Accessible smart cities? Inspecting the accessibility of Brazilian municipalities' mobile applications

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ABSTRACT

The use of interactive technologies to aid in the implementation of smart cities has a significant potential to support disabled users in performing their activities as citizens. In this study, we present an investigation of the accessibility of a sample of 10 mobile Android™ applications of Brazilian municipalities, two from each of the five big geographical regions of the country, focusing especially on users with visual disabilities. The results showed that many of the applications were not in accordance with accessibility guidelines, with an average of 57 instances of violations and an average of 11.6 different criteria violated per application. The main problems included issues like not addressing labelling of non-textual content, headings, identifying user location, colour contrast, enabling users to interact using screen reader gestures, focus visibility and lack of adaptation of text contained in image. Although the growth in mobile applications for has boosted the possibilities aligned with the principles of smart cities, there is a strong need for including accessibility in the design of such applications in order for disabled people to benefit from the potential they can have for their lives.

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation (e.g. HCI): Evaluation/methodology

IHC '16, October 04 - 07, 2016, São Paulo, Brazil

ACM 978-1-4503-5235-2/16/10…$15.00
DOI: http://dx.doi.org/10.1145/3033701.3033718

Author Keywords

Accessibility evaluation; Mobile accessibility; Smart Cities

INTRODUCTION

The use of interactive information systems and data has a substantial potential to develop policies and to make applications available to citizens in cities around the globe [13].

The concept of "Smart Cities" encompasses a number of visions and innovations aiming to make cities smarter. According to existing definitions and propositions in the literature, the concept includes points such as [16, 22, 14]: integration of digital services and governance, integration of devices and objects with resources such as Internet of Things (IoT), building large Information and Communication Technology (ICT) infrastructure in cities, using knowledge and data to offer new and improved services, among others.

The advancement of such initiatives present many potentials in several areas, and in particular to offering better services and resources to improve the accessibility of the city to disabled people. Many research studies have explored the possibilities of implement ICT resources to improve the lives of disabled people in cities, such as navigation systems for visually disabled users [15, 8, 24, 12] and building other assistive environments in cities [7].

Further to this, many cities and towns have developed mobile applications for smartphones, which have started to provide basic services and information to their citizens, as a first step to move towards the "smart city".

However, little research has been performed to investigate how accessible those mobile applications are to disabled users. Despite being based on simpler solutions than those that use interconnected objects and large network infrastructures, simpler applications are already available in many cities around the world, and provide important resources such as governmental service provision, transport and mobility information, services contact information, tourism information, among others. Making sure these applications are accessible to disabled users using mobile devices is very important as a starting point for making smart cities accessible to those users.

The proposal of the present work was to perform an accessibility inspection of the accessibility of a sample of mobile applications of municipalities in Brazil, with a sample of 10 applications, being two from each of the five big geographical regions in Brazil.

SMART CITIES AND ACCESSIBILITY IN MOBILE APPLICATIONS

In this section, we present the main concepts related to smart cities, accessibility and related work involving accessibility in mobile applications and smart cities.

The Concept of Smart Cities

As pointed out by Neirotti et al. [17], there is no agreed common definition of the concept of "smart cities".

Sadowski and Pasquale [22] states that most definitions and concepts of smart cities "aim to evoke positive change and innovation — at least as the proponents see it — via digital ICT [Information and Communcation Technology]; essentially, building an IoT [Internet of things] at the city-scale by installing networked objects throughout the urban environment (and even human bodies) for a wide range of different purposes".

Nam and Pardo [16] presented a conceptualisation of smart cities aligning to three main dimensions: technology, people, and institutions. In their proposal, they present smart cities approaches that involve "integration of infrastructures and technology-mediated services, social learning for strengthening human infrastructure, and governance for institutional improvement and citizen engagement".

Research projects involving the development of smart cities has also been the target of interest by large research companies, such as IBM. According to McNeill [14], "for IBM, Smarter Cities represents an attempt to solve three strategic problems that face the firm: how to maximise its stored knowledge and ensure its labour costs deliver significant added value; how to construct new sectoral and geographic markets for this knowledge; and how to reduce, standardise and simplify the object of that knowledge – the city – as a scaleable commodity".

