Towards Design Guidelines for Software Applications that Collect User Data for Ubicomp

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ABSTRACT
One of the core requirements of Ubiquitous Computing is to be context-aware. This means that in ubiquitous applications, there is a need to know, among other information, the user profile so that it can be adapted to the different skills and capabilities of users, with regard to physical and cognitive characteristics, and interaction preferences. In the literature, different ways of establishing the user profile can be found, in particular, the use of sensors and software agents. However, each application or service is responsible for collecting user data. No specific applications for data collection have been found that can be used on a large-scale and in an interoperable manner. This paper proposes a set of guidelines that should be followed during the design and development stage of the user's data collection applications. The guidelines were drawn up in the light of the literature and an analysis of the results based on an application of the PICTIVE participatory design technique.

Author Keywords
Ubiquitous Computing, User profile, Data collection, PICTIVE, Participatory Design, Guidelines, Mobile application.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. H.5.2. User Interfaces: Prototyping.

INTRODUCTION

In 1991, Mark Weiser attempted to forecast what computing in the 21st Century would be like by stating that, "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it" [19]. With these words, the father of Ubiquitous Computing (Ubicomp) sought to achieve transparency of use, i.e. computers would disappear from a user´s psychological perspective [18].

To achieve transparency of use, computers must anticipate the user's needs and act proactively to provide appropriate assistance. Systems that have this ability are called context-aware [17]. One of the core requirements of Ubicomp is to be context-aware. This means that in, Ubicomp applications there is a need to know, among other information, the user profile so that Ubicomp can be adapted to the different skills and capabilities of users, with regard to physical and cognitive characteristics and interaction preferences. Each user has a unique set of characteristics that should be taken into consideration during the adaptation of Ubicomp applications. This idea is supported by the 4th Grand Challenge for Research of the Brazilian Computer Society, which says it is necessary to extend the computational systems for all Brazilians, respecting their diversity and differences [2].

As suggested by [13], a user data profile can be classified into three categories: (1) static data, such as the name and hometown, (2) semi-static data, such as allergies and disabilities and (3) dynamic data, such as the current location, daily intake of calories and emotional state. In the literature, different ways of establishing the user profile can be found, in particular, the use of sensors and software agents. However, the focus seems to be on the fact that every application always collects data again, even if it is static.

With the objective of achieving transparency of use as postulated by Weiser [19], data could be collected and sent to the applications and services and a new collection of user data is not required. Without the need to perform a new data collection to each use, ubiquitous applications can provide a more fluid and natural interaction to users. For this reason, this work argues for ubiquitous applications have access to user profiles through software applications that collect user data.

In most studies in the literature, data are collected and the user profile is formed, through instantiation of stereotypes, without intervention by the user [8]. No studies were found that allowed the user to decide whether to agree to the storage and subsequent use of the collected data. Each application or service is responsible for collecting user data. As a result, there was a need to think about what

characteristics the specific user's data collection applications should have.

To address this question, this paper proposes a set of guidelines that must be followed during the design and development stage of the user's data collection applications. In the context of this study, the user's data collection applications seek to obtain information related to the user profile that is sent to the Ubicomp systems. The PICTIVE participatory design technique was applied to a group of users, designers and developers to design an application that collects personal data (such as age, gender, and education), personality traits, and user preferences related to the interface, interests (such as types of film and music) and health. On the basis of the results of applying this technique, it was possible to define twelve fundamental guidelines for the design of software applications that collect user data to Ubicomp.

This paper is structured as follows: first, there is an examination of related works that suggest ways for data collection to compose the user profile. Following this, there is an outline of the PICTIVE technique and how it was employed in designing an application to collect user data. In addition, the proposed guidelines are formalized. Finally, the conclusions are summarized and recommendations made for future.

USER DATA COLLECTION FOR UBICOMP

In the literature, several studies propose ways to collect data that is related to the user profile. As it will be seen in this section, each of these works proposes its own way of collecting user data.

