Ubiquitous Environments and Brazilian Personas: Can our citizens universally access this technology?

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Abstract. *Ubiquitous technology has great power to simplify and improve people's life. However, as the 4th Grand Research Challenge for the Brazilian Computer Society mentions, it is necessary to extend computational systems to all Brazilians, respecting their diversity and differences. This paper presents an analytical approach to evaluate ubiquitous environments which considers the Personas technique as well as videos, scenarios and the GQM (Goal, Question and Metric) method. A feasibility study in the Brazilian scenario reveals that known ubiquitous environments partially meet the interaction requirements of disable people.*

1. Introduction

Ubiquitous technology may play important roles in different knowledge areas [Kjeldskov and Skov 2007]. An example of such technology is the ubiquitous system defined as "integration between computing nodes and the physical world" [Kindberg and Fox 2002]. According to Kindberg and Fox (2002), the world contains ubiquitous systems that operate in environments like houses, flats, or airport rooms. These environments, characterized by Satyanarayanan (2001), are "saturated with computing and communication capability, yet gracefully integrated with human users".

Ubiquitous computing allows users to interact with the system just like humans interact with the physical world [Abowd et al 2002]. Ubiquitous system evaluation is thus important so one can understand how ubiquitous computing impacts everyday life [Abowd and Mynatt 2000].

Abowd argues that an effective evaluation is possible by observing real users interacting with the system routinely in an authentic environment [Abowd and Mynatt 2000]. In Human-Computer Interaction (HCI), such evaluations are said to be empirical. In other words, they are performed with the participation of real users. However, the same author highlights difficulties for performing empirical evaluations in ubiquitous environments. As examples of the main limitations, Abowd mentions the cost, space, people and time [Abowd and Mynatt 2000]. In this context, it is common for such systems to be evaluated in restricted environments and by members of the proposing group, either as evaluators or even playing users' roles.

Moreover, considering the premises from the Universal Design [Trace 2012] or Design for All [Stephanidis 2001], it becomes necessary to evaluate computational systems and account for user diversity, not only those profiles classified as mediums

[Fischer 2001]. Considering different user's profiles in ubiquitous environments - although necessary - makes it even more difficult to perform empirical evaluations.

Given the scenario described, this paper aims to present an analytical approach for ubiquitous system evaluation that considers user diversity and can be applied by evaluators who are not necessarily the developers. In contrast to empirical evaluation, specialists perform analytical evaluations [Nielsen 1993]. This approach is based on using Personas [Cooper 1999], videos, scenarios and the GQM (Goal, Question and Metric) method [Solingen and Berghout 1999]. The Personas technique is used to characterize the target users of the evaluation and support the evaluator. Demonstration videos of using the systems are used to analyze how users interact. Scenarios are created based on the environment features, so it may be possible to visualize system use by the created personas.

To verify the feasibility of this approach and the results, a case study has been created. Three ubiquitous environments have had their features evaluated according to the needs and preferences of two chosen personas. These personas were created considering the diversity of the Brazilian population. They have been inserted in ubiquitous environments through the created scenarios. The observation data has been collected and interpreted according to the evaluation goal. The results of the case study suggest that the ubiquitous environments partially meet the interaction requirements of disable people.

2. Evaluating ubiquitous environments

When attempting to evaluate ubiquitous systems, researchers have adopted both well-established HCI techniques, like Usability Tests [Rubin 1994] and Lag Sequential Analysis (LSA) [Consolvo et al 2002], a technique created for environmental analysis. Three ubiquitous systems that have been evaluated are presented below with the evaluation techniques used.

Labscape [Consolvo et al 2002] is an application of ubiquitous computing that works as a laboratory assistant. The application saves the data generated during the experiment and makes it available ubiquitously, allowing biologists to organize their data in a structural format. In his work, Consolvo et al. (2002) evaluated the system, checking how physical activity is related to information use and creation. A quantitative evaluation was performed using the LSA technique. This technique consists of collecting quantitative data and observing users in their work environments while they perform their usual activities. To evaluate Labscape, data has been encoded from videos, and the following metrics have been collected: number of movements in laboratory, how the information is saved and the intercalation of Landscape use with the physical work.

