Accessibility as a Quality Requirement: Geographic Information Systems on the Web

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ABSTRACT
Web applications enable users with different profiles and necessities to access information from diversified locations and with different access tools. Besides the aspects that have already been discussed in works from the Software Quality domain, the accessibility to information and the Internet flexibility have been considered more and more important. Thus, considering accessibility as an important quality attribute for Web applications, in this paper we investigate the subject considering the context of Geographic Information Systems on the Web. Preliminary results of accessibility evaluation on some WebGIS applications show that this domain presents several challenges to be coped with in the design of their user interfaces.

Keywords

Accessibility, Quality, Web GIS Applications.

INTRODUCTION
The Internet has facilitated access and information sharing in a worldwide scale, starting with the hypermedia – a combination of multimedia (texts, sound, videos, cartoons, etc) and hypertexts (links in a contextual form that allow access to other resources, to organize and to structure information). They can be used to create interfaces that facilitate interaction between users and system functionality.

Geographic Information Systems (GIS) are software aimed at the manipulation, management and visualization of geo-referenced data. The term geo-referenced indicates data that are explicitly linked to geographic coordinates. Geographic data are defined from two components: position (location on Earth) and non-spatial attributes (descriptive characteristics). For example, a land has non-spatial attributes, such as the name of the owner or purchase value.

The use of GIS from the Web has increased in what we call the WebGIS. The WebGIS application is a system that makes geographic information available on the Web through geographic representations and often allows map interaction, as *zoom, pan* (movement), access to descriptive information related to maps etc. Examples of Web GIS application include those available in the Agritempo site [1], and in the FUNCEME site – Ceara's Weather Forecast Foundation and Hydric Resources [8], both related to the agriculture domain, presenting also weather forecast information, agriculture production in different regions, etc. Mapquest [12] and Apontador [2] are also other Web GIS application examples, but related to the urban domain; they present information about routes between cities, commercial establishments, hospitals close to a specific place, real time highway video images, etc.

In a wide sense, the interface is the part of a computer system that is perceived by the user, through which he/she communicates with the system to accomplish tasks in specific domains. It can be a motivation factor or it can be a decisive factor in the rejection of the system. An efficient system, considered by its functional structure, should have an interface that positively influences its quality in use. Quality in use is a factor relative to the user; therefore, the interface design demands more attention to the flexibility of the interaction and the information access, i.e., the accessibility as a way of attending the necessity of different users. This necessity concerns information and interaction access, technologies used (ex. web-browsers, hardware devices), the users' physical and cognitive characteristics (ex. mobility, visual and audio acuity, information understanding), the conditions offered by the environment (ex. space for approach and use, light and noise).

In the Web scenario, the differences between users are pronounced, due to the different situations they have in using its applications. This factor needs to be examined in the development of Web GIS applications, considering that the nature of geographic information naturally valorizes the visual presentation of information. Offering alternatives to this type of representation means amplifying the geographic information, making it viable by adequate use of the hypermedia and by the designers' orientation for the web-accessibility standards.

In quality models that valorize quality in use, as ISO 14598-1 [1] and ISO 9241 [11], no explicit attention has

been given to accessibility. Our goal in this work is to present accessibility as an attribute of quality, which also has to be considered in the interface design of Web GIS applications. We discuss the subject through a case study that involves preliminary accessibility evaluation of applications from the Geographic Information System domain in the Web, selected from Schmiguel *et al* [17].

This paper is organized in the following way: Section 2 presents a brief literature overview on quality in the use of software and its relation to accessibility and accessibility in Web GIS applications. Section 3 presents the case study discussing a preliminary accessibility evaluation in Web GIS applications and its main results. Section 4 presents the final considerations regarding accessibility as a quality requirement for the Web GIS application.

QUALITY IN SOFTWARE USE AND ACCESSIBILITY

People with different interests on a product have different views about quality concepts [6] and on how quality should be reached in the software production process [3,4]. Most of these approaches are not related to quality perceived by the user, which is considered to be an intrinsically imprecise judgment made on the quality of a product [3].

However, some quality models have also considered quality from the users' point of view. The ISO 9126 [9] model, for example, identifies six characteristics for a software product: functionality, reliability, usability, efficiency, maintenance and portability. In this model, the usability characteristic is related to the understanding, learning and operation capabilities in the use of a software product. ISO DIS 14598-1 [10] defines external quality as those related to the explicit and implicit necessities of a product when used under specific conditions; it also defines quality in use as effectiveness, efficiency and satisfaction from which specific users can reach specific objectives in specific environments.

