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Article

A methodology to design a domotics human-machine interface for visually impaired people

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Abstract: According to the World Health Organization (WHO), more than one billion people in the world have some disability. A 2017 report of the Brazilian Geography and Statistics Institute (IBGE) shows that 45.6 million Brazilians have an impairment, among which 18.8 million declare vision issues not fixed by glasses or contact lenses. So, a significant population leads to developing many legal mechanisms to guarantee their quality-of-life. Potentially, these mechanisms should regulate many aspects of urban design to assure the accessibility of any environment. However, there are several design challenges to be overcome. In this paper, we address the problem of developing Human-Machine Interfaces (HMI) for visually impaired people, focusing on residential automation systems (domotics). The efficient development of such interfaces needs a link among two accessibility areas: domotics and HMI. We used pre-tests, human-computer interaction (HCI) techniques, and the user's emotional state identification to determine the user's profile. We must highlight that the design is intended to be used by any user, visually impaired or not. That is, the system should be universal. The methodology described can be used to assess the efficiency and quality metrics of accessibility in domotics systems.

Keywords: Accessibility, Interfaces, Home automation, Visually impaired user.

1. Introduction

Domotics (residential automation systems) is a set of services provided by integrated systems and designed to meet the basic needs of the occupants of a building. The design of domotics systems focuses on the user's requirements, and universality should be one of the main goals in the design process. Universal design is a term used to designate a set of critical points, rules, and recommendations to ensure accessibility of any product based to serve a wide range of users irrespective of their abilities (ABDULLAH; JIAN, 2019).

Regarding home automation, the accurate identification of the interface that can meet the user's needs in the best way can potentially foster accessibility to integrate the user into the domotics system. According to Norman, Draper, Taylor e Francis (1986), an interface links two systems enabling communication among them. In other words, the interface is the name given to something serving to connect two systems regardless of their structures. Thus, the expression Human-Computer Interface (HCI) refers to an interface connecting two different systems that exchange information: a human and a machine.

In the opinion of Hakobyan *et al*. (2013), visual loss inevitably leads to impaired ability to access information and perform everyday tasks. Mobile devices are among the best examples of distributed systems having Human-Machine Interfaces (HMI) with a low learning curve for users with impaired vision. Furthermore, information accessibility for the visually impaired has been enhanced generally by the development of tactile and auditory-based presentation methods as effective alternatives to the traditional visual representation of information (BINNS et al.,

2012),(MOSKOVITCH; WALKER, 2010),(REVELL; STANTON, 2016). According to Satyanarayanan (1996), this new paradigm is called mobile computing.

According to Weiser (2002), in recent decades, users have begun to attribute greater importance to the use of computation in their routines, taking computation away from the workstations and making it increasingly invisible. One of the points addressed in this paper is the question of accessibility in a context unlike any of those dealt with in the specialized literature on disability. Here, the point in focus is that at the end of the procedure known as the 'pre-test' there should be a methodology capable of ensuring the users the accessibility to the technologies in the state-of-art, which are naturally inserted in the users' daily routines. The intention is to link the topics of accessibility and domotics in the context of interface project based on a universal design, meeting the user needs with different characteristics. The design topics are addressed to the general public but focused on users with visual disabilities. The emotional design subject is addressed to obtain a solution that will be satisfactory for all users.

Therefore, to accomplish a persona, a methodology based on the pre-test, observation, and questionnaires (based on emotional design) was applied to users without visual impairment but simulating a recently acquired one to survey the requirements for creating the interface suitable for domotics environments. In this way, the pre-test was done in the University of Brasilia, and a persona with the codename *João-da-Silva* was created after data analysis.

After the execution of the first experiments, the pre-test set was applied to users with partial and total visual disability at the Special Education Center for Visually Impaired People. This second pre-test used the points identified in the first one in addition to administering a questionnaire and direct observation. Therefore a new persona was created with the codename *Mariana*.

By putting the two personas together, it was possible to develop a mobile application making it feasible to automate a domestic environment, making it effectively accessible to any user: with reduced visual acuity, total blindness, or recently traumatized users, as well as the ordinary users with no disability. Therefore, this paper proposes methodologies for developing an accessible interface that uses good practices, standards, and guidelines for a mobile application, achieving all the control and activation of devices in a residential environment. Furthermore, by using a pre-test approach, this work is addressed to give a contribution to the purpose of developing automated residential/commercial systems capable of providing access to Users with Visual Impairment (UVI), but without excluding the possibility of other users accessing the same interface and the same system.