For example, [14] proposes an architecture to support the user interface customization process. In this architecture, environmental sensors data and mobile user data are employed. The sensors detect information related to temperature, location, noise, etc. In the user's mobile device, information about the device is obtained and preferences and failures are collected through user testing. The proposed architecture integrates all of the captured data and establishes rules to define the user interface customization.

In light of the Ubicomp environments, [4] proposes a personalized system that aims to support the establishment, management and application of user interface preferences. The preferences are obtained from mobile device data. The data are related to user behavior (e.g. sound volume, font size and resolution that the user normally chooses.). The user behavior history is stored so that it can serve as input for learning algorithms, such as Neural Network learning, Bayesian Network learning and decision tree learning. The preferences produced by the learning execution are passed on to a Preference Manager that is responsible for incorporating them with the others. As a result of this process, user preferences are obtained that can be used by other services.

With the aim of reducing the amount of human involvement in user profile data collection, [9] provides a framework based on expert systems that use sensory networks and ontology technologies. The data detected by the sensors are stored in a fact database. The user contextual preferences, such as cuisine and products preferences, are collected by means of a mobile device that uses a dialogue-based interface. The data collected from the mobile device are stored in the ontology. The combination of ontology-based data and the fact base with rules that have been predefined by domain experts shows the most appropriate services.

Chibani [3] describes a semantic middleware that aims to provide context-aware knowledge for Ubicomp applications. The middleware has a layer composed of service-oriented context-aware agents. These agents are responsible for capturing the context from sensors. The captured data are modeled by the User Context Ontology for Ubiquitous Services (UCOUS), an ontology defined by OWL, to provide a semantic description of contextual knowledge in a format that is understandable by any service agent in an Ubicomp environment. The User class that has the Context and Preference properties describes the system user´s contextual knowledge. Contextual information is shared with the service agents.

Martinez-Villaseñor, Gonzalez-Mendoza and Hernandez-Gress [13] detect data from sensors in personal devices, social network user profiles, a specialized web application to monitor diet and physical health, and semantic web technologies such as the FOAF[1] ontology. Some of these data are static, some are semi-static and some change constantly. The authors argue that each of these data are important for application personalization and adaptation. However, as each source provides the data in a different data model, the authors propose the use of an ontology based on the Simple Knowledge Organization for the Web (SKOS), to model the user profile.

It can be observed that most of the work uses sensors for user data collection. Some studies combine the use of sensors with other data sources, such as personal mobile device [13, 14], ontologies [8, 13] and social networks [13]. However, there are studies that only use one of these sources [3, 4]. It was only in [9] that an interface was provided to allow the users to enter and confirm some of their preferences directly. Nevertheless, preferences depend exclusively on the context; no general preferences are collected that are important in all contexts, such as those related to the interface.

Regardless of the collection form, the users must be aware of the data type being collected and need an interface that allows them to validate the correctness of the data collected (when appropriate) and agree or not with the data storage

[1] An acronym of Friend of a Friend: http://www.foaf-project.org/.

and sharing. In view of this, there is a need to think about which characteristics the specific applications for user data collection should have.

With this goal in mind, the PICTIVE technique was employed to establish a set of guidelines that should be taken into account when designing the user collection application. The participative design technique, PICTIVE, was chosen with the aim of gathering the users, designers and developers during the process of designing the mobile application for the collection of the user data. Furthermore, the technique enables the creation of an application prototype through the use of low-tech elements, like office supplies, and allows design decisions are recorded for later analysis.

PARTICIPATORY DESIGN OF A MOBILE APPLICATION FOR COLLECTING USER PROFILES

The PICTIVE participatory design technique - Plastic Interface for Collaborative Technology Initiatives through Video Exploration – was proposed by [15] with the objective of increasing the degree of user participation in the design process. The PICTIVE goals are as follows [15]:

1. "to empower users to act as full participants in the design of systems that will have an impact on their jobs and their work-lives";
2. "to improve knowledge acquisition for design, and the quality of the resulting system, by involving the people with job expertise (the people who do the job) in the design process";
3. "to improve the flow of the software engineering process by bringing representatives from major components of that process into the design phase as co-owners of the design".