UbiHome [Oh and Woo 2005] is an application that provides users with "user-centered services". By exploring context-awareness, the application provides services according to the user intent, while supporting flexible interaction between the user and ubiHome environment. Oh and Woo (2005) evaluated the usability of the proposed model through an iterative experiment involving users in a domestic environment using the ubiHome services. Thirty people used the ubiHome application services. The following metrics were collected during the evaluation: learning time, efficient use time, system memory efficiency and recovery rate. Usability has been estimated by averaging the data formed from 20 users' average who took part in the test. Besides usability, the degree of satisfaction was also measured through a qualitative analysis.

As noted by its authors themselves, applying the LSA technique has an elevated cost, and the variables in each experiment make it difficult to analyze the data and compare pieces of data directly [Consolvo et al 2002]. Besides applying the LSA technique, the Labscape evaluation was performed in a real-use environment with high cost and evaluation time [Abowd and Mynatt, 2000]. The remaining techniques used in the other two evaluations do not consider user diversity, their needs or preferences.

The evaluation approach proposed in this work uses techniques that minimize the problems mentioned above. The user diversity is handled using personas that represent user categories. The analysis of videos demonstrating how to use the systems being evaluated aims to reduce the need of deploying the system in real environments. The scenarios offer support during the process by allowing personas to be inserted to the evaluation environment.

3. The analytical approach

The analytical approach to evaluate ubiquitous environments proposed in this paper was based on: personas, videos and scenarios. Below, we explain the Personas technique, using videos and creating scenarios to form a ubiquitous environment evaluation proposal.

3.1. Personas

Jakob Nielsen highlighted the need to know the class of people who will use a system [Nielsen 1993]. According to him, knowing specific information about a user, including his/her job, education level and age, helps prevent learning difficulties and defines appropriate limits for user interface complexity [Nielsen 1993].

Thinking about this necessity, Alan Cooper created the concept of personas [Cooper 1999]. Personas are defined as unreal people who represent real people during the design process. According to Cooper, personas are "hypothetical archetypes of actual users (…) they are defined with significant rigor and precision" [Cooper 1999].

For Pruitt and Adlin (2006), "personas are fictitious, specific, concrete representations of target users", they shape a user as they "put a face on the user" and transmit "information about users to your product team in ways that other artifacts cannot". Personas usually are used at the beginning of a product conception process, with the main goal of allowing user-centered design.

The Persona Lifecycle

The persona lifecycle framework, created by Pruitt and Adlin (2006), presents persona use as the lifecycle of a person starting from family planning and going until retirement. They present the five phases of persona life: Family planning; Conception and Gestation; Birth and Maturation; Adulthood; Lifetime achievement and Retirement.

The framework is aimed mainly in the design process of products in organizations. In our proposed approach, we adapt the conception and pregnancy phase from the framework proposed by Pruitt and Adlin (2006). The conception and pregnancy phase defines how many personas will be created and which qualities and descriptive elements will be included in each persona's document.

3.2. Videos

One way to show the features of the ubiquitous systems adopted by researchers is to make videos about the available applications [Aura 2012, Gaia 2012, Oxygen 2012]. Using videos was included in the proposed approach because they allow us to observe details of the user-system interaction.

Initially, one must select which videos are going to be used in the evaluation. As mentioned, such videos must contain details about the user-system interaction. Next, the features offered by the system are identified. Each system has a set of components and services; however, not all the systems should be selected for evaluation. The selection criterion must consider whether the material available presents details about the user-system interaction. That information is important and imperative for the proposed evaluation. A single video may contain more than one feature of interest.

3.3. Scenarios

A scenario is defined as "a concise description of a persona using a software-based product to achieve a goal" [Cooper 1999]. Scenarios help in persona construction and validation. With a context and details available, one can think as a persona and predict its actions.

For the proposed ubiquitous environment evaluation, scenarios are created based on the personas created and the features identified in the ubiquitous systems.