Thus, software quality can be understood from a set of attributes that a product must have so that it complies with the users' necessities. When developing a software product, the aim is to reach the necessary and sufficient quality for each specific context of use, when the product is delivered and really used [5]. For this reason it is necessary to identify the necessary quality characteristics for a software product and specify to what extent these characteristics need to be reached to satisfy the users' needs.

In the Web, clarity and usability are features generally demanded by the users [6]. Accessibility has been more and more understood as a necessary condition to usability; if a software is not accessible it won't be considered effective, efficient or pleasant to someone [7].

Aiming at guaranteeing the usability in the design for the Web, Nielsen [14] established some basic principles that should be considered: clarity of the information architecture, navigation facility, simplicity, content relevance, consistency, time tolerance and focus on users. This last one, which summarizes the formers, has a direct relation to accessibility, characterized by flexibility that should be offered to the interaction and to the access of available information in Web sites. Without this flexibility users with special needs (ex. the elderly, people with disabilities, children, etc) can have their access to the Web systems disrupted. The usability of a Web application, therefore, depends on the accessibility factors.

Web GIS applications represent a challenge in terms of accessibility. Frequently these applications use images (maps) to show geographic information to the users. Another feature that can be highlighted is the use of colors to code information transmitted in maps (ex. to show different values for temperature, vegetation, agricultural production, etc). If alternatives are not offered to these representations, many users will have limited access to the geographic information. Information shown in maps, for instance, can be made more flexible by the use of descriptive texts, data tables and graphics that offer other equivalent information.

The use of textual descriptions is necessary for users of textual web-browser (ex. Lynx), users who are unable to carry the image in their web-browser, and screen reader users (ex. blind people, people with law vision). These textual descriptions can be offered by text alternative to images (ALT attribute for images presented at HTML), but they are not always sufficient due to the information complexity usually presented in maps. This way, a description corresponding to graphical elements can add information to the map helping regular users in interpreting the information offered.

Although data tables can be offered as alternatives to maps and be useful to users who may have difficulties in distinguishing colors (ex. colored blind users), they offer considerable challenges to the linear presentation of information. Users of screen readers can not consider the information presented on the maps if they do not have alternative representations. Another form of presenting geographic information is by graphics (ex. to illustrate temperature change in the last few months, to illustrate rain distribution). These should also be complemented by textual descriptions making the information accessible to users who cannot visually interpret them.

The use of colors as the only element of meaning in graphics has been criticized in the ISO norms [11], in the W3C accessibility recommendations [2] and also in literature on information visualization [19,20]; there are users unable to access information which are exclusively based on the use of colors for interpretation. In the use of Web GIS applications, color is frequently used as the only element of meaning as for instance, in the subtitle resource to associate information to the map. This

apparent incongruousness in terms of information representation in the Web GIS applications and the accessibility recommendations from W3C [22] motivated us in the case study that was conducted in this work.

CASE STUDY

To accomplish this case study, we used three Web GIS applications, whose content is related to weather forecast, and other information required for agriculture: Embrapa's Agritempo [1], FUNCEME [8] and SIMEPAR [18]. The choice of these three applications is a result from a previous work [17], which verified interaction aspects in these systems. In that work, the 'Static Map Server' category had a higher quantity of identified applications, influencing the choice of two applications for this analysis: FUNCEME and SIMEPAR. FUNCEME is the application that presented more interactive possibilities, while SIMEPAR presented more content elements. One of the applications belongs to the Brazilian Northeast Region (FUNCEME), and the other to the South Region (SIMEPAR). Embrapa's (Agritempo) Web GIS belongs to the 'Map Generator' class, offering more interactive possibilities in relation to the 'Static Map Server'. This Web GIS application was developed for the context of the Federal Government.

Thus, this case study aims at investigateing accessibility as a quality attribute, considering systems that offer different levels of interaction for their users.