2. Persons with disabilities

A person's disability may be congenital or acquired from some random event in the course of their lifetime. The International Classification of Functioning, Disability, and Health (CIF) considers that deficiencies are problems in function or body structure, such as a significant deviation or loss (WORLD HEALTH ORGANIZATION., 2002). The Brazilian Dorina Nowill Foundation for the Blind considers that persons with visual impairments can be classified into two main groups (DORINA DE GOUVÊA NOWILL, [s.d.]), as following:

a) Blind – there is a total loss of vision or such minimal capacity to see such that the person requires the Braille system to be able to read and write.
b) Poor or subnormal vision – typified by persistent impairment of the visual function even after treatment or correction. The person with a reduced vision can read enlarged impress texts with appropriate optical resources.

With the advent of new mobile devices such as smartphones and tablets, residential automation has gained a great ally in assisting the life of persons with disabilities. In addition to facilitating the access of people with disability, the associated technology generates a better quality of life for that population group. A point to highlight here is that a system accessible to visually impaired users does not exclude seeing users.

3. Relationship among interface, accessibility and domotics.

Carey (1988) defines an interface as a point of contact between two entities. In his view, the interfaces between computers and human beings can be endowed with various characteristics that include the surroundings or context, the dialogue, and the manipulation techniques. This paper focuses on the accessibility of users with visual disabilities in automated domotics environments. Figure 1 shows the various relations among HCI, domotics, and accessibility. The intersections show the possible ties between pairs of areas (namely, intersections *a*, *b* and *c*) and a more specific confluence depicted in the intersection *d*, which is the one this paper will concentrate on. In this context, the *a* relation represents the technology of interfaces proposed by companies belonging to the domotics sector and designed to meet the needs of the general public, involving remote control, command panels, touch screen and other such devices bearing in mind that current domotics systems frequently involve sophisticated micro-processed embedded systems. The *b* relation refers to interface project proposals for a specific public such as people with disabilities but designed for general contexts, not associated with the question of residential automation. Relation *c* refers to the efforts to adapt domotics to users with specific characteristics. In this sense, the respective solutions may involve the use of sensors and electromechanical devices without necessarily mentioning the aspects of the interfaces. Finally, the *d* relation shows a more specific intersection, suggesting the possibility of adapting conventional HCI technology for users with disabilities and directed towards making use of the resources of domotics. In this context, this work addresses the relation expressed in *d*, especially in meeting the needs of Users with Visual Impairment (UDV).

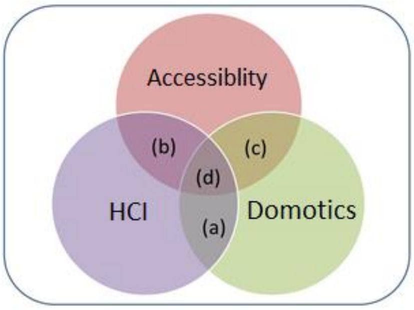

Figure 1. Relations among HCI, Domotics and Accessibility.

Liou (1992) argued in favor of the importance of dialogue and the use of questionnaires and interviews, quality of knowledge acquired, the amount of effort needed, and the skills required to address the user needs. The techniques proposed by Dhaliwal e Benbasat (1990) are helpful for further analysis. Frame 1 shows how data can be obtained from the user.

Frame 1. Methods for studying the user (adapted from [2])

Questions	***Observation***	***Documentary Analysis***	***Advantages***	***Disadvantages***
Questionnaire	Participative Observation	Diaries	Fast and cheap	Solving ambiguities Low response rate Exceeding the timeframe. Late questionnaires may be a write off.
Interview	Participative Observation	Content Analysis	Direct contact with interviewer. The interviewer can ask for further details of the answers.	Susceptible to distortions Expensive and requires training for interviewers.
Delfos Technique		Citation analysis	As in indicator of the future it makes it feasible to establish correlations or prepare for possible events.	Requires statistics skills.
		Library Documents	Systematic approach that requests experts' opinions	Results may no longer be true in the future.

4. Residential automation (domotics).

Automation installed in a domestic setting is known as domotics, a term derived from the fusion of the Latin Domus meaning home and robotics (LI *et al.*, 2016). According to this, a domotics object is a generic agent that can communicate with other environmental agents. Furthermore, to incorporate the technology to become entirely transparent for its user, Weiser [8] introduced the principle of ubiquitous computing, meaning the presence of pervasive computing aspects in residential environments. In this way, for instance, a domestic ubiquitous/pervasive computing environment might interconnect lighting Conte *et a*l. (2007) and environmental controls with an intelligent system so that illumination and heating conditions in a room might be modulated continuously and imperceptibly.