Implementing resources to make cities "smarter" requires that administrators and citizens be able to use data and resources to manage and use their environment. The growth in the development and availability of mobile applications to help in several contexts, such as mobility, natural resources management, tourism, public services, and many others.

In this paper, in particular, we investigate the accessibility of mobile applications to disabled users. We analysed commonly used mobile applications to make city information available to citizens in terms of how they implement or not resources to allow their use by disabled users.

Accessibility and Mobile Applications

Providing people with disabilities with access to technological resources is very important to ensure they can also perform their tasks and use systems in the same way as mainstream users. ISO 9241-Part 171 [18] presents the concept of software accessibility as one close to that of usability to disabled people, and not as a disjunct concept. According to ISO 9241 – Part 11 [9], the concept of usability is defined as "the extent to which a product [service or environment] can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". Part 171 of ISO 9241 [18] defines software accessibility as "the usability of a product, service, environment or facility by people with the widest range of capabilities", including people with disabilities.

The manufacturers of popular systems for mobile devices, such as Apple's iOS [2], Android [1] and others provide some guidance to help developers provide more accessible applications. Such guidelines include issues such as how to make non-textual content accessible and to make elements accessible via gestures. However, those guidelines are often limited to very specific technical questions related to the systems and do not include broader guidelines often encountered in other accessibility guidelines, such as Web accessibility guidelines.

The investigation of techniques to develop accessible applications for mobile devices has received increased attention in the literature. Research in the area include early studies, such as a study conducted in 2006 [21] to propose accessibility guidelines for key-based smartphones.

Kane et al. [10] investigated how to improve accessible interaction in mobile devices by using better gestures to help visually-impaired users. The proposal of general accessibility guidelines for mobile interaction was also the aim of a study conducted by Piccolo et al. [20], including issues with privacy of content shown in the screen, appropriate metaphors and autonomy.

In a study conducted by Leporini et al.[11] using an online questionnaire with 55 blind users, they investigated the accessibility and usability of mobile devices with iOS™ and the VoiceOver screen reader, concluding that VoiceOver was an important addition to their accessibility to mobile applications, but that they still had issues with complex operations, such as text entry.

Chiti and Leporini [4], in another study, involved four users with visual impairments in the evaluation of a prototype of an Android™ system. The results showed that the use of Android™ with the TalkBack screen readers still presented challenges for the use by blind users.

Clegg-Vinell et al. [5] analysed accessibility problems encountered by people with different disabilities with Websites in mobile devices. Their goal was to contrast problems encountered by disabled users with Web accessibility guidelines and guidelines for developing mobile Websites from the World Wide Web Consortium (W3C). The results pointed out that several types of problems encountered by users were not covered by the guidelines and in other cases the severity of problems were not aligned with the priority levels of the guidelines, showing a need for more empirical research on accessibility design practices for mobile interaction.

Park et al. [19] involved four blind participants in a study comprising interviews about how they use mobile applications followed by observation of their use, resulting in a set of 10 heuristics. One of the main points raised in the paper is the need to better define widely accepted guidelines for evaluating the accessibility of mobile applications.

In another recent study performed by the research group of the authors of the present paper [23], the guidelines from the Web Content Accessibility Guidelines 2.0 [3] from the World Wide Web Consortium (W3C) were adapted for the context of mobile applications. The study analysed four e-government mobile apps, and the results from the methodological adjustments were very important to help develop the present paper.

Smart Cities and Accessibility

Using available data and interconnected devices and technologies in cities was place as a big promise to help make "smart cities" more accessible to people with disabilities.

In this section, we describe related studies that proposed technologies and approaches to use "smart" resources to provide more accessible services to disabled users.

In a study developed by Mirri et al. [15], the authors developed the mPASS software. mPASS is a prototype which enables route planning via a smartphone, in order to plan routes that avoid obstacles that may be encountered by disabled people, as well as calculating alternative routes. The application presents obstacles marked by other users and comments about the nature of the obstacles. The application was tested by 60 users, including blind, partially-sighted and older people.

The investigation of mobile applications to help provide way-finding and obstacle avoidance to disabled users has also been pursed by many other research studies [8, 24, 12]. This example of application shows how using city and crowd sourcing information can help improve the accessibility of city environments to disabled users.