Methods and Procedures

Melo *et al* [13], presenting a Web accessibility evaluation case carried out with the participation of a blind user, mention different methods that can help the Web accessibility evaluation: (1) the use of graphic and text web-browsers; (2) automatic markup languages validation; (3) accessibility verification with semi-automatic tools; (4) evaluation with users with different abilities and/or disabilities. These methods have been used together as a tool in the preliminary Web sites accessibility evaluation and in evaluation of conformity with accessibility recommendations of the W3C (World Wide Web Consortium) [21].

To preliminarily investigate the accessibility of the chosen Web GIS applications, methods (1) and (3) were used, once they are easy to use and offer the possibility to promptly identify aspects that directly interfere with the users' experience. The use of different web-browsing configurations is one of the methods suggested by the W3C [21], to identify issues that interfere directly in the interaction and the accessibility to information; presentation of equivalent information through different channels (ex. image, sound and text), flexibility in the content presentation, as well as access to the Web page interaction elements (ex. links and forms elements). Table 1, describes the way we used the web-browsers, following the orientation given by W3C [21].
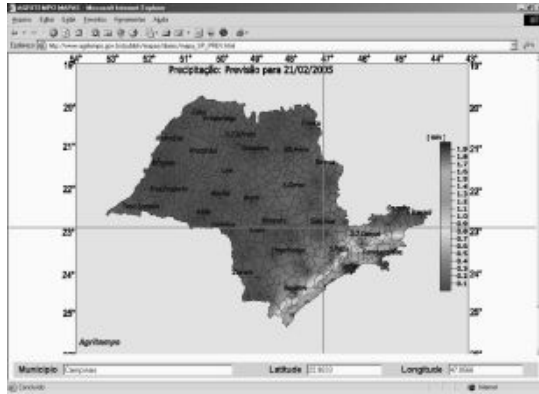
Web-Browser	Use/Observation	
Internet Explorer 6.0 (I.E. 6.0)	A)	Images turned off
	B)	Sound turned off
	C)	Different font sizes
	D)	Window resized to less than maximum
	E)	Pages viewed in gray scale
	F)	Use of TAB key to access links and form elements
Lynx 2.8.5	A)	Equivalent information availability
	B)	Linearization of information

Table 1. Use of web-browsers in web-accessibility evaluation

The service at Bobby portal [5], suggested by W3C [21] for the semi-automatic accessibility verification, generated, for each evaluated page, a report identifying the recommendation of the document *"Web Content Accessibility Guidelines 1.0"* [22] and also suggesting verifications that should be done manually. In compliance with the recommendation from W3C [22] this tool organizes the report items in different priority levels: 1,2 and 3. Table 2, summarizes the meaning given to these priorities.

Priority	Meaning
Priority 1	It concerns the basic requirements so that determined groups of users can access available documents in the Web. Ex: Supply alternative text to all images.
Priority 2	Refers to what should be satisfied as a way of promoting the removal of significant barriers in the access to Web documents. Example: Using relative dimensioning and positioning (percentage values) instead of absolute values (in pixels).

Priority 3	It concerns what may be satisfied for improving the access to Web documents. Example: Identifying the language of the text.

Table 2. W3C Priority for Web content accessibility

The evaluated pages were those belonging to the execution steps necessary to complete the task of verifying the weather forecast, i.e. we evaluated the "accessibility of pages which takes the user to the weather forecast". In FUNCEME case, the Ceará state weather forecast was verified; in SIMEPAR, the forecast for the state of Paraná; and in Agritempo, the forecast for the São Paulo State. The evaluation was done on 02.03.2005 for FUNCEME, 04.03.2005 for SIMEPAR and the 21.02.2005 for Agritempo.

Preliminary Results
From the verification using web-browser Internet Explorer 6.0, we highlight the following:

A) <u>Non-activated images:</u> These applications do not offer, for the evaluated pages, alternative texts to most of the images shown, including map images and graphics. Although it is not a rule, FUNCEME portal offers comments that complement the given information in some of the maps; the same happens to the SIMEPAR portal. Figure 1, shows a few evaluated pages with activated and non-activated images, respectively.

(a)

(a')

(b)

(b')

(c)   (c')

Figure 1. Sample of Web GIS applications pages at FUNCEME (a e a'), at SIMEPAR (b e b') and at Agritempo (c e c') with activated and non-activated images

B) Non-activated sound: there is no information, as the verified pages do not have sound resources.