Generally speaking, a domotics system consists of a communication network allowing to interconnect a series of devices, equipment, and other systems to obtain information about the residential environment and its surroundings, carrying out specific actions to supervise or manage it. Devices like sensors and actuators exchange information among themselves or with intelligent central units (in this case, the central automation unit). They are also capable of processing the data received and triggering actions, e.g., equipment parameters, warnings, messages, etc. In some cases, they may receive a confirmation of the actions carried out via feedback mechanisms.

5. The hardware implementation of the on-line discontinuity detection system

a) HCI aspects

In a computational environment, the interface provides access to information, data, controls, commands, and messages. The human-computer interface is defined as the point of contact between the computer and the computer user (CHALMERS, 2003). Moran (1981) states that the interface "is part of the computational system with which the person, physically, perceptively or conceptually enters into contact." The interface is the visible part of the system and, if it has been well designed, it generates positive feelings that sustain a good Human-Computer Interface (HCI). A well-designed interface makes the interaction with the system more natural to learn and use (enhanced usability).

Figure 2 depicts this critical issue, considering the relationship between a user and a system composed of an interface and an application. In this context, HCI involves studying the design, evaluation, and implementation of interactive computational systems for human usability, as well as the central phenomena in the surroundings. In that concern, it is crucial to take four essential elements into account in the context of usability: (i) the system, (ii) the users, (iii) the task, and (iv) the environment (SHACKEL, 1986).

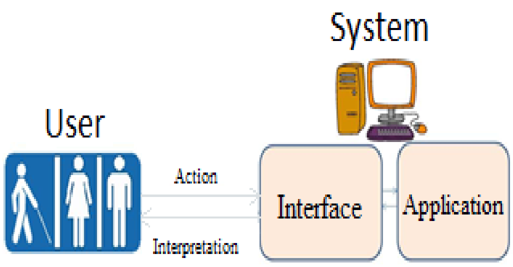

Figure 2. The Human-Computer interaction process (adapted from Revell; Stanton (2016))

Those elements are involved in two essential processes: (a) the user-system interaction and (b) the system development. Interaction is the communication between the persons and the interactive systems. Concerning the first process (user-system interaction), Carroll (1991) reports that the primary key to HCI is understanding and facilitating the creation of user interfaces and, in doing so, to view them as an interdisciplinary area involving some interface, where the primary goals are to (REX HARTSON, 1998):

1. Identify user needs and verify how the designers understand those needs;
2. Identify any interface or interaction problems.
3. Investigate how the interface affects the user's way of interacting;
4. Compare the interface project with other alternative ones;
5. Achieve metrically quantifiable usability objectives, and
6. Check for conformity with a standard or a set of heuristics.

The second process (the system development) must be approached from the methodological point of view, which involves recommendations based on an assessment of interactive systems, bearing in mind the user-system interaction process described above. To that end, a study must be conducted of the user's behavior, emotions, and expectations regarding the system, to ensure that it will be more accessible and directed at addressing their specificities.

b) Emotional Design

In a real-life context, the design is oriented by the experiences and emotions of the final user of the creation, which is why the study of the individual is so essential to the process of creating the system design. Whatever design the designer comes up with should be capable of triggering a specific emotion in the user. According to Demir et al. [23], one of the leading causes of emotion related to happiness and contentment (regarding the product design) is the consistency of the motives that led to the acquisition of the particular product. That being so, contentment and satisfaction involve evaluation of (a) awareness of the cause and (b) fulfillment of expectations (DEMIR; DESMET; HEKKERT, 2009).

Emotional design attributes great importance to the aspect of the user's emotions, taking into account: (a) specific user tasks and (b) activities associated. Therefore, it is essential to hear what the users have to say and attempt to satisfy their needs. That will ensure that they will be able to carry out their tasks autonomously and with accessibility appropriate to the needs of each group of disabled. The emotion that each system user invests in carrying out a task must be considered to create interfaces dedicated to addressing each kind of user group. For that reason, this paper establishes a research method for investigating user needs in the context of the concepts addressed in this section, based on pre-tests, interviews, questionnaires, and observation, whereby a set of system users (with varying degrees of visual impairment) are submitted to the process of navigating in previously defined interfaces. Therefore, we have decided that emotional design issues should also be included. Accordingly, the objective is to define techniques that help accommodate and express the differences between the system users with visual disabilities. Therefore, we will focus on the best interface methodologies in the sphere of domotics organized according to archetypes or personas that are representative of the profiles of visually impaired users.

c) Tasks versus Activities

The requirements analysis of the tasks and the user's needs can be done when the analysts are generating a description of the work process. User requirements are one of the most significant factors behind the failure of IT design, especially in accessibility and usability issues (MKPOJIOGU; HASHIM, 2016). The task analysis aims to provide the designer with a vision of the users and the steps they need to carry out. Limbourg *et al*. (2005) state that task modeling consists of formalizing the tasks to be able to map them in the graphic interface.