Other studies have also pursued the goal of building more inclusive smart cities. López-de-Ipiña et al. [7] presented discussions about their experiences building accessible environments for shopping malls and city contexts. They argue that it is necessary to develop more research to provide integrated user-centred approaches to implementing smart city resources to appropriately address the needs of disabled users.

Although there is evidence of the development of specific accessibility features related to smart cities, there is little research into the accessibility of mobile applications already deployed in cities around the world.

METHOD

The study reported in this paper was based on an evaluation of a sample of mobile applications deployed in Brazilian municipalities. The evaluation comprised of accessibility inspections of the applications using an adaptation of the WCAG 2.0 success criteria for mobile applications, performed in a previous study developed by the authors' research group [23].

Sample of Evaluated Applications

The evaluation focused on applications aimed at providing information related to the cities to their citizens and visitors.

Each selected application provides governmental and tourism services of the city, such as historical information, latest news, tourist attractions, location of public services, events, bus schedules and useful phone numbers. Most applications were classified at the News & Magazines, Communitacion or Travel & Local categories at the Google Play store. The applications had been developed by the municipal governmental authorities or by independent companies or individuals.

In order to perform accessibility evaluations encompassing a more diverse range of cities in Brazil, ten applications were selected for the Android™ platform and categorized into the five big geographical regions defined by the IBGE (Brazilian Institute of Geography and Statistics). We surveyed existing applications for Brazilian cities and selected two of them from different states in each of the five regions.

The following apps were included in the sample:

- **Midwest region**: *Guia Corumbá* (Corumbá Guide) from Mato Grosso do Sul state and *Visite Brasília* (Visit Brasília) from the Federal District;
- **Northeast region**: *Prefeitura de Fortaleza* (Fortaleza City Council) from Ceará state and *Recife Pra Sempre* (Recife Forever) from Pernambuco state;
- **North region**: *Guia Porto Velho* (Porto Velho guide) from Rondônia state and *Guia Prefeitura de Rio Branco* (Guide - Rio Branco City Council) from Acre state;
- **Southeast region**: *Belo Horizonte Oficial* (Belo Horizonte official) from Minas Gerais state and *Prefeitura de Jundiaí* (Jundiaí City Council) from São Paulo state;
- **South region**: *Curta Curitiba* (Enjoy Curitiba) from Paraná state and *Porto Alegre - Oficial* (Porto Alegre - Official) from Rio Grande do Sul state.

We only selected Android™ applications for the present study. The choice for this platform was due to its wider use in Brazil in comparison to other platforms, as pointed in a poll performed by Kantar Worldpanel ComTech [6], with more than 90% of market share. Further to this, the initial search performed by the authors showed that there was a much wider variety of mobile applications for Brazilian cities for Android™ than for Windows™ and iOS™.

Accessibility Evaluation Procedure

The evaluation procedure used in the present study was an inspection using a review of guidelines performed by four expert evaluators.

At the present moment, there are no widely accepted accessibility guidelines to evaluate mobile applications. As previously mentioned, Apple's and Android's accessibility guides are limited to more technical issues related to their specific interface components and do not include broader issues that well-established guidelines present, such as Web accessibity guidelines. Thus, we assessed different options to perform the evaluations based on existing accessibility guidelines, namely ISO 9241-171 [18] for software accessibility and WCAG 2.0 [3] from the W3C for web accessibility.

According to the Web Accessibility Initiative (WAI), who created WCAG 2.0, the recommendations in the current version of the guidelines were made with the effort to be compatible with different current and future technologies. The guidelines present in WCAG 2.0 also had wider support from tools and documentation to perform evaluations when compared to other accessibility guidelines. For these reasons, we opted to use the WCAG 2.0 success criteria as basis for the evaluation, after adapting specific success criteria to the context of mobile applications.

All 61 success criteria available at the Web Content Accessibility Guidelines 2.0 (WCAG 2.0) [3] were used in the analyses. The success criteria are divided into three conformance levels: A (lowest), AA and AAA (highest).

