Infrastructure Awareness

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ABSTRACT

Ubiquitous Computing designs infrastructures that weave into the fabric of everyday life, and become invisible by fading in the background. However, this invisibility keeps users from understanding and adopting them. To address this problem we introduce the notion of *Infrastructure Awareness* (IA). IA is the user's awareness about properties of an infrastructure. Our hypothesis is that IA facilitates the users' understanding of infrastructures, and thereby supports their adoption. This dissertation investigates three dimensions of IA: conceptual, methodological, and technological. The conceptual dimension defines IA in terms of an awareness model and a design space. The methodological dimension reflects on the usage of user-centred design when designing for invisibility, and proposes a new user-centred design activity for IA systems. The technological dimension creates two proof-of-concept applications, GridOrbit and GridNotify, to illustrate the notion of IA systems.

ACM Classification Keywords

H.5.2 Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design, Human Factors, Theory

Author Keywords

Infrastructures, Adoption, Infrastructure Awareness.

INTRODUCTION

The Mini-Grid project [1] aims to build a voluntary grid infrastructure for the execution of bioalgorithms. The Mini-Grid is follows the principles of being distributed, P2P, and voluntary. The Mini-Grid harvests computing power from the donating devices and uses it to execute everyone's tasks. The capacity of the Mini-Grid is affected by its voluntary nature, as it relies on users to donate the computing power that can be harvested. However, as an infrastructure the Mini-Grid is embedded in the users' activities and hence invisible. Initial user studies showed that researchers did not understand the Mini-Grid concept, specially in relation to donating computing power. They thought the Mini-Grid had clusters of servers, or that in donating computing power the Mini-Grid would take control of their devices. Reflecting on this discussion, we realized that the invisibility of the Mini-Grid kept users from understanding it. The invisibility of the Mini-Grid would lead to poor adoption, few volunteers, and thus very limited capacity.

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The problem of volunteers for the Mini-Grid is an instance of a more general problem in Ubiquitous Computing. Ubiquitous computing research follows Weiser's vision [14] of designing systems that weave into the fabric of everyday life and disappear in the background of users' attention. Invisibility is a design ideal for Ubiquitous Computing, as we expect to have many devices covering the different settings where everyday life occurs. However, it also presents new challenges. Poole et al. [12] argue that invisibility prevents users from forming accurate mental models of the underlying infrastructures they use, and thereby from exploiting their full potential. In another study Poole et al. [13] say invisibility leads to folk stories and misconceptions of the infrastructures, and argue that it affects long term adoption. Invisibility is a design ideal of ubiquitous computing infrastructures that works against their adoption.

INFRASTRUCTURE AWARENESS

To address this problem we propose the notion of *Infrastructure Awareness*. Infrastructure Awareness is about making technologies visible in ways that do not occupy the user attention. This new visibility, should also motivate users to use the technologies and provide feedback on the interactions with it. The goal is to provide users with the awareness about the infrastructure that invisibility forbids. The notion of Infrastructure Awareness is defined as:

> Infrastructure Awareness is the user's awareness about properties of an infrastructure.

Awareness is obtained through perception mechanisms in the different senses: sight, hearing, taste, smell, and touch. Designers can choose whether to embed perception mechanisms as part of the infrastructure design, or to provide them from systems independent of the infrastructure. The empirical work of this dissertation focuses on designing and building independent infrastructure awareness systems for visual perception. In doing so, we build on top of the Awareness Systems research and include the issue of supporting adoption of infrastructures. We also propose the usage of ambient display technologies to warranty the information will be displayed in the periphery of users' attention. Ambient displays support the switching between focus and periphery, allowing users to obtain detailed information when needed, and the system to use different motivation strategies. We define infrastructure awareness systems as:

> Infrastructure awareness systems expose infrastructures to perception through ambient technologies, providing users with awareness of their properties, motivating their use, and providing feedback on the user interactions.

Our hypothesis is that Infrastructures Awareness supports the adoption of invisible infrastructures. We investigate our hypothesis and Infrastructure Awareness according to three dimensions: conceptual, methodological, and technological.

RELATED WORK

Adoption of Grid Infrastructures

Similar projects to the Mini-Grid include the Internet-based Boinc[1] and World Community Grid[2]. To recruit volunteers they rely on word-of-mouth, and an altruist image with project names like "Help Conquer Cancer", and "FightAIDS@Home". Today, they use Internet presence in Facebook, Twitter, and widgets that can be embedded on volunteer's blogs. Volunteers can team up and compete in donating the more CPU resources to a specific project. Volunteers can also obtain details for their personal or team efforts by visiting the website of the projects or running a screen-saver application.

Infrastructure Awareness shares the ideas of feedback and awareness presented in these projects. However, Infrastructure Awareness targets local infrastructures and populations.