The technique uses office supplies (such as pens, highlighters, paper, Post-It™ notes of various sizes, stickers, and paper clips) and designs objects (such as query fields, menu bars, dialog boxes, etc.). The use of these low-tech elements are combined with video recording. During the design session, the participants are asked to think about what they would like the system to do. The design session is recorded so that the design decisions and the opinions of the different participants can be registered. Later, the system developers will make use of the recordings.

The PICTIVE technique was applied to a group of twenty people who included users, designers and developers. The next subsection describes how the PICTIVE technique was employed in a user's data collection application design.

Planning

As highlighted by [16], to ensure better data privacy, it is important that the users profile is stored on their own personal mobile device. In view of this, it was decided to use the mobile device as a data collection instrument, where instantiated user's profile will be stored. Since the Android platform is used worldwide, a set of system icons was chosen and the border or a real Nexus 4 smartphone was printed and cut-out to make the design of the screens more realistic.

The data set, which the application was designed to collect, was extracted from the GUMO ontology [6]. The GUMO ontology makes use of UbisWorld model [5] to identify the dimensions of the basic user model. The UbisWorld allows the representation of user information, such as demographics, interests, psychological and physiological states, personal characteristics, among others. To extract the data set to be collected by the application, the UbiCARD [1] technique was applied. UbiCARD allows the identification of different users profiles and their needs and preferences that arise during interaction in Ubicomp environments. From the technique application, the following data set was extracted from the GUMO ontology: demographics data, skills and abilities, personality traits, emotional states and user preferences (such as cinematographic and musical genres). By applying UbiCARD, developers and designers can identify what data are needed for their applications. Thereafter, the data set of the user's data collection application can be expanded.

A profile questionnaire was also prepared, which was intended to be completed before the design session. Apart from video recordings, we decided to use the Design Rationale [11] to document the design decisions made by groups.

Profiles of the participants

The twenty members of the group comprised both men and women aged between 21 and 50, with an educational level ranging from higher education to postgraduate level. As can be seen in Table 1, out of the total number of participants, 55% had been involved in a design process and 60% had some knowledge (ranging from basic to advanced) of mobile applications development. The participants were divided into four groups containing five participants each. As can be seen in Table 2, there were users, designers and developers within each group.

Expertise	Percentage (relative to the total number of participants)
Participation in the design process	55%
Participation in the technique or practice of participatory design	35%
Development experience	100%
Mobile application development experience	60%

Table 1. Expertise: percentage with regard to the whole group.

Expertise / Groups	Participation in the design process	Mobile application development experience
1	3/5	2/5
2	4/5	3/5
3	3/5	3/5
4	1/5	4/5

Table 2. Expertise: percentage in each group.

During the design session

Before the design session started, the PICTIVE technique was shown to the participants. It was explained that a) the technique would be employed to design the user's data collection application; b) the data would be used to instantiate the user profile; and c) the user profile would be subsequently available to Ubicomp applications and services. It was also explained that some of the data that needed to be collected could be obtained from the Facebook social network. Finally, they were given of office supplies, design objects, a sheet containing the dataset that was to be collected and a card stock that was to be used as the shared surface design (see Figure 1).

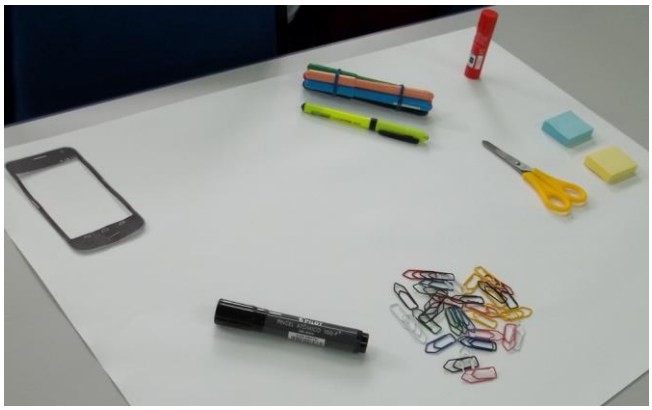

Figure 1. Office supplies used for the PICTIVE technique application.