We made adaptations to success criteria that made specific references that were not applicable directly to the context of mobile applications, such as mentions to keyboard navigation and Web markup languages, as performed in a previous study conducted by the authors' research group [23].

One adaptation was performed in Success Criterion - 2.1.1 "Keyboard: All functionality of the content is operable through a keyboard interface without requiring specific timings for individual keystrokes, except where the underlying function requires input that depends on the path of the user's movement and not just the endpoints", in order to better reflect how some disabled users use tablets and smartphones with gestures. When using assistive technologies in mobile applications, all content is made operable by touch screen gestures such as "swipe right", to move to the next item on the screen, "swipe left", to move to the previous item on the screen and "double tap", to activate the currently focused item. These gestures simulate the "tab" key used in keyboard navigation by screen-reader users in desktop computers.

We also adapted other success criteria that assume the use of Web-based technologies, such as HTML (HyperText Markup Language). Adjustments were necessary for Success Criterion 4.1.1 - "Parsing: In content implemented using markup languages, elements have complete start and end tags, elements are nested according to their specifications, elements do not contain duplicate attributes, and any IDs are unique, except where the specifications allow these features". To evaluate mobile applications developed for the Android™ platform, the evaluators had to consider other technologies, such as the appropriate use of interface components in the Java programming language and verify which programming faults could cause problems to users of assistive technologies.

After adapting the guidelines to the context of mobile devices, the four specialists evaluated the conformance of the municipalities' applications to the 61 success criteria in WCAG 2.0 for three screens of each application. The evaluators performed manual inspections using different adaptations on smartphones, such as using the screen reader TalkBalk.

For the selection of the screens, we chose to use common features present in most applications. For this reason, we used a screen with the description of a given public service or regional event, a selection menu and a page with phone contact information, which were common to all the 10 applications evaluated in the sample.

All four evaluators were undergraduate students who had undertaken Human-Computer Interaction courses and performed accessibility inspections. Two of the evaluators had extensive previous experience with designing and evaluating accessible mobile applications. The two other less experienced evaluators had further training in the research lab before conducting the evaluations. The applications evaluated were evenly distributed among the four evaluators, with each application being evaluated by one of the members of the team following the same protocol.

For each of the 30 screens evaluated, the evaluators used the basic gestures used in TalkBack to navigate in the items in the screen and registered the number of violations of each success criterion in each screen, as well as a more detailed description of the main problems encountered that would potentially cause issues to disabled users. For Success Criterion 2.4.6 - "Headings and Labels: Headings and labels describe topic or purpose", for example, we noted the number of occasions in which the titles and labels in the screen in question were not descriptive enough, causing visually disabled users using screen readers to miss the meaning of elements when read out of context, such as in a table of contents.

The evaluations were performed using a Moto G 2nd Generation with Android™ 6.0 with the screen reader TalkBack 4.5.0.

RESULTS AND DISCUSSION

In this section we present the main results and discussion of findings from the study. The first subsection presents a quantitative analysis of the number of problems encountered in the applications, and the second describes the main types of problems encountered in the applications.

Conformance Analysis

The first analysis performed in this study was a quantitative description of the number of instances of WCAG 2.0 success criteria violations for each application and the number of different success criteria violated. Table 1 presents the two measures broken down by conformance level. The regions of each application are identified by the following acronyms: MW - Midwest, NE - Northeast, N - North, SE - Southeast and S - South.

The results at Table 1 show that none of the applications would have been deemed as even the lowest level-A compliant level. The average number of instances of violations of success criteria across the applications was 58.2, and the average number of different success criteria violated per application was 11.6.

Application	Instances of success criteria violations				Number of different success criteria violated			
	Level A	*Level AA*	*Level AAA*	*Total*	*Level A*	*Level AA*	*Level AAA*	*Total*
Belo Horizonte Oficial (SE)	15	5	2	22	5	2	2	9
Curta Curitiba (S)	29	17	4	50	6	4	3	13
Guia Corumbá (MW)	16	11	21	48	8	2	3	13
Guia Porto Velho (N)	29	1	21	51	5	1	3	9
Guia Prefeitura de Rio Branco (N)	4	0	0	4	3	0	0	3
Porto Alegre - Oficial (S)	10	14	31	55	6	2	4	12
Prefeitura de Fortaleza (NE)	22	12	18	52	5	3	5	13
Prefeitura de Jundiaí (SE)	19	14	13	46	6	3	5	14
Recife Pra Sempre (NE)	41	73	38	152	8	5	8	21
Visite Brasília (MW)	52	24	14	90	4	2	3	9
Average	23.7	17.1	16.2	57	5.6	2.4	3.6	11.6

