Evaluating the Interaction of Users with Low Vision in a Multimodal Environment

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***Abstract*—This paper presents the PlatMult environment, a multimodal platform that aims to provide accessibility in interactive kiosks to users with low vision and elderly ones. The PlatMult solution is composed of a screen magnifier (visual stimulus), a screen reader (auditory stimulus), and motor feedback (tactile feedback). The evaluation of the interaction with users with low vision is described, focusing on usability and accessibility aspects. This paper also discusses the potential of the platform for social and digital inclusivity. We conclude that the PlatMult, with its integrated features, helps users to access and use information systems in a suitable way.**

Keywords—PlatMult environment; low vision; usability; accessibility.

I. Introduction

The advances made in Information and Communication Technologies (ICT) have resulted in benefits to society in many fields like industry, services, and even social inclusion.

ICT provides facilities to citizens, especially with regard to accessing, publishing, and sharing information. As an example, we can mention the automatic teller machines (ATMs) and interactive kiosks available in banks, bus terminals, airports, and libraries.

Despite all the progress that has been made, there are some people who cannot benefit from these technologies. Although many of the technologies are useful for people with disabilities, these people tend to have less access to these solutions. This work focuses particularly on those with visual impairments.

Among people with visual impairment a large contingent falls in the group with low vision. According to the classification of the World Health Organization (WHO), low vision refers to individuals who can only see an image at 20 feet (about 6m) where a person with normal vision would see it at 200 feet (about 60m). For Corn and Erin [5], low vision is a condition characterized by vision lag, where correction or improvement cannot be achieved by surgical means or solved with the use of conventional glasses.

Assistive Technologies (ATs) have emerged as an attempt to guarantee the same access rights to these people. AT, according Cook and Hussey [6], is a wide range of equipment, services, strategies, and practices designed and implemented to mitigate the problems faced by individuals with disabilities.

The implementation of hardware and software components, with increasing consideration given to the accessibility, usability, and adaptability features in their solutions, is now a reality. The challenge has been to seek simpler interfaces which can be immediately assimilated and handled correctly by users.

This work proposes a multisensory platform called PlatMult, implemented under the free platform philosophy, which is oriented towards but not restricted to people with low vision. Here we present some of the main results and discussions emerging from tests that we have conducted on our solution involving users with low vision. The methodologies adopted in the evaluation of PlatMult are based on the Nielsen's Heuristics [10] and usability principles. We therefore, seek to identify and correct the problems and gaps found in its interface. As a result of the interaction evaluation, changes are proposed to provide a better user experience.

This paper is organized as follows. Section II presents some related works. In the Section III the PlatMult platform is described. In Section IV, a brief description of the evaluation methods used is given. In Section V, the methodology used is described, and in Section VI the main results obtained up to now are discussed. The conclusions as well as future works are presented in Section VII.

II. Related Works

iBrowse interface software [12] was developed to help visually impaired people to access Internet. The software, adopted a similar designing strategy of the previously implemented LowBrowse software which acted as an extension add-on of Firefox browser. Its implementation, instead of following the traditional magnification technique, allows the low vision users to adjust parameters, such as font size, color and spacing, and then to read all the websites in their maximum reading efficiency. The tool provides also a screen reader using the traditional text-to-speech (TTS)

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technology. In terms of implementation this solution uses the same Firefox plugin strategy we have adopted in our implementation but differently of our proposal changes the webpage content and do not furnish interaction motor feedback.

Sandhya and Devi [14] evaluate the level of accessibility in AJAX content and JAWS screen reader. AJAX stands for Asynchronous JavaScript and XML. AJAX allows feature-rich, dynamic web applications which use server-side processing without requiring the traditional submit or retrieve webpage methodology. If the screen reader is not prepared to this asynchronous updating, it will harm the user interaction. Moreover, the screen reader is limited to read images, advertisements banners and big data tables. Despite the authors list some recommendations to make screen reader accessible in webpages content, no user evaluation was done.

