activities.

Table 10. End-user Evaluation: Activities and its scores.

Activity	U1	U2	U3	U4	U5	U6	U7	U8	Total
Act. 1	50	50	50	50	50	30	50	50	**380**
Act. 2	50	30	50	50	0	50	50	50	**330**
Act. 3	50	50	0	30	0	30	0	0	**160**
Act. 4	0	0	0	0	0	0	0	0	**0**
Act. 5	50	50	50	50	50	50	50	50	**400**
Act. 6	50	50	50	50	30	50	50	50	**380**
Act. 7	50	50	50	50	50	50	50	50	**400**
Act. 8	50	50	50	30	50	50	50	50	**380**
Act. 9	0	0	0	0	0	0	0	0	**0**

Applying the equation (3) defined in Section 3.3.1, it is possible to reclassify activities based on their average score, using the criteria specified on **Metric3** as it follows on Table 11.

Table 11. Average classification of the activities.

Activity	Average score	Average Classification
Activity 1	47.5 points	fully achieved, without difficulties
Activity 2	41.25 points	fully achieved, without difficulties
Activity 3	20 points	partially achieved
Activity 4	0 points	not achieved
Activity 5	50 points	fully achieved, without difficulties
Activity 6	47.5 points	fully achieved, without difficulties
Activity 7	50 points	fully achieved, without difficulties
Activity 8	47.5 points	fully achieved, without difficulties
Activity 9	0 points	not achieved

The answer to Question3, defined in Section 3.3.1, follows:

Question3: What level of ease of access and level of success users can develop the list of proposed activities?

Answer3: Most of the proposed activities could not only be accessed but also completed successfully and without difficulty by visually impaired users. Nine activities were proposed to the users, and in six of them (Activities 1, 2, 5, 6, 7 and 8) we did not observe significant problems both in terms of accessibility and performing activities. In Activity 3, there were significant access problems: according to Table 7, 50% of visually impaired users could not access the information necessary to complete the task, whilst 25% were able to complete the task, but with difficulty, classifying the activity, on average, as "partially achieved". It is also possible to identify in **Metric2** that Activity 3 showed high average time to perform, indicating accessibility problems. In the two remaining activities (Activities 4 and 9) there were significant problems of access, so that none of the users in any of the evaluations have successfully accessed the elements of the website and got to complete the activities. These activities achieved the maximum execution time, as defined in **Metric2**, indicating that there were no success on the tasks, in terms of accessibility.

4. CONCLUSION AND FUTURE WORK

According to the assessments performed, it is possible to observe the existence of problems regarding the accessibility on the domain of web-based map applications. In the expert-based evaluation, there are several Success Criteria not met, making it impossible for the visually impaired user to perform specific tasks. None of the websites examined by experts reached the Level A of WCAG 2.0 conformance, since several Success Criteria for this level have not been met. All websites analyzed presented accessibility problems in the tool-based evaluation. Tools used for the automatic evaluation performed tests on the same websites used in the expert-based evaluation, aiming to identify Success Criteria that were not being met. It was detected that Google Maps showed a greater number of errors than other websites, due to Success Criteria not implemented. Moreover, Success Criteria not met were found in all analyzed websites and according to the evaluation tools, the websites did not reach Level A of WCAG 2.0.

In the end-user evaluation, it was found that elements responsible for zooming the map were not accessible via keyboard, so the screen reader could not read these features to the users. Other minor problems and difficulties observed by the researcher in this end-user evaluation were: navigability between fields; edit text fields without proper description; changing the visualization mode of the map; option "photos" is not properly described; elements with no indication of their type/functionality; possibility of using keyboard commands not clearly informed to the user. From these access barriers encountered in the user-based evaluation, which violates several WCAG 2.0 Success Criteria, it is possible to conclude that the web systems cannot be considered Level A in this guideline.

The evaluations presented in this paper identified several accessibility problems in the websites analyzed due to non-implementation of the Success Criteria defined in WCAG - Level A. These problems preclude the user that is in a specific condition to have full access to the tool functionality, making it impossible to make proper use of the technological tool offered. The results obtained in this study provide basis for future research and implementation in the area of the problems identified.

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