C) Considering font size variation: Generally all the texts presented by FUNCEME portal are amplified when using the resource offered by the web-browser for font increase and reduction. In the SIMEPAR portal, only the text presented at the top of the interactive menu increased. In Agritempo only one of the titles over one of the maps had

its text increased in size. It is also common in these applications the use of images to convey informative content. Thus, besides their information being inaccessible to some of the users they are not increased by the Internet Explorer 6.0 web-browser. In Figure 2, an example of the text increase for the Web GIS application from FUNCEME is available.

(a)   (a')

Figure 2. Sample of Web GIS application at FUNCEME, where the page appears with a normal text size (a) and with a bigger text size (a')

D) <u>Redimensioned windows:</u> None of the evaluated pages, even those showing narrower images than the minimized window size, had their content adapted to different dimensions of the web-browser window. Consequently, as we redimensioned the window size to smaller sizes, the pages started to demand the use of horizontal scrolling to access their content. Figure 3 shows the main pages of each Web GIS evaluated application.

Figure 3. Web GIS application main pages for FUNCEME (a), SIMEPAR (b) and Agritempo (c) visualized with the size of the IE 6.0 web-browser window reduced horizontally

E) <u>Pages exhibited in gray scale:</u> Generally, most of the evaluated pages showed contrast in the presentation of the textual information, except for Agritempo's main page, as shown in Figure 4, where it is easy to perceive the absence of the contrast between the highlighted text and the white background of the page. We noticed the absence of contrast in the map and in the subtitles shown in FUNCEME and Agritempo's Web GIS applications — both convey information by the use of different colors. We could perceive that a SIMEPAR's map present both pictorial and textual information, in the presentation of their information. These resources complement the information offered in the maps via color but they also have to be supported by the text format description, in such a way the relevant information can be interpreted by

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devices such as screen readers. Samples of maps evaluated in the pages are presented in Figure 5.

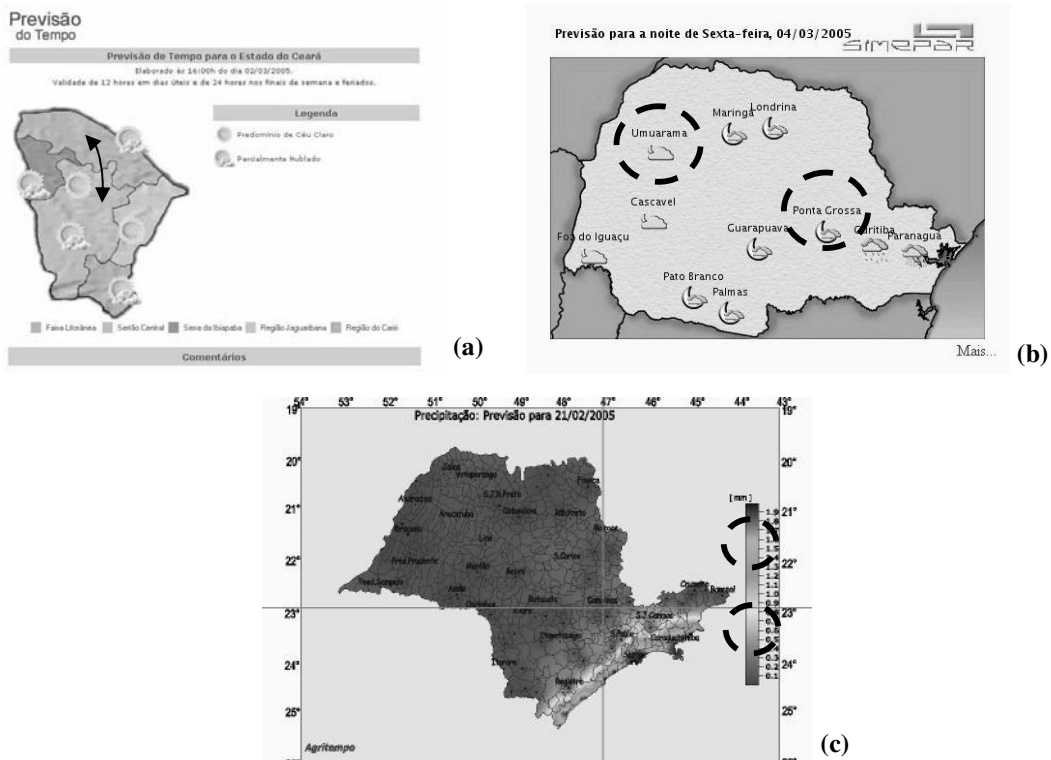**Figure 4. Main page of Agritempo portal**