Tae et al. [8] propose an interactive kiosk for blind people with tactile interface (braille) and voice to identify images and characters on the screen area. Saito et al. [13] present flexible solution for blind and deaf people. Using a touch screen interface it can magnify images in different sizes and the both use voice messages and braille input. Tichy and Steinbrunner [15] have developed a tactile feedback for cursor control device with haptics.

Differently from the above cited works, this paper presents and evaluates the user interaction with the PlatMult platform, a tool developed specially to provide accessibility for low vision people. The main characteristic of this solution is the use of three different axes of interaction: visual, auditory and tactile.

III. THE PLATMULT PLATFORM

PlatMult [3] is an integrated solution of hardware and software developed to provide a multisensorial environment in interactive kiosks and ATMs, providing accessibility for users with low vision and elderly users. The solution (Figure 1) uses three areas of interaction: visual, audio, and tactile, which are integrated into a single solution, making it possible to provide users with better experiences.

One of this project's requirements is a low cost, to allow access to a great number of people. To assemble our prototype we used parts of computers and cell phones discarded by people and companies. The carcasses of slot machines were used as shown in Figure 2. It is important to highlight that slot machines are prohibited in Brazil, so the ones used in this project were donated by the Brazilian courts. The hardware platform uses a desktop computer with the following configuration: a Celeron 2 GHz processor with 1 GByte RAM and a 40 GByte hard drive. This configuration uses restricted hardware resources with outdated processors which can also be obtained through donations from organizations.

Additionally, the entire implementation was based on the free software philosophy. Ubuntu is the operating system used in this project; the windows manager is GNOME and the graphics server; see Xorg [16]. For accessibility features, the Assistive Technology Service Provider Interface (AT-SPI) library [1] is used. In this project, all the developed applications are free.

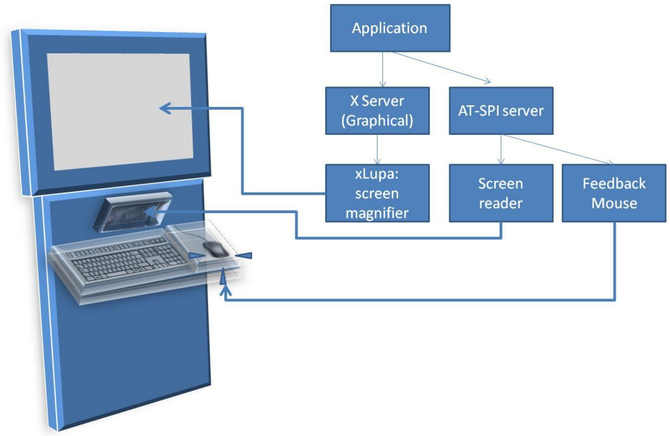

Figure 1. Overview of the PlatMult environment with the visual, auditory, and tactile components

Figure 2. Prototype of the PlatMult

The component responsible for providing the visual stimulus is the xLupa, an adaptative and free screen magnifier. The characteristics of the screen magnifier are full screen magnification and configuration of brightness, contrast, and the magnification factor. Additionally, the xLupa provides a mouse configuration, enabling the user to increase the pointer size or even change to a cross-pointer type.

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Besides the visual features, there is also a screen reader to read texts as well as menu items, buttons, windows, and so on, based on the events reported by the accessibility Application Programming Interface (API) or AT-SPI. The screen reader was designed to warn the user about his or her actions, such as removal or insertion of characters in a text. The voice synthesis process is accomplished by eSpeak free-software; see [7].

The tactile stimulus is provided using a mouse with a motor feedback feature. The tactile feedback is activated when the mouse pointer is over menu items, links, and figures inside a webpage.

The feedback circuit in the mouse is constructed at low cost and aims at ease of implementation. To vibrate, the mouse uses the same principle as cell phones, which means that there is an engine with unbalanced weights on the axis. Such vibration occurs when the engine is activated and the weight causes the device to vibrate. Starting the engine requires 5 V and thus it is possible to use a parallel or USB port. So, the adapted mouse is connected to the PS/2 port (for normal operation) and to the parallel or USB port to receive vibration commands. Figure 3 shows a mouse that was built in this project. The vibration engine is glued to the mouse to allow tactile feedback.