3.4. GQM

Victor Basili and David Weiss defined the GQM (Goal, Question, Metric) method in the 1970s with the goal of understanding the types of changes in NASA projects. H. Dieter Rombach extended the method, making it possible to apply it in other measured areas. GQM allows writing goals, defining questions, taking the more specific goals and suggesting relevant metrics for the goals. The method contains four phases: planning, definition, data collection and interpretation.

As per the method definition, metrics must provide quantitative information to answer the question set [Solingen and Berghout 1999]. In the proposed approach, GQM is used in an adapted way, so the metric set does not offer quantitative information for the evaluation.

3.5. The application

Once personas are created, the video selection is made and scenarios are defined, the GQM method is used to create a set of metrics, according to the evaluation goal. During the evaluation, such metrics will be applied to all system features. The evaluation application goal must be collecting the defined metrics.

Personas allow the evaluator to think about user needs and preferences. During the video analysis, the evaluator is put in the users' place through the personas and collects the metrics of the feature being evaluated at that moment. After the application,

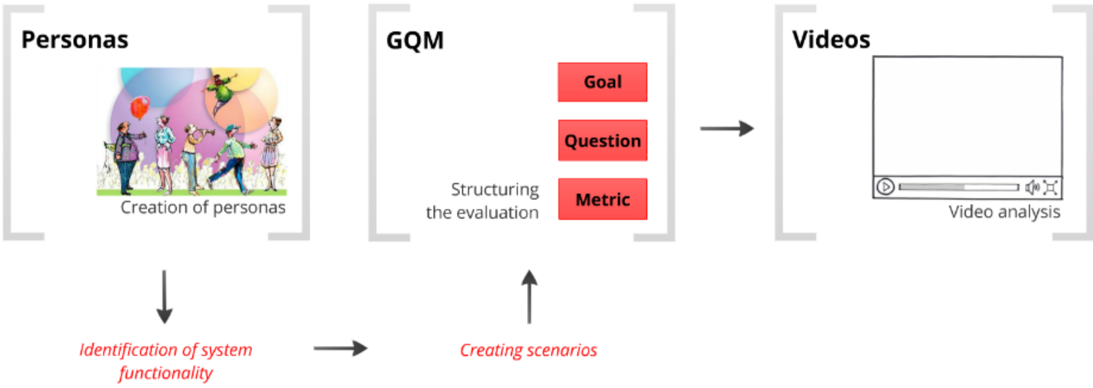

Figure 1. Steps of the analytical approach for ubiquitous environment evaluation

the collected data are tabulated and interpreted according to a predetermined criterion. Figure 1 shows the steps of the proposed approach.

4. Feasibility study

To verify the feasibility of the proposed approach, a case study has been made.

4.1. Evaluated Systems

For the case study, three ubiquitous system projects have been selected: Aura (2012), Gaia (2012), and Oxygen (2012).

Aura

The goal of the Aura project is to provide each user with an aura invisible of computing and information services that persist independently of the location. Designed at Carnegie Mellon University, Aura designs, implements, deploys and evaluates a large-scale system, showing the concept of a personal information aura that extends itself to various types of computers [Aura 2012].

Gaia

The project was developed by the Computer Science Department of the University of Illinois at Urbana-Champaign, and the main motivation to this research was the absence of a software infrastructure appropriate to help the development of ubiquitous computing applications [Román et al 2002]. Gaia is a distributed middleware that brings the functionality of an operating system to physical spaces. The main idea is to create and deploy applications in spaces with different settings, using the available resources.

Oxygen

The Oxygen project was developed in the Laboratory for Computer Science (LCS) in partnership with the Artificial Intelligence Laboratory (AIL), both from the Massachusetts Institute of Technology (MIT). Its goal is to reach ubiquity in environments through user-centered computation, bringing an "abundance of computation and communication within easy reach of humans through natural perceptual interfaces of speech and vision" [Rudolph 2001].

4.2. Creation of personas

The next step was applying the conception phase of the persona lifecycle framework. Five user categories were considered (young, elderly, men with formal work, illiterate, elderly women, and visually impaired people) from socio-demographic data [IBGE 2012] of the Brazilian population.