Figure 5. Maps presented by Web GIS applications for FUNCEME (a), for SIMEPAR (b) and Agritempo (c)

F) <u>The use of the TAB key:</u> Among evaluated pages, those from Agritempo had their links and form elements all reachable by TAB key, i.e., they do not demand the use of the mouse for access. With FUNCEME's

application main page, the access options to the portal, are reachable only by using the mouse, differently from other pages, where the links and form elements are all reachable using the TAB key. SIMEPAR's portal pages present few of its links reachable only by using the mouse, such as those offered in its menu, present in the main page and in other portal internal pages. Some of the links of the left menu, offered in the internal pages of SIMEPAR portal, are activated by using only the mouse. Figure 6, points to links in the SIMEPAR applications that can not be activated by using the TAB key.
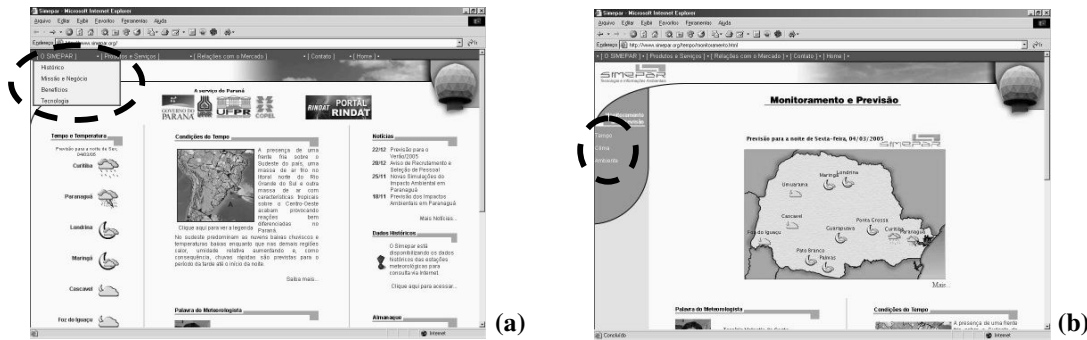

Figure 6. Main page for the SIMEPAR portal (a) and page on monitoring and forecast

From the verification carried out with the textual web-browser Lynx, we highlight the following:

A) <u>Availability of equivalent information</u>: The evaluated pages of FUNCEME Web GIS application do not present equivalent information to the portion of the image-map (ex main page that offers site navigation options), to its portal access and to the geographical maps presented in the path covered to complete the task of verifying the weather forecast for the state of Ceará. Moreover, this application does not offer textual descriptions to help in the identification of the *frames* used in the organization of its pages. In presenting the weather forecast, it offers textual information, complementing what is given by the map. A usual problem of this application is the absence of alternative texts to the images or more detailed descriptions of the information presented in these images, when necessary.

The SIMEPAR Web GIS does not offer alternative text to most of its images and its top menu is not available for the users of textual browser like Lynx. Though it offers more complementary information in texts than what is presented using maps, it is also common in this application the use of texts conveyed by images without alternative texts. This application as well as FUNCEME, uses frames to organize the presentation of its web-pages with no textual description, difficulting their identification.

The Web GIS application from the Agritempo portal generally presents the same problems as the later applications. This application specially offers many more maps than the previous, without presenting any type of textual information that could help some users to understand what is presented in the maps.

B) <u>Sequel information presentation</u>: In the FUNCEME Web GIS application, the linear information presentation suffers interference from the absence of the alternative texts to the images, as well as the use of map images and frames without equivalent textual information. It is noticeable the structure absence in the presentation of the information when linearized. As for the SIMEPAR Web GIS having a quantity of images without alternative text, the sequential presentation of the information is also harmed. In the same way as the previous ones, the Web GIS application of the Agritempo portal has the linearization of its information harmed by the use of images without adequate alternative texts.

From the use of Bobby service [5] of semiautomatic accessibility verification, we summarized in Tables 3, 4 and 5, next, the result for the accessibility problems that were identified automatically. The Tables organize the quantified data in the following way: for each evaluated page from Agritempo Web GIS, FUNCEME and SIMEPAR, the number of accessibility problems is grouped by priority level.