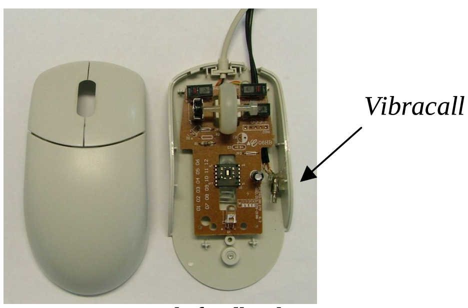

Figure 3. Mouse with feedback motor

The tactile server is implemented according to the same principle as the screen reader and uses the events generated by the AT-SPI.

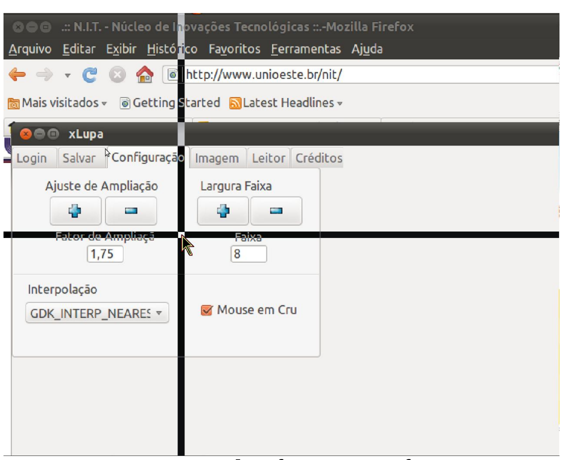

Figure 4. Example of xLupa configuration

Figure 4 illustrates one configuration screen for adjustments of the magnification factor and mouse size that permit user adaptation to environment.

IV. EVALUATION METHODS

The human–computer interface (HCI) evaluation is the process where the evaluator judges the quality of use of an HCI solution and aims to identify problems in the interface which may spoil the user’s experience.

Due to several factors, such as the gathering bad or wrong requisites and implementation problems, the final result of a development process is not always a good quality product. The evaluation of these products makes it possible to release higher quality products.

During the software development process it is possible to identify two very distinct groups of actors involved. The first group comprises the people responsible for the final product concept, and the second, the people who will use the software. Because of this, an evaluation is performed from two different perspectives: the developers’ and the users’ perspectives, to guarantee that the product will be of higher quality.

From the users’ perspective, the interaction with the system and how to achieve their goals will be evaluated. Aspects like usability, accessibility, and the interface’s communicability issues need to be considered.

There are various methods of HCI evaluation, which can be classified as investigation, observation, and inspection described for Barbosa and Silva [2], and Rogers, Sharp and Preece [17]. The investigation methods normally allow the evaluator to find out the users’ opinions and expectations of a system. On the other hand, the observation methods provide data about usage situations, allowing the identification of real problems. Finally, the inspection methods allow the evaluator to predict the consequences of design decisions.

The evaluations performed on PlatMult were an inspection evaluation using Nielsen heuristics and an observation evaluation using a usability test. As a first inspection evaluation and because the team expertise in Nielsen's Heuristics, we opted for this method, although other methods of evaluation are being explored to continue the evaluation process.

The use of Nielsen’s set of ten heuristics is a method that was created to find usability problems during the design process; see [10] and [11]. The severity rating for each problem takes into account three factors: frequency, impact and persistency.

Given these three factors, the severity scale varies from a cosmetic problem to be solved if there is enough time in the project’s schedule to a catastrophic problem which needs to be solved before the end of the project.

The usability test is an evaluation method where real users evaluate the software’s interface according to usability factors like ease of learning, task memorization, user satisfaction, productivity, and error prevention.

Usability tests aim to evaluate the usability quality present in software, mainly by evaluating the user’s performance when using the software [17].