Table 1. Number of instances of violations of success criteria and different success criteria violated per conformance level

These results show that the applications have a significant number of violations of accessibility guidelines that can present barriers to disabled users. There was also significant variation in both the number of instances of violations and number of different success criteria violated.

Detailed Description of The Main Problems Encountered and Implications

Following the analysis of the conformance levels, we analysed which were the success criteria that occurred most frequently in the applications evaluated.

Table 2 shows the list of the 14 most frequently violated success criteria (SC) in the evaluations. The table is in decreasing order of how many applications violated each of them, followed by the total number of times they were violated.

Success criteria	*Applications that violated the SC*	*Total number of violations of the SC*
1.1.1 Non-text Content	9	69
2.4.6 Headings and Labels	9	60
2.4.8 Location	9	20
2.4.2 Page Titled	9	21
4.1.2 Name, Role, Value	8	73
1.4.6 Contrast (Enhanced)	7	79
1.4.3 Contrast (Minimum)	6	43
2.4.10 Section Headings	6	14
1.3.2 Meaningful Sequence	5	17
1.4.5 Images of Text	4	23
2.1.3 Screen Reader Gestures	4	17
2.1.2 No Gestures Trap	4	8
2.4.7 Focus Visible	3	40
1.4.9 Images of Text (No Exception)	2	16

Table 2. Success criteria most frequently violated in the evaluations

In the following subsections, we describe and discuss each of the main types of success criteria violated and the implications for the mobile applications of the cities.

Non-text Content

Success criterion 1.1.1 states that “Non-text Content: All non-text content that is presented to the user has a text alternative that serves the equivalent purpose, except for the situations listed below”.

In the analysis of the main types of problems encountered in the mobile applications of the cities analysed, many present a number of issues in common, as can be observed in Table 2. Almost all applications analysed violated SC 1.1.1, with a total of 69 violations across all applications.

A number of buttons implemented in the interfaces used images to represent their functionality. However, in many cases such images did not have any associated alternative text that could be read by screen readers. Examples of such issue are shown in Figure 1, from the from Porto Velho app, such as the lack of textual description of the magnifier button (search) and the gear button (settings). This lack of description would mean blind users would not know what those buttons do. These problems could be fixed by correctly using the ImageButton element with an alternative text, such as in the following code:

```
<ImageButton
android:layout_width="wrap_content"
android:layout_height="wrap_content"
android:id="@+id/imageButton"
android:layout_alignParentTop="true"
android:layout_alignRight="@+id/textView2"
android:layout_alignEnd="@+id/textView2"
android:contentDescription="Alternative Text"
/>
```

Figure 1. Navigation bar of the Porto Velho city app

The attribute “contentDescription”, present in the aforementioned code, would provide an alternative text that would describe the image in the button, making it accessible to blind users.

In the same way as in Web applications, implementing accessible images in mobile applications that aim to contribute to “smart cities” is the first step towards providing more accessible apps and inclusive cities. Finding so many instances of such a basic accessibility shows that a significant effort of awareness-raising needs to be carried out with policy-makers and people involved in the development of those apps.

Headings and Labels

This section presents problems related to SC 2.4.6 and SC 2.4.10. SC 2.4.6 states that screens should provide “Headings and labels describe topic or purpose” and SC 2.4.10 states that “Section headings are used to organize the content”.

The goal of the two success criteria is to help users understand which information is presented in each page and how this information is organised. In order for pages to be properly organised, it is important that meaningful headings be provided to indicate the purpose of each section, such as navigation, section headings, footer, and others. This is particularly helpful to blind users to know what to expect to find in different parts of the content without having to navigate entire pages.