Otherwise, the description of the activities and their steps involved should be orientated by the specific objectives to be achieved. In the case of multiple activities, it is necessary to study tasks whose occurrence can be predicted, as well as the possibilities of anticipating tasks, the possibility of sharing tasks by different operators, and any tasks that may interfere with each other.

The activity study is a process involving three basic steps:

1. Analyzing the real situation: studying and interpreting the actual situation;
2. Synthesizing an intervention: planning and executing an intervention in the actual situation;
3. Assessing the new situation: verifying the effect of the intervention, comparing the new post-intervention situation to the former one.

In this work, the tasks and activities are used to understand the user-orientated emotional and visceral design and improve the user's experience whenever they use the accessibility applicative known in this case as Home Affordable – HA. Additionally, an applicative (related to the interface) will be created based on the experiences with the personas created after analyzing and observing the pre-tests carried out with users with unimpaired vision at the University of Brasilia and with users with wholly or partially impaired vision at the Special Education Center for Persons with Impaired Vision (Centro de Ensino Especial de Deficientes Visuais – CEEDV). In summary, the persona was created from the pre-tests with users with both unimpaired and partial vision and given the name João and Mariana.

6. Definition of the pre-tests

a) Definitions

The Pre-tests and Post-tests measure the knowledge acquired by the participants in a qualification process. The pre-test is a set of questions the participants answer before the process to determine the extent of their existing knowledge regarding the contents to be taught. Perneger et al. (2015), the pre-test is a data-gathering instrument designed to ensure the validity and the precision of the terms involved, to verify if the target public understands the questions and answer options proposed, as intended by the researcher,

The pre-test evaluates three aspects of each item: (a) the degree of difficulty, (b) the level of discrimination, that is, to what extent the item differentiates those who know from those who do not, and (c) the possibility of being right by chance. It also determines the proportions of persons who chose each alternative from the answers offered in the test. A test sheet should include difficult items, average difficulty, and easy to answer ones. The number of questions can vary from test to test.

b) About the Persona and the methods used

Cooper (2004) states that the person is a set of information representing and characterizing the user being studied. Therefore, based on a series of interviews with real individuals, the figure of an archetypical (a kind of standard or model user) is synthesized by the persona. In this way, the idea is to apply this concept to develop a product that will satisfy the needs of many types of users. Traditionally personas are elaborated using interviews, live observation, pre-tests, and other qualitative means. However, it is crucial to acquire it, taking into account the knowledge of both the users' social and psychological aspects to gain a perception of the fundamental motivations that permeate their actions (SHACKEL, 1986).

In the context of this work, pre-tests and observations of two groups of users were done in different scenarios. The first environment was the University of Brasilia, involving a group of 20 (twenty) volunteer students all over 18 (eighteen). The idea was to analyze their reactions when confronted with the ambits native to the users with recently acquired visual impairment. The second environment consisted of 21 (twenty-one) users with partial or total visual impairment, all volunteers and over 18, and either students or users of the CEEDV library. The idea was to analyze their reactions when using cell phones, smartphones, or computers with accessibility software, to access the same internet domain as the other groups and carry out the required tasks in a predetermined time.

After the pre-tests with the users with no visual impairments, it was possible to identify the main difficulties facing users who had experienced temporary or permanent trauma and the experience of a user with visual impairment. That enabled the perception of the emotional design for such users and improved the background while creating the applicative.

In the case of the pre-tests carried out at the CEEDV with the volunteers with a partial or total visual disability, it was possible to detect the most significant difficulties preventing those users from carrying out the tasks with the same skill as a likely person with normal vision. The analysis of the pre-tests was related to: (i) the parameters that had led them to choose determined solutions for carrying out the tasks, (ii) which solutions were used most frequently and why, and (iii) which related solutions could be used to improve the applicative in the smartphones.

After the completion of data gathering and processing, it was possible to create the personas that would be the basis for creating the residential automation applicative to ensure accessibility of the system to UVTs, but which could also be used by persons with unimpaired sight and those recently traumatized.

7. Discussion of the concepts adopted in the method

The products designed in Brazil with inadequate financial resources do not offer much support or potential to visually impaired persons. In that regard, Amano et al. [28] have insisted on the importance of dialogue, questionnaires, and interviews as the means to address such users' needs adequately. Frame 1 shows how data can be gathered from potential system users (AMANO, GONZÁLEZ-VARO e SUTHERLAND, 2016).