Based on the identified features, the following system uses contexts were created: a teenager at school or college interacting with the system to accomplish tasks, study, attend classes, present seminars; an elderly person who needs to interact with the system in different ways; a woman interacting with the system while performing activities at her formal work; a man interacting with the system while performing activities at his formal work and; a visually impaired woman who needs to interact with the system in a different way.

Following the steps proposed in the framework, the user's categories were refined, based on details from the socio-demographic data collected previously and five subcategories have been defined: a school-aged boy; a visually impaired girl who attends an undergraduate distance course; an elderly woman with attention deficit and memorization problems; a woman with an informal job and is responsible for domestic services and; a man with a formal job.

Based on the five skeletons created, five personas have been developed. Each persona has a name, a slogan that highlights its main characteristic and information about its personality, technology resources use and daily main activities.

Although the five personas created characterize the average Brazilian population, this paper focuses on evaluating three characteristics of these users: visual impairment, low literacy and attention deficit and/or memorization problems.

The personas Patrícia (Figure 2a) and Francisca (Figure 2b) have been chosen, as they possess these characteristics. Patrícia is a young visually impaired student, and Francisca is an elderly woman with low literacy, attention deficit and memorization problems.

Figure 2. Personas Patrícia (a) and Francisca (b)

4.3. Identification of system functionality

Based on the videos available, five functionality categories have been identified and selected for evaluation: speech recognition, adaptation when a context change is detected, collaboration, availability of contextual information and using techniques for augmented reality.

Table 1 shows that not all projects have all of these features. It was thus not possible to evaluate the ubiquitous systems based on the same features. Nonetheless, the goal of this study is not to compare the systems, but to evaluate them individually in relation to the possibility of use by the two chosen personas. Therefore, this fact had no impact on the evaluation.

4.4. Creating scenarios

Seven scenarios have been created to evaluate the features of the systems. In Table 1, the scenarios are related to the features of each system, according to its utilization. The chosen situations put personas in everyday use situations. The scenarios have been divided into four categories. A detailed description of those categories is given below:

At home:

1. Francisca is watching a movie in the living room at her daughter Claudia's house. When Danilo comes home from school, Francisca decides to go the bedroom and let her grandson, Danilo, play his video game, which is installed on the living room TV. However, she wants to keep watching to the movie in her bedroom;
2. Patricia had an undergraduate test on Sunday and her father, Mario, went to pick her up at the end of day in the support pole. As usual, she went home listening music in her Smartphone. At home, she went directly to her bedroom, takes off the earphones and wants the current song to keep playing in her stereo;

Table 1. Ubiquitous systems, their respective features and the scenarios used during the evaluation

System	Feature	Scenarios
Aura	Adaptation when it detects a context change	1 and 2
Gaia	Speech recognition	6 and 7
	Adaptation when it detects a context change	1, 2 and 4
	Collaboration	5
	Use of techniques for augmented reality	3
Oxygen	Speech recognition	6 and 7
	Adaptation when it detects a context change	1 and 2
	Collaboration	4 and 5
	Availability of contextual information	3

At the museum:

3. Over the weekend, Mario decided to take his family to visit an exposure fair. The museum provides a mobile device with visual and speech recognition for each group so the visitors can consult the schedule and access the museum map. Francisca and Patrícia wish to use the tool;

At the school:

4. Francisca and Patrícia go with Mario to a fair at the school at which he works. The fair offers access to some applications, and Patrícia and Francisca are excited to use them. To use the system resources, Francisca and Patrícia must authenticate their identities;
5. After participating in the fair, Patrícia and Francisca go with Mario to the school laboratory where he needs to test some devices for next week's class. The devices are part of a collaborative system that allows using many input devices. Mario asks whether they want to test it, and they say yes;

Miscellaneous:

6. Although Francisca calls her daughter Claudia every day, Francisca cannot seem to memorize her phone number. To solve this problem, she uses an address book. Francisca needs to look for her daughter's phone number using the speech recognition resource of the ubiquitous systems;
7. Patricia is doing a research for her undergraduate homework and needs to find a list of OSI (Open Systems Interconnection) layer protocols. Patricia must do her research using the speech recognition resource of the ubiquitous systems.

4.5. Applying the approach

Aiming to organize the evaluation and support it during the process, we have opted to use the GQM method.