It is expected that, for a blind user, the first information to be read out by screen readers is a descriptive heading with the title of the page. During the evaluations, 90% of the applications did not present a good heading or present inadequate information. The application of the city of Fortaleza was a good example of use of a good main heading, as shown in Figure 2, showing the main title with the purpose of listing social networks.

Figure 2. City of Fortaleza’s application with a clear title describing a social networks’ page

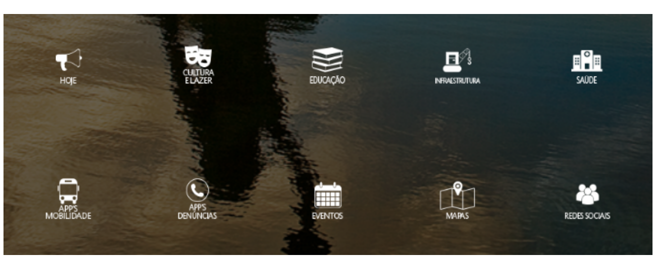

Figure 3. Menu buttons of the Fortaleza city council’s app

Some of the labels describing sections and features are laid out as images that do not always have an alternative text. Considering that such images also represent labels to features, this can be a further barrier to users. The example in Figure 3 shows 10 labels with images not described in text, preventing users from knowing what their functionality is.

As with regards to SC 2.4.10 (section headings), it is important to point out that providing such headings is important to speed up the reading of content by blind users when skim-reading content, especially in long pages. In the evaluation performed, all applications had contact pages with information about addresses and phone numbers of important local government agencies, along with hospitals, police stations and airports. However, in 6 out of 10 cases, those long lists did not have section headings to help organize content. This can be very unhelpful to disabled users who may “drawn” in content, such as in the case of smart cities’ applications with large amounts of information.

Location

SC 2.4.8 states that “Information about the user’s location within a set of Web pages is available”. This SC was violated by almost all of the applications evaluated.

The aim of this criterion is to help users locate themselves within the application. Addressing this SC includes techniques such as providing a “breadcrumb trail” or providing a map of the app. In the application of the Recife city shown in Figure 4, a button showing what the previous page is (*início* - home) helps users to know where to go back to.

Figure 4. Information in the *Recife pra Sempre* application, with location information of previous pages

Page Titled

SC 2.4.2 states that “pages have titles that describe topic or purpose”, in order for users to quickly identify what the page they have arrived is about.

Figure 5 shows a good example of the use of this criterion. The Porto Alegre application shows clearly in the title that the page is related to useful phone numbers.

Figure 6 of the Brasília application, on the other hand, does not clearly state a title of the page, making the user have to infer what the page is about, which can be very challenging to screen reader users.

Figure 5. Useful telephone numbers in the Porto Alegre application

Figure 6. Phone number page of the Brasília app - no title

Name, Role, Value

SC 4.1.2 states that "For all user interface components (including but not limited to: form elements, links and components generated by scripts), the name and role can be programmatically determined; states, properties, and values that can be set by the user can be programmatically set; and notification of changes to these items is available to user agents, including assistive technologies".

In many occasions, the elements of the page were not clearly identified with their associated roles. The names provided to items did not help users identify what they were meant for in the interface. In other occasions, buttons were identified as links due to poor association of the interface elements used to identify the features.

Colour Constrast

WCAG 2.0 has two success criteria related to colour contrast, with two different levels accepted according to the conformance level (AA or AAA). SC 1.4.3 (level AA) and SC 1.4.6 (level AAA) address issues related to colour contrast. SC 1.4.3 demands colour contrast of 4.5:1 (proportion of luminosity between foreground and background colours) for most cases, whilst SC 1.4.6 demands contrast of 7:1.

Providing good colour contrast is very important in mobile applications, as this can affect partially-sighted users significantly. Besides, even users without visual disabilities may be impacted by poor colour contrasts if in places with bright sunshine.

The evaluation of colour contrast was performed using the WCAG Contrast Checker tool, illustrated in Figure 8. The screen shown in Figure 7 illustrates an example of violation of the colour contrast success criteria, as the grey on grey contrast is not adequate for partially-sighted users.