In our research, the users were analyzed in controlled scenarios to carry out tasks in an environment without accessibility. Therefore, pretests, observation, and interviews were used to study the user and obtain a basis of information to create the personas. This process will assist in the creation of the best possible method for designing an accessible interface for system users with visual impairments in a residential environment.

7.1 Sample-size calculation

To work with a sample in which it is possible to estimate a random variable (of size N), the minimum sample size (n) can be determined by defining an acceptable sample error (e). The acceptable sample error is taken to be the difference (that the research deems to be acceptable) between the value given by the statistical calculations and the actual value of the parameter to be estimated.

$$\mathbf{n} = \frac{\mathbf{N}\times\mathbf{Z}^2\times\mathbf{p}\times(\mathbf{1}-\mathbf{p})}{\mathbf{Z}^2\times\mathbf{p}\times(\mathbf{1}-\mathbf{p})+\mathbf{e}^2\times(\mathbf{N}-\mathbf{1})} \quad (1)$$

where:
n = the size of the sample to be calculated;
N = the size of the universe to be sampled;
Z = the deviation of the mean value that is deemed acceptable to achieve the desired confidence level;
e = maximum permissible margin of error (e.g. 5%);
p = the expected proportion.

In our study, the Federal District was selected as the universe's scope to be sampled, given the impossibility of expanding it to embrace Brazil as a whole because of temporal and financial limitations. The population of Brasilia in 2018 was 208,5 million. Of that number, 388,890 were completely blind, 68,047 had a severe visual impairment, and 6,436 had some degree of visual impairment.

7.2 The Method used

For research purposes, we used the following methods:

1. Pretest, live observation and questionnaire;
2. Analysis of the tables;
3. Creation of personas based on analysis of two groups of system users.

The sample was divided into two parts:
- The first consisted of 20 users (male and female) without visual impairment, student volunteers all over 18. The average age was 30, and the minimum schooling level was a graduate qualification.
- The second consisted of 21 male and female students of the CEEDV with partial or total visual impairment, the average age of 30 and a minimum schooling level of complete primary education.

The first sample was drawn from students studying the discipline 'Special Topics in Communication and Information Mediation: Design Centered on the Information User'. We can highlight that none of the students had any visual impairment. These users had never taken a pre-test for that purpose, and most of the students found it strange. The scenarios simulating visual difficulties were organized in such a way the participants could be evaluated. Furthermore, journalistic material reported on a big national news website was indicated for the pre-test.

In the pre-test of the first sample, we divided the users into two groups: (a) users taking the pre-test using a cell phone, and (b) users who took it using a computer.

The pre-tests of the second sample group with total or partial visual impairment were conducted in the CEEDV, which made available a suitable space, and a document entitled Co-participant Institution Term was duly formalized. Frame 2 depicts the method and tasks used during the pre-test.

Frame 2. Methods for studying the system users

Methods	Tasks
Venue – UnB a) Use of the system with the screen disconnected or with the participant blindfolded. PURPOSE -Simulate the environment of a visually impaired user. b) Use of the Web page in the accessibility mode using different contrast and font size options. PURPOSE – Simulate the environment of a person with a partial visual impairment.	*Simulation of total visual impairment:* Use of the user's favourite browser to access the news site indicated by the pre-test manager and do so with the assistance of previously installed NVDA software, and report a news item that is on the front page of the news site.
c) Use of the keyboard only; the mouse cannot be used. PURPOSE – People with visual impairments use the keyboard to carry out tasks with the computer.	Use the keyboard to go to the menu of options on the front page or a tab to open another as suggested by the pre-test manager.

d) Use of free NVDA software for reading computer monitor screens. PURPOSE – Free screen-reading Software accessible and compatible with windows. e) Use of earphones. PURPOSE – Not to interfere with the other tests

The pre-test of the second sample (total or partial UVI) was performed in the CEEDV. For this, the school needed to make available the place duly formalized by the Term of the Coparticipant Institution. Once the research project and location had been formalized, it was necessary to ensure that the volunteer system users met specific requirements. They had to be: (a) over eighteen (18), (b) literate and with a schooling level equivalent to complete primary education, (c) able to write their full names (for legal reasons), (d) capable of opening a WEB page, (e) capable of writing a short text in a text document and (f) able to use cell phones with an Android operational system.

To validate the user pre-test, the same had to respect the requirement that all volunteers should sign a Term of Free Informed Consent (TFIC). Therefore, the group was divided into two pre-test evaluations: (a) system users taking the pre-test using a cell phone, and (b) those who took it using a computer.

On average, the pre-test, including the questionnaire and the interview in which the user answered questions present in the three research instruments, lasted one hour. The user was guaranteed the right to withdraw from the process at any moment without there being any retaliation or negative repercussion for doing so. The stages of the pre-test are set out in Frame 3.