With the usability test it is possible to evaluate the user's success rate when performing a task and the number of mistakes made, allowing those mistakes to be classified. Basically, according to Barbosa and Silva [2] and Rogers, Sharp and Preece [17], a usability test is composed of the following tasks:

(i) Preparation, which includes a creation of a guide containing the tasks which must be performed by the participants, recruiting a group of appropriate users, preparing the material for observation and recording, and finally executing a pilot test.

(ii) Data gathering, which aims to observe and register the performance and opinions of the participants during the controlled periods of use.

(iii) Interpretation and (iv) consolidation of results. This step includes gathering, counting, and summarizing the data collected from the participants and compiling a report of the results.

V. METHODOLOGY

PlatMult as a whole was inspected by three evaluators based on the Nielsen heuristics in an attempt to identify violations of these heuristics, which were documented according to the aspect, location, and degree of severity. For each violation, possible solutions detected for the problem are proposed.

Since the initial platform conception, experts such as ophthalmologists and teachers who work directly with students with low vision, as well as a group of low vision users participated in the process of requirements elicitation and interaction design. For the user tests presented here, two users were selected given their stereotypes. This small group was chosen to enable intensive and controlled evaluation, in order to proof the concept. All tests were followed by the experts and developers. In the future works, other usability tests will be proposed, involving other users.

Two users participated in the validation tests performed here, both of whom have low vision and significant hearing deficiency. They have beginner-level ability in the use of the Linux Operating System and the screen magnifier xLupa incorporated in PlatMult. A teacher specialized in special education also helped the testers and the appraisers to carry out the tests during the experiment.

Although, at first glance, the number of testers may seem low, the results obtained are expressive because the users have multiple deficiencies and are young. One is a teacher of students with visual deficiencies in the public education system and the other is a student enrolled in the special students class maintained by the public government. This student, besides being blind and deaf, has a severe debility of his right hand which obliges him to use his left hand despite being right-handed.

It is worth mentioning that although they are both users with some knowledge of computational environments, they have undergone training in the use of the xLupa magnifier delivered by other members of the project. In both cases, outside of the university or school where the project is being developed, their use of computers is infrequent, and this was their first contact with a screen magnifier. One of the users frequently uses a computer with a voice synthesis solution called DOSVOX, described for Borges in [4].

The guide which was followed in the experiment was elaborated so as to reflect everyday use and the proposed use of PlatMult. During the tests, the users completed a series of tasks including an Internet search scenario. For each task, we were able to evaluate the interaction, identifying problems encountered in utilizing the platform. The results include the total number of errors and the time needed to complete each given task.

The test guide was divided into two parts, the first with the xLupa activated and the second with all three features (visual, tactile, and auditory) available on PlatMult activated.

A. Usability Test – Scenario 1

In the first part, the following tasks were given to the users:

a) Activating xLupa, preferably without the automated initialization feature activated. The aim was to test whether the user was able to identify one of the two possible ways to initialize the screen magnifier.

b) Setting up his or her profile on xLupa, selecting the magnification factor and the color pattern which were more suited to him or her. This test also involved configuring the mouse pointer and applying the antialiasing algorithm to the text and images.

The objective of this task was to verify whether the user was able to manipulate the menus for changing the magnification factor and color. The task provided answers to the following questions: Is the user capable of identifying which factor and/or patterns have been selected? Is he or she able to differentiate the selected configuration from the other available ones?

These two initial tasks, (a) and (b), were also used to verify whether the basic configuration applied was adequate for a good experience of the utilization of xLupa or whether it was necessary to make some adjustments to the settings, which had to be set up every time until they were considered satisfactory. The objective was to verify whether the users had sufficient knowledge to perform such adjustments.

c) Initializing the browser Firefox, accessing Google's webpage, and searching for information specified by the evaluation team.

This task was done to identify the degree of ease/difficulty of use, and the users performed the following tasks:

d) Finding the Firefox URL address bar;

e) Typing in the desired URL address;

f) Finding Google's search field;

g) Finding the link indicated by the evaluation team;

h) Finding the solicited information on the webpage.