Appropriable Infrastructures

Appropriation is the process by which people adopt and adapt technologies fitting them into their own working practices [4]. When appropriating technologies users go beyond adoption to accommodate technologies to fit their actual needs, even if they are different than the original intend of the designer. Even though we do not study the issue of appropriation, appropriation research deals with adoption. Mainwaring et al. [10] argue for appropriable infrastructures where users could "build and express their identities". In doing so, infrastructures should be made visible and accessible for users to reconfigure them. Dourish et al. [4] argue for mechanisms like: *preserve visibility*, *support for multiple perspectives on information*, and *make information sharing an application matter*. Preserve visibility aims at providing means for users "to understand how a system works, in order to understand how to make it work for them".

Both approaches call for embedding mechanisms in the infrastructures to make them visible. Infrastructure awareness is different in that it does not intend to guide the design of infrastructures, and can be added and removed at will later after deployment. Moreover, Infrastructure Awareness aims to support just adoption, not the whole issue of appropriation. Finally, these approaches do not consider the aspect of motivating user engagement.

Seamful Design

Chalmers et al. [3] study the limits of sensing technologies in ubiquitous computing systems in terms of accuracy and uncertainty. These limits are called *seams*. A seam appears when sensors fail or reach their limits. Designers usually hide the seams from users, and resort to default application behaviours. Chalmers studies these seams and their impact on technology adoption. Being invisible features of the systems, Chalmers evaluates different ways technology designers deal with seams, and by assimilating Heidegger's phenomenology, proposes to leave part of the interpretation process on the users. His approach calls to make seams visible as beautiful seams. By being exposed to the seams, users can reflect on the limitations of the systems and adjust their own behaviour. Chalmers argues that seamful design is a powerful tool to support the adoption of ubiquitous computing systems.

Infrastructure Awareness takes inspiration from Seamful Design, in making technologies visible as the starting point for their adoption. However, Infrastructure Awareness does not focus on the limits of the systems, or seams, but in the whole infrastructure. Rather than exposing the system's seams, Infrastructure Awareness exposes the infrastructure itself.

RESEARCH APPROACH

This research work follows Mackay's triangulation process [9] in its three perspectives: *theory*, *observation*, and *design*. These perspectives relate to our conceptual, methodological and technological investigation dimensions respectively. The following list gives an account of how we moved among perspectives:

- We moved from user studies, to the characterization of invisibility as a problem in the adoption of invisible infrastructures.
- We moved from identifying infrastructure awareness as a key element in adoption, to user studies on how best provide this awareness to biologists using the Mini-Grid.
- We drew implications for design from our user studies, and engaged in a user-centred design process for our first prototype named GridOrbit.
- We iterated between designing GridOrbit, performing user studies, and running user-centred design sessions.
- We reflected on using user-centred design [7] in dealing with invisible infrastructures.
- We moved from proposing a new user-centred design technique, to the redesign of GridOrbit. We also added a new application called GridNotify.
- We iterated between designing GridOrbit, designing GridNotify, performing user studies, and running user-centred design sessions.
- We are moving from the design of GridOrbit and GridNotify, to executing a long term evaluation. We will analyse the collected data, and reflect on its implications for Infrastructure Awareness.

[1] http://boinc.berkley.edu/
[2] http://www.worldcommunitygrid.org/

CONTRIBUTIONS

Our main contribution is to introduce the notion of Infrastructure Awareness, which we investigate around three dimensions: conceptual, methodological, and technological.

Conceptual Dimension

At the conceptual dimension, the contribution is an awareness model and a design space for Infrastructure Awareness.

We build on top of Benford and Fahlén's spatial model of awareness [2] to include invisibility, infrastructures, and infrastructure awareness systems. The spatial model of awareness defines entities as having a *focus* and a *nimbus*. Awareness of entity A toward entity B happens when A's focus meets B's nimbus. We propose to add infrastructures in a new dimension that users cannot see, hence invisible as presented in figure 1A. Here, there are two obstacles to awareness: first the user (U) focuses on different things other than the infrastructure (I), and second the infrastructure's invisibility (shown in dashed lines) keeps the user from seeing it and reflecting on it. In figure 1B Infrastructure Awareness systems are added as a bridging entity between the two dimensions.

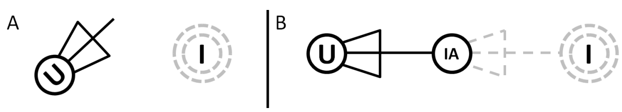

Figure 1: Infrastructure Awareness' awareness model. The circle represent the object's nimbus. The cone represents the object's focus and its orientation.

We extend Markopoulos et al.'s design space for social awareness systems [11] to include the new dimensions of *coverage*, *fidelity* and *motivation*. Fidelity relates to how close the information shown by the infrastructure awareness system is to the original infrastructure. Coverage relates to how much of the infrastructure is visualized. Motivation, relates to motivation model being used to motivate adoption. For motivation we draw on Froelich et al.'s study on eco-feedback technologies [5], and its two groups of motivation models: rational choice models and norm-activation models.

Methodological Dimension

At the methodological dimension, our contribution is a user-centred design technique for infrastructure awareness systems.