Following the steps to apply the method, the evaluation goal is identified. The goal of evaluating the case study performed is to verify whether the chosen ubiquitous systems are flexible and meet the Brazilian population's diversity. Three questions have been developed to help verify this goal: Can the systems be used by visually impaired people? Can the systems be used by people with low literacy? Can the systems be used by people with attention deficit and/or memorization problems?

The chosen metrics have been applied to all previously identified system features. For each feature, it was verified whether it could be used by visually impaired people, people with low literacy and people with attention deficit and/or memorization problems. The metrics have been set in a question format, and a questionnaire has been created and answered during the test with personas. Contained in this questionnaire are the following questions that should be answered by a simple yes or no:

Q1. Can the feature be used by visually impaired people? If not, is there an interaction alternative?

Q2. Can the feature be used by people with low literacy? If not, is there an interaction alternative?

Q3. Can the feature be used by people with attention deficit and/or memorization problems? If not, is there an interaction alternative?

Each feature has been evaluated using the demonstration videos provided by the Aura, Gaia and Oxygen projects. The questionnaire has been applied to each feature.

The Aura system had the “adaptation when a context change is detected” feature evaluated. When interacting with the system, users need to know the exact location of the sensors so the system can properly identify the context change. As the system does not provide feedback related to the sensor locations, its utilization by visually impaired people is compromised. Knowing the exact sensor locations also requires great cognitive effort, compromising the use by people with attention deficit and/or memorization problems. Figure 3a shows a user passing his arm over the newspaper (the sensor is located there) before going to another room.

To use the speech recognition feature provided by the Gaia system, the user needs to know keywords to be able to interact with the system. Again, this requires greater cognitive effort, compromising the use of the system by users with attention deficit and/or memorization problems.

For adaptation when a context change is detected, the Gaia system uses biometry to authenticate the user and customize his work area. This feature can be used by the two personas chosen for the evaluation.

The Gaia system also recognizes users through Ubisense tags. In figure 3b, the user has an Ubisense tag in his pocket. Entering the room, the system identifies and customizes his work area. This feature can be used by the two personas chosen for the evaluation.

One feature of the Gaia system uses augmented reality. The user interacts by touching elements that are mapped by the system. When the user touches the elements, the system makes sound information available. This feature has been classified as usable by the two personas chosen for the evaluation.

The Oxygen system provides two speech recognition prototypes. The evaluation questionnaire has been applied to these prototypes. In the first one, the speech recognize what the user says, requiring data input from the keyboard. This feature has been classified as unusable by both visually impaired users and users with attention deficit

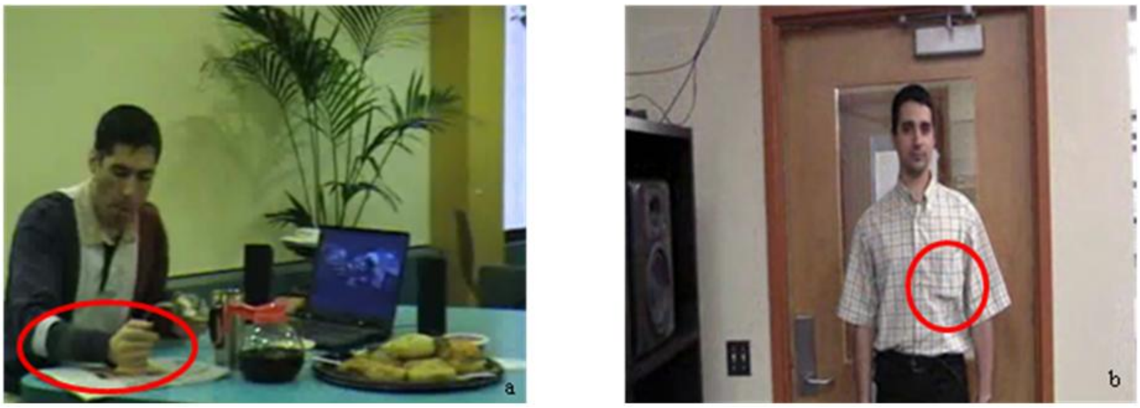

Figure 3. Evaluation of systems Aura (a) and Gaia (b)

and/or memorization problems. For visually impaired users, the system has an alternative for data input using the keyboard. In the second prototype, the feature has been classified as usable by visually impaired users and users with low literacy. However, the system again requires users to know specific keywords for interaction, requiring greater cognitive effort for users with attention deficit and/or memorization problems.