	Page 1	Page 2	Page 2'	Page 3	Total
Priority 1	15	2	9	12	38
Priority 2	22	2	136	65	225
Priority 3	10	1	15	19	45
Total	47	5	160	96	308

Table 3. Problems quantified by using Bobby for FUNCEME's application

	Page 1	Page 2	Total
Priority 1	23	19	42
Priority 2	48	25	73
Priority 3	23	15	38
Total	94	59	153

Table 4. Problems quantified by using for SIMEPAR's application

	Page 1	Page 2	Page 3	Page 3'	Page 4	Total
Priority 1	68	83	2	19	652	824
Priority 2	69	80	1	41	662	853
Priority 3	33	35	1	23	3	95
Total	170	198	4	83	1317	1772

Table 5. Problems quantified by using the Bobby for Agritempo's application

The data on Tables 3, 4 and 5 show higher occurrence of problems regarding priority 2 in the three evaluated applications. A problem in priority 2, shown in the three applications, is the use of absolute values in the dimensioning of the table columns and the size of the font used, a fact that directly influences the flexibility of the information presentation in different screen resolutions. Considering all the pages evaluated, page 2' (presented by page 2's frame) in the FUNCEME application had the higher number of priority 2 faults: 136 were counted, 96% refereeing to the use of absolute values for dimensioning the table columns.

Concerning the recommendation for priority 1, the Web GIS applications presented a meaningful quantity of problems in their *homepages*. FUNCEME and SIMEPAR presented higher quantity of problems. In Tables 3 and 5, it is possible to observe that page 2 from FUNCEME and page 3 from Agritempo present a reduced quantity of accessibility problems reported by the Bobby system. These reduced numbers, however, do not indicate a more careful design of these pages, once they are not visible to the user, but they organize *frame* sets for content, i.e., they structure the presentation of other pages (page 2' in the FUNCEME application and page 3' in the Agritempo application).

The Agritempo's Web GIS application is the one that presented the highest number of errors, in the three levels of priority, once its last page exhibits a geographic map which is an image map (term used in the HTML page editing to identify an image whose parts have semantic and/or specific functions). Each portion of this image map refers to a city in the geographic map, where access to information on the local weather, latitude and longitude, depend on a good visual acuity and the use of the mouse.

The highest values for priority 1 and 2 from Agritempo, 652 and 662 refer to the absence of alternative text for each portion of the image map and to the fact that the access to the information propagated by this image map is restricted to the mouse. The alternative text for each portion, besides informing the name of the city, its latitude and longitude, should also offer information about the weather forecast from the city it refers to, by using colors. In a certain way, in its homepage, Agritempo presents a technical solution to solve this question by offering, in the image map, an index for geographic information referring to each Brazilian state.

Discussion

From the preliminary evaluation, it can be noticed that questions relative to accessibility have been neglected regarding the representation of the geographic information as well as the page structuring and information distribution in general. Besides not reaching geographic information appropriately, some users are going to have a deeply poor experience with the basic information provided by these applications and their functionality.

As we look at Table 6, which synthesizes the results presented in the last section, it is possible to see that the identified accessibility problems are, in general, recurrent in the three evaluated applications.

		FUNCEME	**SIMEPAR**	**Agritempo**
Internet Explorer 6.0	A) Images turned off	- Usually without alternative text	- Usually without alternative text	- Usually without alternative text
	B) Sound turned off	- Not applicable	- Not applicable	- Not applicable
	C) Different font sizes	- Usually it changes - Text written in image	- Usually it doesn't change - Text written in image	- Usually it doesn't change - Text written in image
	D) Windows resized to less than maximum	- Horizontal scrolling	- Horizontal scrolling	- Horizontal scrolling
	E) Pages viewed in gray scale	- Good contrast in the text exhibition - Alternative to color in some maps - Few contrast in maps exhibition	- Good contrast in the text exhibition - Alternative to color in some maps	- Good contrast in the text exhibition - Few contrast in maps exhibition - Portion of the text in main page with few contrast to its background
	F) Use of TAB key	- Image-map options in the main page are unreachable	- Some links reachable only using mouse	- Links and formulary elements are reachable
Lynx	A) Equivalent information availability	- Absence of alternative text in general (images and frames) - Unavailable interaction elements	- Absence of alternative text in general (images and frames) - Unavailable interaction elements	- Absence of alternative text in general (images and frames) - Unavailable interaction elements - Presents more maps without equivalents information
	B) Linearization of information	- Structure compromised because of the absence of alternative text to images	- Structure compromised because of the absence of alternative text to images	- Structure compromised because of the absence of alteranative to the images
Bobby	Priority1	38	42	824
	Priority 2	225	73	853
	Priority 3	45	38	95