The interaction between the four groups (see Figure 2) was recorded by cameras and after the creation of the design, the participants described a proposed solution (see Figure 3).

Figure 2. Interaction between the four groups during the design session.

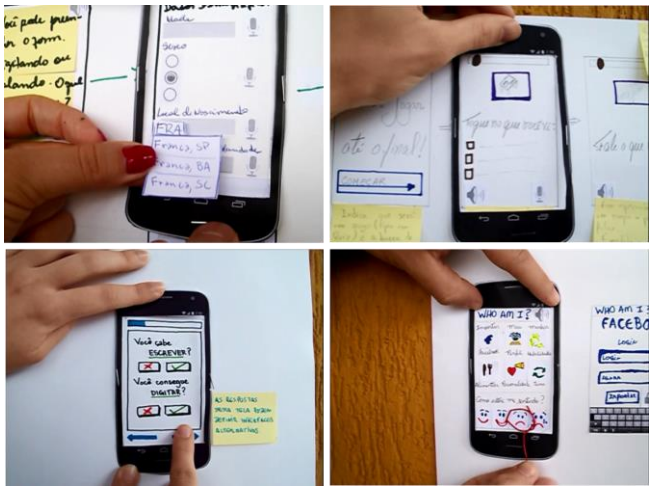

Figure 3. Participants describing the design solutions proposed.

During the design session, the designers noted the decisions that were made and, finally, documented them with the aid of the Compendium software tool[2].

Analysis of the four design proposals

The participants raised several issues mainly related to accessibility, privacy and security. The video recordings, design rationale maps and design solutions proposed, provided a view of the various design decisions made by the groups.

The participants showed an underlying concern with privacy and security issues. As user's profile is stored on their own mobile device, one participant argued:

"Today, those who use applications that involve personal information may wonder: will someone be able to access my information? If I lose my smartphone or it gets stolen, will someone be able to access my data?"

One of the participants pointed out the need for the interface to provide a means of making them feel relaxed about their security and privacy. Another participant expressed the need for the users to be able to choose the type of information that is available in their user profile. As a design solution, Group 1 suggested the idea of protecting data with a password (see Figure 4.a). If the password was entered incorrectly more than three times, the user profile would be sent to a previously registered user's email address, and their profile would be deleted from the device. Group 3 suggested synchronizing the user profile with other devices (see Figure 4.b).

These design solutions, proposed by the groups, allowed the definition of three guidelines relating to user's privacy and security of their data: (1) Provide mechanisms for data protection: (2) Create and disseminate a privacy policy;

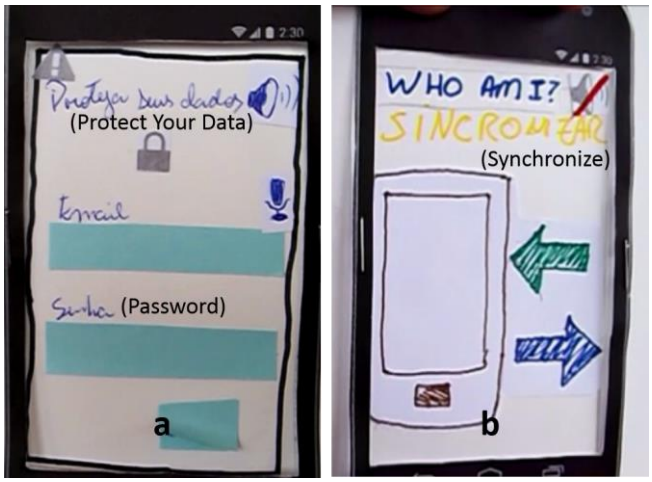

Figure 4. Design suggestions for privacy and security issues.

and (3) Allow the users to decide when their data will be shared.