The collaboration feature of the Oxygen system offers an electronic blackboard that tries to extract design reasons from drawings made by users. However, the tool is completely visual, so it cannot be used by visually impaired users. The tool also requires knowing specific commands. The tool has been classified as unusable by users with attention deficit problem and/or memorization problems.

For context information availability, the Oxygen system uses speech and facial recognition. For authentication, the user must align his face correctly in front of the camera. This requirement does not allow the tool to be used by visually impaired users. Additionally, the system requires specific keywords for the speech recognition interaction, decreasing its ability to be used by users with attention deficit and/or memorization problems.

The results obtained by applying the questionnaire have been analyzed according to the characteristics under evaluation: visual impairment, low literacy, attention deficit and/or memorization ability. The following interpretation model has been used: meets, if all questions made for a given system received a yes answer; partially meets, if questions made for a given system had both yes and no answers; does not meet, if all questions made for a given system had only no answers.

Table 2 displays the results of applying the interpretation model described.

In this case study, we have evaluated three ubiquitous systems according to a set of identified features from documents and audio-visual materials available in the literature and retrieved from the Internet by the project researchers, according to three defined criteria: meets or does not meet the needs of visually impaired users; meets or

Table 2. Results interpretation

System	Personas characteristics	Interpretation
Aura	Visual impairment	Does not meet
Gaia	Low literacy	Meets
	Attention deficit and/or memorization problems	Does not meet
	Visual impairment	Meets
	Low literacy	Partially meets
Oxygen	Attention deficit and/or memorization problems	Partially meets
	Visual impairment	Partially meets
	Low literacy	Meets
	Attention deficit and/or memorization problems	Partially meets

does not meet the needs of users with low literacy and; meets or does not meet the needs of users with attention deficit and/or memorization problems.

For the evaluation, we have opted to use the Personas technique, which defines user categories for the selected ubiquitous systems. The obtained results suggest that the evaluated ubiquitous systems partially meet the needs of visually impaired users, with low literacy and with attention deficit and/or memorization problems.

5. Conclusions and future work

In this paper, we have proposed an analytical approach for evaluating ubiquitous systems. Using the Personas technique, we have created representations for user classes that will use the system during the evaluation. Due to difficulties related to accessing and deploying real environments for executing the evaluations, we have used demonstration videos of the features of the evaluated systems. To insert personas into these environments, we have created usage scenarios.

The results also suggest the need for alternative design to improve usability and accessibility for disable users. For instance, the users need to know the location of the sensors in the Aura and Gaia enviroments. Moreover, the use of augmented reality in Gaia is only possible if the user knows the location of the objects which are used as interfaces. For both problems, a tactile map could be used to assist the visually impaired on locating the sensors and interface objects. In addition to the tactile map, tactile paving could help visually impaired users to locate themselves in the environment

Through the case study, some limitations of the proposed approach have been noticed. First, the videos used do not show all possible interaction methods. This causes partial identification of alternative interactions, especially when a given feature is classified as unable to meet a user's need. To decrease the possibilities of getting false negatives using the approach application, developers should provide videos containing different forms of interaction that the systems do provide.

Because of its analytical aspect, this approach requires evaluators to put themselves in the place of a persona. For the results to be more precise, it is important that personas are well characterized, which requires greater attention when creating these epistemic users. The Personas technique was originally proposed to support designers at the moment of creation of products. In this paper, we have adopted the technique as part of an evaluation approach.

The proposed approach can be applied by a single evaluator. Its application can thus be considered fast and of low cost. Nonetheless, the obtained results offer a partial view. As future work, we propose investigating how other evaluators can be involved to minimize the impressions of one single evaluator.

Acknowledgments

The authors thank Rodrigo Bossini and colleagues from LIFeS-UFSCar for their insightful comments.

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