B. Usability Test –Scenario 2

The stages of the second usability test were very similar to those of the first; however, the steps related to the xLupa's configuration were not repeated, and the users had to perform the following tasks:

a) Activating the screen reader on xLupa's configuration window.

This task aimed to determine whether the users had enough knowledge of how to activate the screen reader, and if so, to determine the degree of ease/difficulty with which they performed the task. If they were not able to do it, the study aimed to find out the reason why.

b) Initializing Firefox, and, with the plugin and screen reader activated, accessing Google and searching for different requested information so that the process would not be repetitive. These actions were performed with the objective of observing how these features influence the user's experience.

One of the first actions performed by the users was based on the initial configuration of the profile of each user and comprised adjusting the tool's functionality, more specifically the magnifier, and their visual needs.

The participants, aided by the teacher who watched them, answered a questionnaire post-test inquiring about the utility of the environment, difficulties with the interactions, their motives, and alternative ways to make the platform easier to use. Questions were also asked about the prototype's ergonomics.

VI. Results and Discussion

This section presents the results gathered after the application of the inspection and observation methods.

A. *Nielsen heuristics evaluation*

In this section, only the violations of the Nielsen heuristics will be reported.

User control and freedom: A problem occurs at the visual acuity selection screen and color scheme selection. If the user selects an inappropriate magnification factor and/or color scheme, he or she will have some difficulty solving the problem because the only way to do so is to close the magnifier, restart it, and then redo the configuration process. This was classified as a problem because this process tends to be hard for users with low vision to perform without help.

The results showed, however, that this difficulty may be considered cosmetic, given the fact that this functionality is accessed during the profile's initial configuration, and with the automated loading of the last saved profile, it becomes a minor problem. With regard to the platform itself, however, the most appropriate solution would be to add a button giving the user the option to restore the default settings without closing the software.

Another violation of this heuristic was found under the "Save" tab with regard to the "Remove" button, which executes the operation as soon as the button is clicked without giving the user the option to cancel the action. As a solution to this violation, the addition of an alert window asking the user to confirm the action is suggested.

Consistency and standards: One problem was found at the configuration screen. On the "Save" tab, the options "Save" and "Update" perform the same operation, and because of this, the user may get confused as both operations store current user information. The problem was classified as small, and the solution to this problem would be to automatically update the user configurations, rendering the "Update" button useless; therefore, the "Update" button would be removed and only the "Save" button would be left, which would only be used to create a new user profile.

Match between the system and the real world: One problem in this category was detected at the configuration screen. Under the "Configurations" tab, it was difficult for the user to understand the meaning and effect of the feature "Strip width". The problem was classified as small, considering that the user does not use this feature often. A possible solution would be to name the feature differently, for example as "Cross-pointer size".

Another violation of this heuristic can be found at the configuration screen, under the "Configurations" tab, with regard to the selection of the type of Interpolation. The terms which identify the types are technical and are related to the implemented framework. The problem was classified as small. A simple change of names and descriptions to less technical terms would be sufficient to fix this problem. Another possible solution would be to move these options to a new tab called "Advanced Configuration", since it is a feature that is accessed by individuals who aid users with low vision.

Another problem at the configuration screen was found in the "Image" tab. A violation was found in that the term "Image" does not inform the user about what types of configurations this feature handles. This problem was classified as small, and could be easily fixed by changing the tab name to "Image settings'.

Another problem was seen at the configuration screen under the "Image" tab, where the labels on the checkboxes "Change theme" and "Gray" were not clear to the users. The problem was classified as small and could be fixed by a simple change of the names to "High contrast" and "Shades of gray".

Another violation of this heuristic was found at the configuration screen, under the "Reader" tab, with regard to the buttons "Play" and "Stop", which are both written in English. However as the program will be used by Portuguese-speaking users, the labels should be translated into Portuguese.

At the configuration screen, under the "Reader" tab, the label "Speed" is too vague and does not represent the function properly. The solution would be to change the label to "Reading speed" or "Reader's speed".