We also noted the concern of participants with accessibility issues. Group 4 put forward the suggestion that the accessibility features should be configured on the first access to the application, so that they could cater for the user' needs. This concern was also observed in the design issues raised with regard to the design rationale: "How should the hearing ability test be carried out? If someone decided to select an item to show that he has no visual capacity, how did he arrive at this option?". Through these solutions, the design guideline "First collect the data related to accessibility" was proposed.

One participant expressed a concern about accessibility issues in the following comment:

"We thought about using the interface to reach the largest number of people (...) people with low literacy, visual impairment, hearing impairment (...)"

Instead of asking direct questions about user capabilities, Group 2 suggested that they could be inferred indirectly. For example, to determine if there is any hearing loss, the user should click a button when he heard a certain sound. In the case of any visual problem, the user should state which elements he was looking at in a given image and with regard to possible problems of diction, the user should describe what he sees in a given image. These observations indicate the need to offer different forms of interaction for the users. For this reason, the guideline "Using multimodal interfaces" was proposed.

Another concern of the participants was to encourage users to fill in all the profile data. The groups adopted different approaches to do this: a progress bar (see Figure 5.a) a welcome message (see Figure 5.b) and Gamification [12]. Group 2, said it chose to use Gamification:

[2] http://compendium.open.ac.uk/

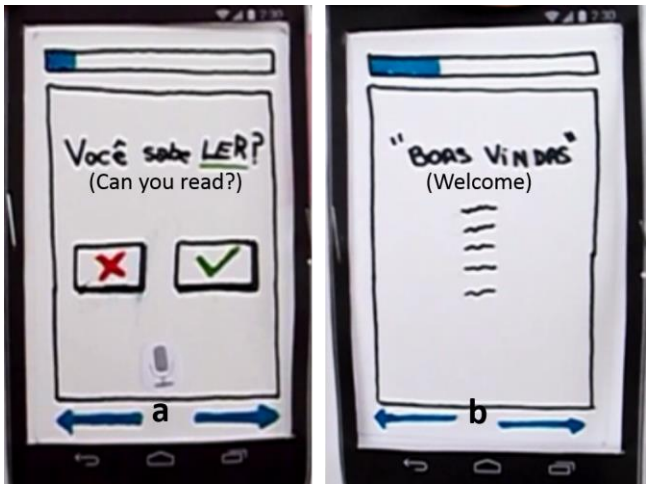

Figure 5. Design suggestions to stimulate the user to fill in all the data.

"We use Gamification to assist us in collecting the information (...) we use a progress bar, but you might want to use a scoring system to encourage people to answer the questions."

The guideline "Encourage users to fill in all the data" emerged from these design solutions.

Some groups have suggested that the largest amount of information should be collected from Facebook to populate the user profile, and reduce the effort required to fill in all the data. If not all the information is available in the Facebook profile or the users do not want the application to access their profile, some of the groups have suggested the use of forms so that information can be completed manually.

These design solutions allowed the definition of the following guidelines: (1) Reducing the amount of data collected; (2) Data capture from external sources should be optional; (3) Allow the users to validate the data obtained from external sources; and (4) Allow the users to select which types of data are obtained from external sources.

As the emotional state fluctuates all the time, Group 3 and Group 4 suggested that this information should be collected in the first application screen (see Figure 6) to make it easier for the users to gain access to the information and encourage them to update it more often:

"The user does not need to get an icon on the home screen; (...). Unlike all of the features that are permanent, we think that the collection of data on emotions needed more effort a, so we decided to leave it on the first screen."

Through these solutions, the design guideline "Facilitate access to dynamic data" was proposed.

In the next section, there will be an examination of the proposed guidelines, based on observation and an analysis of the results obtained from employing the PICTIVE technique.