Frame 3. The pre-test stages

First stage of Pre-test	Second Stage of pre-test
Venue: CEEDV	
1) Invite system users to take the pre-test.	1. Enter the site: <http://g1.globo.com>
2) Presentation of the researcher's personnel.	2. 10 minutes to navigate the site and know its structure
3) Presentation of the individual system users.	3. Find the specified item from page material suggested by the researcher
4) Presentation of the work proposal.	4. Find the suggested multi-media content.
5) Start of the pre-test with step by step explanations.	5. Use the site search icon to find second suggested material in secondary pages

The details of proceeding in each scenario consisted of a series of tasks, as described in Frame 4 and 5. The system users were free to choose to sit the pre-test together with others or individually. At the end of the pre-test, the person was invited to answer a questionnaire with some questions referring to the test and others asking them to describe how they felt when they were taking it. That was part of the intention to obtain the user's emotional design, and after that, the person was asked to make suggestions as to how the page could be improved or how an applicative that they preferred could be better adapted.

Frame 4. Description of tasks and scenarios for the pre-tests for participants with partial visual impairment

Scenario	Task
User with partial visual impairment	1) Use of the user's favorite browser to access the news site indicated by the researcher.
Using a computer	2) Access the page's accessibility module.
	3) Verify whether the front page news item was fully understood.
	4) Access the video available via the video tab, verify if there is an option f subtitles and if there is, verify if there are font size options.
	5) Verify if there were any problems with the links and advertising.
	6) Locate a specific item indicated by the researcher using the site's searcl engine.

User with partial visual impairment Using a cell phone with an Andrc operating system	7) Use the cell phone's accessibility function to access the suggested site. 8) Access the front-page news item. 9) Verify whether the page size increases with a touch of the cell phone oı the house is accessible itself. 10) Access the video available via the video tab, verify if there is an option f subtitles and if there is verify if there are font size options. 11) Verify if there were any problems with the links and advertising. 12) Locate a specific item indicated by the researcher using the site's searcl engine.

Frame 5. Description of tasks and scenarios for the pre-tests for participants with total visual impairment

Scenario	Task
User with total visual impairment Using a Computer	1.Use of the user's favorite browser to access the news site indicated by the researcher. 2. Verify the front-page news item using NVDA text reader software. 3. Check whether the page has an accessibility option, images, and icons reader that obeys W3C directives. 4. Using the sites accessibility mechanisms, watch a video and check whether the suggested news item being heard or read is the same and whether the user notices any differences. 5. Locate the site's search icon and access the second suggested news item. 6. Verify whether there were any problems with the links and advertising.
User with total visual impairment *Using a cell phone with an Android operating system*	1. Use the cell phone's accessibility function to access the suggested site. 2. Access the front-page news item using the cell phones talk back function. 3. Check whether the page has an accessibility option and graphics, images and icons reader that obeys W3C directives. 4. Using the sites accessibility mechanisms watch a video and check whether the suggested news item being heard or read is the same and whether the user notices any differences. 5. Locate the site's search icon and access the second suggested news item. 6. Verify whether there were any problems with the links and advertising.

Once the University of Brasilia and the Ethics Committees, and the CEEDV had granted permission to carry out the experiments, the pre-tests were conducted with the participants with partial and total visual impairment. In that context, the steps taken were as follows:

1. UVI uses the system to criticize it.
2. They carry out the tasks set.
3. They made considerations.
4. They answered the questionnaires and conducted the interview.
5. Tables and analyses were achieved.
6. Graphs were accomplished.
7. The personas were obtained based on the pre-tests.
8. The creation of the application based on the personas was introduced.
9. Application and simulation in a test situation and domotics situation were achieved.

8. Description of the personas based on the pre-tests

The creation of the personas was based on those characteristics most commonly detected among the dissatisfied users and the satisfied users. Those were arranged in graphs and tables to facilitate the analyses. In addition, subjective responses were also taken into account, analyzed and inserted in graphs and tables in the same way. In that way, it was possible to create a persona named *João da Silva* based on the pre-test data gathered from the UnB students and another called *Mariana Cordeiro* based on the data gathered from the CEEDV volunteers. Each of the personas was designed to answer the following questions:

1. What real problem regarding poor accessibility did the system user identify?
2. Which trajectory or trajectories did the participant follow to overcome that difficulty?
3. How did the system user feel about the pre-test experience?
4. What led the user to choose or not the proposed interface model for testing?

Once the personas were created, it was possible to implement a graphics interface that addressed all the primary requirements formulated during the pre-tests, facilitating the learning process for the use of the applicative and reducing the time taken to carry out the desired actions. Frame 5 shows the persona generated from the pre-test data, including an illustration of the persona on the left and a description of the persona in the other columns.