This was the first inspection performed of the interface of xLupa, and it could be very helpful to allow the developer team to make improvements for users with low vision. Furthermore, it is through the xLupa's interface that the user interacts with the system.

B. *Usability test results*

To complement the evaluation, the usability test was performed to verify the performance and level of satisfaction of the two real users with low vision when they interacted with the PlatMult platform to execute everyday tasks as mentioned above.

During the tests, the evaluators reported that the mouse pointer was too small before the initialization of xLupa, which would cause difficulties for users with low vision. In addition, the speed of movement of the pointer was another difficulty.

There were moments at which both testers got lost in the middle of the information shown on the screen. The main reason for this was the vertical rolling, an essential feature in an amplified screen, where not all of the information will fit on the screen. In situations like this, it is necessary to carry out user training.

The evaluation team had difficulty understanding what the screen reader was saying in some cases, especially when browsing the Internet.

Another problem was the operating system update notifications, which overlapped the information that the user might have wanted to find.

The users reported that the motor feedback mouse was very useful, especially for browsing the Internet, because it helped in identifying useful information on screen.

As for the screen reader, the users reported that it was very useful, mainly when typing text, and they did not report any problems with it. Finally, it is worth mentioning that this analysis works being done with these students prioritizes not only visual stimuli but also pedagogic tasks and cognitive aspects.

The students' interaction with the group was positive, because they were submitted to basic informatics concepts, memorization exercises, and reading and writing texts. It was observed that these exercises contributed to developing the visual part and main focus of our work.

VII. Conclusion and Future Work

This paper presented the process and results of a usability evaluation of the PlatMult environment by inspection and observation, which is important in the current state of the project, where improvements to the interaction and interface will be made.

In the tests, both users with low vision mentioned the mouse pointer speed as a problem. One suggested way of fixing this problem would be to integrate an option to configure the mouse speed on xLupa's interface.

The screen reader proved useful and efficient. Despite this, it is recommended that users with low vision should not use screen readers, to avoiding discouraging them from training their vision.

With this experiment, it is possible to conclude that the PlatMult, with its integrated features, helps users to access and use information systems in a suitable way.

Although these tests were performed to evaluate the features of the tool's accessibility, it is worth mentioning that investment in this platform is justified by its different areas of applicability. The present solution can be useful in ATM terminals of banks and also in sectors of governmental services like public libraries and schools.

In future works, some observed violations of the Nielsen heuristics will be fixed in the interface. The interactive kiosk is then expected to have a high degree of accessibility for the final user. During the usability tests, one of the difficulties identified was the mouse pointer size and speed before the activation of the screen magnifier. One solution, using shortcut keys to activate and configure some parameters of the screen magnifier, is being developed by the team. Additionally, the magnifier can be configured to be initialized together with the operating system startup, removing the difficulties of running xLupa.

Others inspection methods such as Cognitive Walkthrough described in [9], and ISO 9241-210 will be better investigated and applied.

Another point which was identified during the test was the notification interface of the operating system. In this case study, the operating system was run using its default configurations, which included alerts about package updates. With the aim of standardizing and easing installation on new machines, a new repository will be set up containing the packages and an operating system installer which includes all the accessibility features of PlatMult. The operating system will be configured so that alerts are not shown while the system is being used.

With regard to the usability tests, we intend to test new scenarios, mainly including the use of Internet services, such as post office services and government health care services. Additionally, scenarios involving the use of educational software will be developed and applied in usability tests.

We also intend to increase the number of users participating in prototype testing in order to have more coverage from the perspective of users with different characteristics.

With regard to the motor feedback, the initial evaluation, which primarily concerned content in the Internet browser, was positive. A second version of the mouse containing two engines positioned on the right and left sides is under construction. With these two engines, we intend to create vibration patterns which can indicate the importance of the information at which the mouse is pointing and to try to create a spatial stimulus, aiming at a fast localization of the pointer on the screen.

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