Figure 7. Useful phones at Guia Corumbá - poor colour contrast

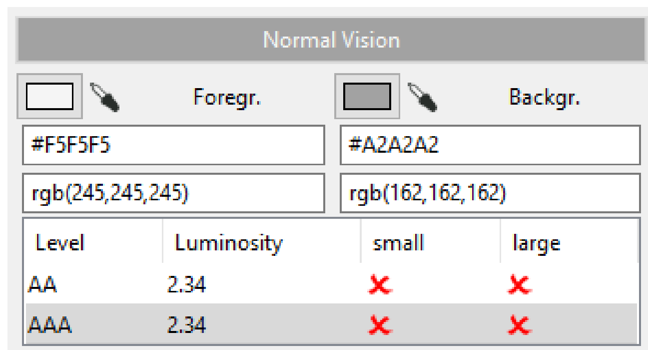

Figure 8. Result of the colour contrast evaluation with WCAG Contrast Checker

Meaningful Sequence

SC 1.3.2 states that "when the sequence in which content is presented affects its meaning, a correct reading sequence can be programmatically determined".

If this SC is not addressed, users with screen readers can become disoriented when their assistive technology, such as the TalkBack screen reader, reads information in the wrong order. This can be especially troublesome when images, text and dynamic content is not placed in a manner that can be interpreted correctly by screen readers. In the Rio Branco application, in its main menu, after opening an first screen, as shown in Figure 9, after scrolling through a list of items, the focus order reached by the screen reader is that shown in Figure 10, which was the first shown in the screen, but not the first in the list.

Another example of violation of this success criterion was in the "Visite Brasília" application. When starting the navigation in order, elements in the right hand side or the screen are read out before what is shown in the order in the screen, as can be seen from the sequence in Figures 11 and 12.

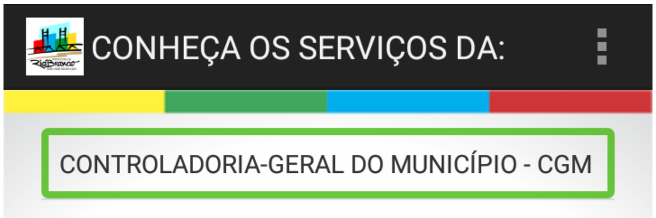

Figure 9. Initial state of list of services in the main menu of the Rio Branco application

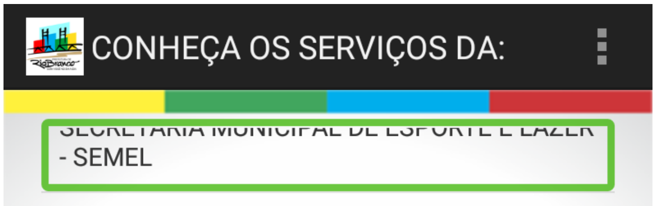

Figure 10. List of services in the Rio Branco application, with focus given to first element on the screen, but not the first on the list

Images of Text

This section presents problems related to SC 1.4.5 and SC 1.4.9, which state that "If the technologies being used can achieve the visual presentation, text is used to convey information rather than images of text". SC 1.4.5, however, makes an exception for customisable text and essential images with text, such as logos.

Figure 3, previously shown in this text, presents an example of a violation of this SC. The screen presents 10 images containing text that could have been laid out as texts, allowing for further adjustments for people with visual impairments. Setting the text as images limits the ability of users to change size and presentation of the text according to their needs.

This can be especially troublesome in smartphones, in which many partially-sighted users need to perform changes such as presenting in high contrast, using gestures to change size, which can be compromised by the use of images with text, since many of such changes may not work appropriately with the text in images as it would work for text in natural format.

Gestures Navigation

According to the adaptation of the definition of SC 2.1.1 “Keyboard” to the context of mobile devices, all functionality and content available on the screen should work when accessed with gestures to navigate the content when used by screen readers.

During the evaluations, it was noticed that in many parts of the content of some of the applications in the sample, there was content not accessible when navigating through the screen using swipe gestures. In the example shown in Figure 1, users who could not see the screen would never know that the place of the attractions and local events even existed, since their navigation using common gestures would never lead them to those contents.

Figure 11. First object focused in the Visite Brasília application

Figure 12. Second object focused in the Visite Brasília application - wrong order

This is a particular sensitive issue in the context of smart cities. Making content available to users who need to navigate in non-visual manner is fundamental to make applications accessible to all users.