9. The choice of the accessible interface based on the persona João da Silva and the persona Mariana Cordeiro

After studying the system users and the development of the personas (João and Mariana), the information was used to create an accessible interface for the domotics system that would not exclusively contemplate the use of those with visual impairments embrace all users. Figure 3 shows how the accessibility methodology was used, and clearly, this interface does not exclude other users with no impairments.

It is possible to solve most of the problems associated with poor accessibility, identified during the pre-test stage, using W3C standards. Frame 6 depicts the conclusion of the pre-tests carried out at the University of Brasilia. Frame 7 is the conclusion of the pre-tests carried out at the CEEDV. The layout was adjusted in order to better address the perspective of the personas with no visual impairments. Figure 4 shows both the options menu and configurations screens which conform with the W3C standards and the layout.

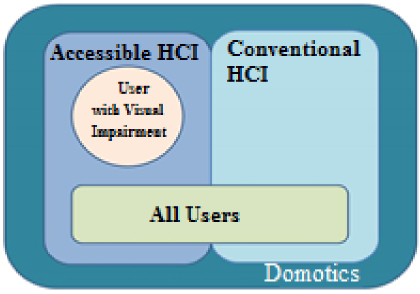

Figure 3. Diagram correlating accessible and conventional HCIs

Frame 6. The Persona João, a user with no visual impairment.

Personal information		IT knowledge:	Observations:	
	*Name*: João da Silva. *Age*:30. *Schooling*: Masters degree student. *Residence:* Federal District. *Marital Status:* married with children. *Employment:* Public sector Degree of visual impairment: None	*User declares:* Satisfactory knowledge level in that area. He can search the internet, access a video, create and edit texts and spreadsheets among other skills. He uses a computer daily in his work, for studies and leisure.	*User declares himself:* He is communicative and capable of exercising his function with the aid of a computer; The emotional pattern during the pre-test: Challenged and motivated to undertake the activity.	*Emotional pattern after the pre-test:* Dissatisfied, disappointed, pensive and especially frustrated. Reassessed certain operations that he had previously thought to be easy and considered the possibility of learning new ways of handling his computer. He was unable to use the computer's shortcut options and did not know how to use the keyboard without being able to see it.

Frame 7. The Persona Mariana, a user with visual impairment.

Personal information		*IT knowledge:*	*Observations:*	
	*Name:* Mariana Cordeiro. *Age:* 30. *Schooling:* Complete higher secondary education. *Residence:* Federal District. *Marital status:* Single, no children. *Employment*: Studying for civil service entrance exams. *Degree of impairment:* Congenital blindness.	*User declares:* She is merely basic IT knowledge but navigates in the internet daily. She can conduct searches, access a video, create and edit texts but for Mariana, the use of the computer is more addressed to accessing social networks and reading the news, and she indeed prefers to do that with her cell phone. In her daily use of the computer, she uses the NVDA screen reader to help her to study for the civil service entrance exams and also for leisure purposes.	*User declares herself:* Communicative but a somewhat inhibited when she has to work with computers because of her difficulty in carrying out some functions. She states that most of the site she tries to access, they do not have accessibility. Her main complaint is the lack of descriptions for the buttons, images and icons and the use of tabular sites and the excessive numbers of drop downs. She prefers to use her cell phone for specific actions. She uses a free screen reading	*Difficulties during the pre-test.* Lack of descriptions and subtitles for images and icons. Lack of descriptions for the icons on the video navigation bars. Lack of audio descriptions and subtitles that could be read on the videos. The excessive number of adverts and automatic links in all parts of the site, especially in the video area, were a great hindrance. The excess of page updates retarded the screen reading process and jeopardized understanding. Menus and marking boxes combined and hard to access. The absence of voice command options for conducting searches or carrying out other actions.

		software called NVDA to access the computer. When using her cell phone or tablet, she uses their accessibility resources. Using her android cell phone for about a year, she found it difficult at first but after four (4) months she could already manage to do most of what she wanted to do on the cell phone. Emotional pattern during the pre-test: Challenged and motivated to carry out the activity.	The excessive and disorganized use of links makes navigation difficult. A sound signal announcing the opening of a link would be helpful. She felt lost Emotional pattern after the pre-test: After many attempts, Mariana managed to carry out the requested tasks but she was still lost concerning icons and links with no descriptions, and she doubted whether she had been successful with the tasks. She felt frustrated and angry because the site locater was an image with no description, so she wasted much time. At the end of the pre-test, she was dissatisfied with her performance of the activities.