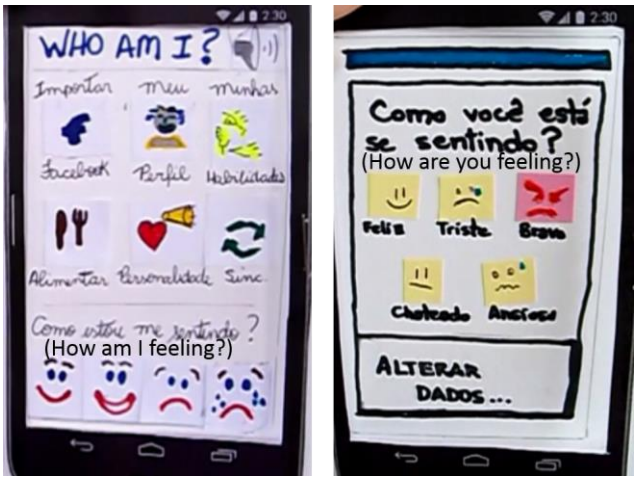

Figure 6. Design suggestions for data collection regarding the user´s emotional state.

GUIDELINES FOR THE DESIGN OF SOFTWARE APPLICATIONS TO COLLECT USER DATA

In this paper, we propose a set of twelve guidelines that should be taken into account during the design and development stage of the user's data collection applications. The guidelines have been divided into three categories: Accessibility, Data Collection, and Privacy & Security.

The Accessibility Guidelines suggest ways to make the interface accessible to the users of data collection applications. The Guidelines for Data Collection explain how the data should be collected and what should be the application behavior when external data sources are used. Finally, the Privacy & Security Guidelines suggest ways of making the users feel comfortable with regard to the privacy and security of their data.

The guidelines proposed in this paper emerged from the four design solutions proposed by the twenty participants of the PICTIVE technique application. The actions to be taken for implementing the Privacy & Security Guidelines were based on the literature. The following guidelines are outlined on the basis of their categories, and ways are suggested to apply them.

Accessibility Guidelines

First collect the data related to accessibility

In addition to providing user profiles for other applications and services, the user's data collection application should also be accessible to users. *What action to take:* Direct the screen flow application so that it collects the accessibility characteristics first.

Using multimodal interfaces

The interface should allow different input and output forms so that it can reach the maximum number of people. *What action to take:*

- provide input and output options based on the accessibility features collected;

- allow the users to choose which form of input and output they wants to use.

Guidelines for Data Collection

Reducing the amount of data collected
If the amount of data to be collected is too large, the users can get tired and give up the filling operation. *What action to take:* obtain the maximum amount of data from external sources.

Encourage users to fill in all the data
If there is a large amount of data that has to be collected, the users should be encouraged to fill in all the data. *What action to take:*

- provide feedback to the users of the number of steps that will have to be carried out, for example, through the use of progress bars;
- show the users the amount of data that was imported from external sources and how much still remains to be completed;
- use welcome messages.

Data capture from external sources should be optional
Not all users want their personal or context information to be captured from external sources such as social networks and sensors. *What action to take:* ask the users if they want their data to be captured by external sources or if they want to enter their data manually.

Allow the users to validate the data obtained from external sources
Among the data collected, there may be some that the users do not wish to be added to their profile or to be shared with other applications and/or services. *What action to take:* create an interface that shows the users the data collected and allows them to choose whether to keep them in their user profile or not.

Allow the users to select which types of data are obtained from external sources
It is important for the users to choose which data will be captured, since this means that the amount of data that has to be validated by the users is reduced. *What action to take:* display a list of data types that will be captured. This will allow the users to add or delete items from this list.

Facilitate access to dynamic data
It must be made easier to obtain access to data that change constantly. *What action to take:*

- if possible, keep the dynamic data on the initial screen;
- if the amount of dynamic data is very large and the data cannot be collected from external sources through sensors, keep them at initial screen is not the best solution to be adopted. However, make the access path to the dynamic data as short as possible.

Privacy & Security Guidelines

Provide mechanisms for data protection
The user's data collection application should provide data protection mechanisms so that nobody else is able to access the user data. *What action to take:*

- allow the users to set a data access password;
- after a fixed number of unsuccessful attempts have been made to enter the password, send their profile to the e-mail address and delete the users data from the mobile;
- while sending data to other applications, use encrypted connections and digital certificates to ensure data security (or a transfer protocol that implements both, as HTTPS).