Table 6. Summary of Preliminary Results

The three applications do not offer systematically alternative texts to the images, which also includes graphics and geographic maps, but also other interface elements which conveys navigation options, as in the case of the image maps presented in the main FUNCEME's homepage. Users of screen readers wouldn't be able to interact with these sites neither understand the geographic information provided by them. Thus these systems wouldn't reach their primary objectives to these specific users.

Of the three evaluated applications the only one that has the possibility of changing its font size is FUNCEME's portal. The use of texts in images is common to the three applications. This type of text, differently from the alternative text, can not be interpreted by screen readers, nor increased by some web-browsers, who are still unable to amplify images. In this case, especially users with low vision would be prevented of using a very common browser resource, which allow changing font size easily. Although they could use screen magnifiers to cope with their interaction with these applications, screen magnifiers usually decrease context information.

The three applications do not enable the content of their pages to be adapted to different web-browser window sizes, i.e., they do not present the flexibility that would be necessary to be accessed from different video resolutions or even different devices. Users who could benefit of this flexibility to access geographic information provided by these systems outside office, using handheld devices like palmtops and cell phones, are prevented of using them.

Generally, even though they present adequate contrast in the exhibition of their texts, the evaluated applications need to consider carefully the use of colors to represent their information in maps, graphics and subtitles. Colored blind and poor sighted users, or those who access information through black and white printed material, can have difficulty identifying associated information; color should not be used as an indispensable element to the interpretation of information transmitted in maps.

Regarding the evaluated applications, only Agritempo did not present any barriers to access its links and forms by using the TAB key. Designing for device-independence is a very important design decision, which should be taken to allow different users to interact through their preferred input or output device. Users who are blind and some users with motors disabilities, for example, could benefit of a design, which allow them to interact through the keyboard. Finally, the offer of equivalent information and adequate structure for the content, so that it can be accessed by different web-browsers (not only graphic) and devices (ex. screen readers and palmtops) need to observed by the three evaluated applications.

Through the use of the Bobby system, we could observe that the quantity of identified errors in the Web GIS from Agritempo was quite meaningful; being the highest of the priority three levels. The three evaluated applications had an expressive number of problems regarding the priority 2 levels. This fact suggests some groups of users would have difficulties to access the content and functionality provided by these Web GIS applications.

CONCLUSION
Interface design has demanded more and more attention to the interaction flexibility for information access. In the case of Geographic Information System applications in the Web, the accessibility has become more important, due to the extremely visual features of the current applications, strongly restricting their use to people who have some type of visual impairment (ex. colored blind, reduced eye sight, blindness, etc). Issues regarding the accessibility to Web GIS applications present a challenge to the representation of geographic information, reflected in the homepages' structure, as well as in the conveying information *per se*.

This accessibility inspection, understood as a quality factor for the Web GIS applications, allowed us to show that some basic tasks such as *verifying the weather forecast* of a town or a region, are not reachable for users with special needs or restricted capacities. This fact was observed in the three evaluated applications. It is important to highlight that one of the considered applications belongs to the Brazilian Federal Government, which should supposedly offer access to information to a wide variety of user situations. Moreover, the evaluated

Web GIS applications do not seem to consider the guidelines defined by current recommendations such as ISO, W3C, etc.; they use map images and colors as the only element of meaning to represent information essential to the geographic information understanding. By observing the preliminary results of the Web GIS applications evaluated, we see that a lot of work should be done towards enabling the access of geographic information to a portion of the population who currently does not have it.

The quality of use of a Web GIS application, quality understood as fitness for use, is directly related to the ways of presentation and representation of the geographic information to the user. The access to this information should not be restricted to a map or graphic image visualization; other artifacts should be available to reach a more diversified category of users. Further work is being done regarding specificities of the geographic domain and their implications for the design and evaluation of this category of information system. In particular, we are working in the development of patterns for the design and evaluation for this application domain.

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