The most relevant questions were utilized to know and understand the user's profile. In that way, the emotional pattern was also taken into account, that is, the difficulties and feelings experienced during the pre-test and questions related to the users' daily lives. The idea behind the method was to remove the leading cause for users' complaints and endeavor to satisfy their expectations concerning the interfaces.

Several user tests were carried out to verify the interface model to determine if the interface did meet the parameters set by both João and Mariana regarding mobile devices. In this way, the accessibility interface model was capable of satisfying the needs of both João and Mariana simultaneously.

(a) (b)

Figure 4. (a) Main screen options; and (b) Prototype for door in the interface.

10. The test stage of the model developed to address the needs of the personas João da Silva and Mariana Cordeiro

To test the method used for the mobile interface, a model house was constructed as in Figure 5. it is composed of four led light bulbs as in Figures 5, and an entrance door Figure 5.a and 5.b. To enable the door to open and close without requiring a second command, a chopper-type electronic power circuit referred to as an H-bridge was inserted in the automation control center, as shown in Figures 6.a and 6.b. That enabled the users to test their considerations regarding the accessibility of the HA applicative. The final version of the prototype is depicted in Figure 6.c.

(a) (b)

Figure 5. (a) Prototype from above model house, and (b) Automation control centre composed of an Arduino-Mega board and an Ethernet

(a) (b) (c)

Figure 6 (a) prototype door from the back, (b) prototype door from the front, and (c) final prototype

The tests were conducted at the University of Brasilia to validate the method used to create the accessible interface enabling people with impaired vision to control their residences using mobile devices, involving three blind persons and three with no visual impediments. The test consisted of these steps:

1. Download and install the software aplicativo.spk to the user's mobile device. The light bulbs represent all the possible devices that could be activated, and that could be installed in residence and the door represents all the possible sensors.
2. Locate and open the applicative on the desktop area of the device.
3. Describe the initial screen.
4. Access the page information button.

5. Access the menu that controls the lights on the initial screen display and switches on one or more lights. That can be done by pressing the "switch on" button or using the "voice command" option.
6. Navigate using the navigation keys "back", "forward" and "home".
7. Access the menu giving access to the door/gate on the initial screen display and activate it using the card or the "voice command" option.
8. Access the "manual" option on the initial screen display and check the accessibility.

11. Conclusions

The use of questionnaires, pre-tests, and interviews can be a powerful ally in the endeavor to improve those interfaces given the knowledge they provide and add to the characterization of possible users with disabilities. In this study, each user was invited to report any difficulties and offer suggestions for improving the interface of the applicative. In the applicative's users, it does comply with and obeys the W3C accessibility norms and guidelines. Getting to know the user's profile is a highly significant factor in creating accessible interface methodologies for automated domestic environments. It is essential to collect a whole set of information during the pre-tests that can be used efficiently and conveniently. The use of such information was boosted by making use of a representation of the user in the form of a persona. Creating the personas made it possible to propose a graphic interface capable of addressing the main requirements that emerged during the pre-tests, thereby facilitating the learning process and reducing the time spent in carrying out the desired actions, and making it possible to descry the eventual applicability of the method proposed.

The interface project is susceptible to discussion and testing by users with visual impairments to develop a cyclical project with a spiral configuration. Such a project can be orientated by the role (tasks) or the profile (data) of the system users. Given that the environment in question is an automated residential one in which the domotics are required to be accessible to every and any type of user, it is crucial to ascertain whether the respective emotional patterns can be used to obtain a satisfactory solution.

The user's relations with technology must not be a reason to attenuate the comfort or convenience they enjoy in residence because it is a highly familiar place. The use of questionnaires, pre-tests, and interviews can be a staunch ally in the endeavor to improve interfaces bearing in mind the information that they contribute to the process of characterizing the possible users and their impairments.

During the pre-tests, the techniques of live observation and interviews revealed that the lack of accessibility within the ambit of the site itself was the factor that presented the students with the most significant difficulty in their efforts to carry out the designated tasks. That showed the urgent need to carry out work to arouse social awareness, especially among those planners and administrators responsible for the norms that should be incorporated into the projects' systems at the outset. In this sense, there was a considerable difficulty experienced in carrying out the tasks, and none of the groups managed to complete all of them; and It proved possible to show the importance of the following aspects:

1. Getting to know the users' needs by using the techniques mentioned in the description of the execution of the proposed method.
2. Use simple language when addressing the user and implanting the interface.
3. Avoid requiring users to exert too much in executing simple tasks.
4. Organize information clearly and logically.
5. Provide sufficient information for the user to clearly understand what is being asked of them.
6. Use the W3C rules to manage the layout.
7. Allow the users to configure the system in a customized manner of their own.

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