We used two methods to design GridOrbit and GridNotify: contextual analysis and user-centred design. Details on the setting, the study design, the participants, and the design prototypes can be found here [8]. During the design process, we identified three challenges when using user-centred design for Infrastructure Awareness: *construction of awareness models*, *designing of domain models*, and *understanding of metaphors* [7]. The most important of the challenges, the construction of awareness models, requires designers to co-construct the awareness models with the participants. However, the awareness model concept and the technical details of the infrastructure are difficult to communicate to the non-technical participants, and for them to retain them.

To address this challenge we propose the AMCard technique. From a methodological stance, the technique takes its outset in the Inspiration Cards technique proposed by Halskov and Dalsgaard [6]. From a theoretical stance, we ground the technique on the awareness model presented earlier. The AMCard technique helps creating a shared definition of the focus and nimbus of the awareness model. The technique does not require users to have deep knowledge of neither the awareness model nor the infrastructure.

Technological Dimension

At the technological dimension, our contribution is the design, development, and evaluation of two proof-of-concept applications, GridOrbit and GridNotify, to illustrate the notion of infrastructure awareness systems. GridOrbit and GridNotify are infrastructure awareness systems designed to support the adoption of the Mini-Grid.

GridOrbit

GridOrbit is an infrastructure awareness system running on public displays, that extracts, transforms, and visualizes data from the Mini-Grid. GridOrbit monitors the network for Mini-Grid network traffic and extracts information relevant for creating awareness. GridOrbit provides three different distance-based interaction zones, in order to support the transition between periphery and focus. The closer the users get to the screen, the more details on the Mini-Grid activity are provided. To motivate adoption, GridOrbit provides the option of being contacted by the Mini-Grid team and have the Mini-Grid client installed in their computers. Figure 2A-B shows GridOrbit's UI design at two different iterations. The design uses different visual metaphors aimed at being attractive while conveying the message (state of the Mini-Grid), and staying in the periphery of user's attention.

(a) WindMill metaphor (b) DeviceCloud metaphor

Figure 2: GridOrbit prototype 1 and 2

GridNotify

GridNotify[3] is an infrastructure awareness system running on the desktop computers of the biologists. GridNotify is a desktop application that monitors the Mini-Grid, displays the current capacity, and displays ambient dialogues (like instant messaging notifications) to motivate the user to become Mini-Grid volunteers. Besides visualizing the Mini-Grid, GridNotify uses different motivation models. GridNo-

[3]GridNotify is being developed together with other members of the Mini-Grid project team.

tify displays the ambient alerts when the user is not running the Mini-Grid client.

GridOrbit and GridNotify Joint Evaluation

To evaluate our hypothesis, we are preparing a long term deployment of the Mini-Grid, GridOrbit, and GridNotify. The experiment will take place at the molecular biology department of University of Aarhus. The aim of the experiment is to recruit volunteers for the Mini-Grid, supporting its adoption. The deployment will last 7 weeks during summer 2010, and data will be collected under three test conditions: first, the Mini-Grid without infrastructure awareness systems. Second, the Mini-Grid and GridOrbit. And third, the Mini-Grid with GridOrbit and GridNotify. The following is the list of activities for the deployment: 1) Introduction of the experiment to the biologists and installation of the Mini-Grid applications. 2) Test condition 1: Baseline study of Mini-Grid usage and interviews to participants. 3) Test condition 2: Introduction of GridOrbit and Mini-Grid activity monitoring. 4) Test condition 3: Introduction of GridNotify and testing of motivation models. 5) Final quantitative and qualitative data collection.

To support the hypothesis we seek to collect data to answer the following questions: What's the impact of GridOrbit in the number of machines connected to the Mini-Grid? What's the impact of GridNotify's motivation strategies in the attitude of researchers toward the Mini-Grid? Does more Mini-Grid activity shown in GridOrbit encourages more researchers to volunteer? Is there a relation between the interactions with GridOrbit and the number of machines connected to the Mini-Grid? To answer these questions the following datasets will be captured under the different test conditions:

1. Number of machines connected to the Mini-Grid every 15 minutes.
2. Number Mini-Grid tasks being submitted and executed by the participant devices.
3. Number of users' visits and interactions with GridOrbit every minute.
4. Users' responses to the motivation strategies of GridNotify.
5. Semi-structure interviews in relation to GridOrbit, GridNotify, and awareness of the Mini-Grid.

FUTURE WORK

The remaining time of my PhD studies is dedicated to evaluating GridOrbit and GridNotify, reflecting on the collected data, and preparing publications.

Risks

The first risk relates to the Mini-Grid infrastructure's instability, which means the Mini-Grid infrastructure could break down during deployment. To counter this situation, GridOrbit and GridNotify are ready to simulate grid activity, turning the experiment into a Wizard-of-Oz experiment, and continuing to monitor the decisions of users to volunteer. A second risk relates to the recruitment of participants and their potential dropping out. To counter this problem we plan to have an initial group of 20+ researchers, which is a big sample group, and try to reach members from other groups along the way.

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