No Gestures Trap

From the adaption of SC 2.1.2 - “No keyboard trap”, in the context of mobile applications, users should not be trapped in certain parts of the screen when using non-visual navigation with gestures to reach next and previous elements.

In Figure 13, from the Rio Branco application, as soon as blind users use a gesture to reach the link “Início” (start), the application will not allow them to continue to explore the remainder of the screen. No matter which gesture is used to go forward or backwards, users will be stuck in that part of the menu. The only way of escaping the trap would be the exploration of the visual elements without using the gestures to go backward and forward, which can be very challenging to users who cannot see the screen.

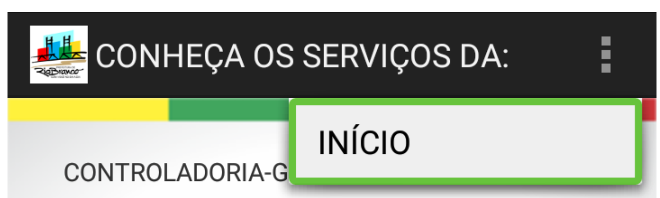

Figure 13. Example from the Rio Branco application - user becomes trapped in the button, not being able to continue navigating

For people with visual disabilities, being trapped in an interface component without being able to leave may be the end of their navigation in applications to have access to services in their cities, and can be a very frustrating experience.

Focus Visible
The goal of SC 2.4.7 is to make all elements with focus with a visible highlight of the place. This is especially important for partially sighted users.

In the example shown in Figure 14 from the *Recife Pra Sempre*, when the button "Onde ficar" (where to stay at) is focused, a green square is place over the button, making it possible for users to distinguish where they are at in the screen.

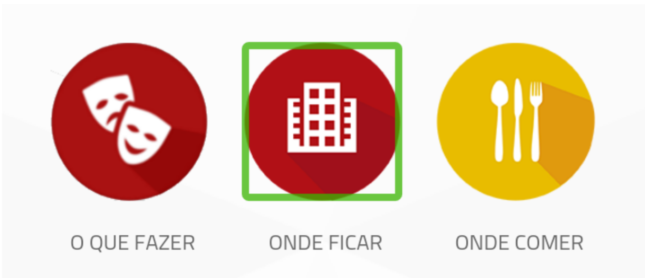

Figure 14. Component with a Visible Focus

In the example in Figure 14, partially-sighted users who also use screen readers can know precisely where the focus of their assistive technology is.

Although only three applications failed this success criterion, a total of 40 instances of violations occurred, showing this can be a significant issue in the applications that prevent users from knowing where in the screen they are when navigating.

CONCLUSIONS AND FUTURE WORK

This paper presented a study on the accessibility of mobile applications of 10 Brazilian municipalities, as initiatives towards the goal of providing smart cities to citizens.

The accessibility inspection performed showed that there are many problems that prevent disabled users from fully interacting with the information and services provided by such applications. Especially, the use of the applications with screen readers such as TalkBack presents a number of issues with the navigation using specialised gestures and description of non-textual elements.

The main problems included issues like not addressing labelling of non-textual content, headings, identifying user location, colour contrast, enabling users to interact using screen reader gestures, focus visibility and lack of adaptation of text contained in image.

Although the growth in mobile applications for has boosted the possibilities aligned with the principles of smart cities, there is a strong need for including accessibility in the design of such applications in order for disabled people to benefit from the potential they can have for their lives. As pointed out by previous research studies, there is a need to provide agreement on widely-accepted sets of design recommendations which are supported by governmental and standard bodies. Contrary to the movements to promote Web Accessibility with standards such as WCAG 2.0 [3], there is scarce provision of guidance and awareness-raising of the needs to make mobile applications more accessible.

As future work, we intend to perform usability tests including users with different disabilities to find what are the main problems they encounter with mobile applications used in their cities. Further to this, we also intend to conduct studies with developers of such applications to know more about their awareness of accessibility issues in mobile devices and of techniques to make their applications more accessible.

ACKNOWLEDGMENTS

The authors would like to thank FAPEMIG and CNPq for the financial support to this work.

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