Create and disseminate a privacy policy
Users need to know how the data collected will be used and how and with whom they are shared; and applications that will receive the user profile need to know the rules that must be followed for the use of this data. *What action to take:*

- define a data privacy policy;
- users should be able to locate the privacy policy easily;
- makes available a privacy policy to Ubicomp applications before sending the user profile.

According to [20], while creating a privacy policy, it should be taken into consideration the nature of personal information (data capture, storage, analysis and integration, and dissemination) and relevant contextual factors (social and institutional context, who are the stakeholders, who wants the data and why, etc.). There are some suggested steps for creating privacy policy: analysis how the privacy is characterized in the media, peer-reviewed journals and in project reports; scrutiny of the privacy policy adopted in other countries; public opinion surveys and other stakeholder consultation techniques, etc. [20].

To turn the privacy policy available, [7, 10] suggest using a protocol that allows the user's data collection application to indicate how the user profile must be used. The Ubicomp applications must know how to use the received data even before receiving them. Therefore, the privacy policy may be embedded in the service discovery protocol.

Allow the users to decide when their data will be shared
Users need to be notified when there is any request for access to their profile. The users should also be able to decide if their profile will be sent or not for Ubicomp applications. *What action to take*: when there is a request for sending profile, display a dialog box asking the users if they agrees to provide profile data for a given application.

Allow the users to backup their data
The users must be able to export their user profile and store it elsewhere. *What action to take*:

- provide an interface to export the user profile;
- allow the users to state where they want to send their profile;
- allow the users to import profile information for the application (when the profile was previously exported).

CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

One of the main requirements of Ubicomp is that it should be context-aware. Thus, Ubicomp applications and services need access to contextual information. This contextual information includes information from the user´s own environment, the device that they are using, and information about their profile. The profile information is essential to provide adapted interfaces for the needs and preferences of the users. In the literature, we found several ways to collect user profile information. However, as has already been emphasized, the forms of collection used fail to take account of user's preferences.

The PICTIVE technique application attempted to create a user's data collection application design. As the premise of privacy and interoperability, the application must be designed to keep the user profile in the user's personal mobile device. Thus, Ubicomp applications and services may have access to that profile without the need to collect certain information with each new interaction. However, this application does not preclude the need for the use of sensors and other forms of data capture. Before, it can be used as an extra data source, mainly static data that are independent of the application context.

Although the main concern of the participants was the way the data collection was carried out, other issues were raised, such as accessibility, privacy and security. These questions were reflected in the design solutions proposed. On the basis of observation and the analytical results of the PICTIVE technique application, this paper proposes a set of twelve guidelines that should be complied with during the user's data collection applications design. The proposed guidelines address the issues raised by participants when the technique was employed.

In defining the guidelines, we sought to address all the issues raised by the participants/groups. Moreover, we pointed out practical and clear recommendations on how designers and developers can follow the guidelines. The recommendations were based on the design solutions proposed by the four groups who participated in the PICTIVE technique application. It is believed that the proposed set of guidelines will help designers and developers to create user's data collection applications that can be used by many people and that take into account privacy and security issues.

Among the set of guidelines presented in this paper, one can be found in the literature. The guideline "Create a privacy policy" was proposed by [10] as part of a set of guidelines to preserve user privacy. Some others can be inferred by developers and designers, such as "Reducing the amount of data collected". However, the guidelines proposed in this paper are specific to create user's data collection applications, and emerged by grouping the results of applying the PICTIVE technique with users, designers and developers.

Based on the guidelines proposed in this paper, a mobile application for collecting data from the user profile is being developed. In future work, some feasibility studies will be conducted with real users. Persuasion strategies will be studied to encourage the users to fill in more data about their profile. We expect that this mobile application can be seen as a physical artifact to make the interaction with Ubicomp applications more accessible, contributing to the 3rd Grand Challenge for Research in Human-Computer Interaction in Brazil.

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