Designing for the Invisible — User-Centered Design of Infrastructure Awareness Systems

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ABSTRACT
Infrastructure awareness systems reveal invisible aspects of infrastructures to their existing or potential users. Designing such systems is challenging as it requires making visible the hidden activity of infrastructures while providing information of interest to the users. To address this challenge we introduce the AMC technique (for Awareness Model Cards). This technique relies conceptually on awareness model's concepts of nimbus and focus. The main objective is to match the users' interests to the information the infrastructure awareness systems can provide, through the use of card matching. This technique provides three benefits: 1) evaluate how relevant is the information displayed by infrastructure awareness systems; 2) identify which of users' interests infrastructure awareness systems do not take into account; 3) identify elements of re-design in the infrastructures themselves, so to improve their adoption.

Author Keywords
Infrastructure Awareness, User-Centred Design, AMCards

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces—*User-centred design*

INTRODUCTION
Infrastructures are persistent socio-technical systems over which services are delivered to support an organization or society in general [3]. Infrastructures can be physical such as the power grid or gas pipes; human such as home-schoolers and gate-community dwellers [8, 11]; or technological such as instant messaging or computational grids [3]. According to Star [14], the most salient characteristics of infrastructures are their embeddedness and transparency (to which we will refer as 'invisibility'), which in turn make it inherently difficult for users to understand and appropriate them [2]. Awareness systems offer a solution for improving the adoption of invisible technology [13]. By providing information that can move back and forth between users' periphery and center of attention, awareness systems foster reflection among users and improve their understanding of the technology [15]. For instance, by showing the current state of energy consumption, sustainability projects seek to trigger reflection on resource usage and to stimulate environmental friendly behaviours [6].

The invisibility of infrastructures, however, possesses a fundamental challenge to the user-centered design of such awareness systems; it is inherently difficult to engage users in a design process about something invisible. The invisibility of an infrastructure inevitable leads to a lack of understanding of the nature and characteristics of an infrastructure. And this lack of understanding is a core hindrance to a user-centred design process, as users make wrong assumptions or ignore the potential of the infrastructure.

To address this challenge, we propose the *Awareness-Model Card (AMC)* technique. From a methodological stance, this technique takes its outset in the Inspiration Cards techniques proposed by Halskov and Dalsgård [5]. This technique helps bring different sources of inspiration into the design process. From a theoretical stance, we ground the technique in Benford and Fahlén's model of awareness [1]. This model uses the terms 'focus' and 'nimbus' to define awareness as taking place when the observing object's focus meets the observed object's nimbus. The AMC technique seeks to instantiate focus and nimbus in the context of users and infrastructures, in order to better match them together.

BACKGROUND
Our work is part of a project which aims to create a peer-to-peer (P2P) computational grid of personal computers within a biology research laboratory. This grid is targeted to help biologist execute their bioinformatics algorithms in a distributed manner. This type of grid is often called a 'voluntary grid' since it relies on volunteers to donate CPU cycles on their personal computers. Hence, such grids are dependent on the number of donors to be effective.

In order to engage people at the lab, we started to investigate how an awareness system for the P2P grid could be designed and initial field studies and interviews indicated that such an awareness system would indeed help the adoption of the grid. Moreover, further design workshops with the biologists formed the idea that a public display environment could help make the grid visible and would engage biologists to donate CPU cycles. However, many visualization strategies can be used on such displays. One option is to show grid usage; another is to highlight which users are donating the most to

DIS 2010, August 16-20, 2010, Aarhus, Denmark.

the grid (an approach often used in other grids). During these design workshops, the core challenge was, however, that the invisibility of the infrastructure restrained participants from understanding the design space, which in turn hindered their engagement and creativity.

THE AMC CONCEPTS

In order to address the challenge of engaging user in the design of awareness systems for an invisible infrastructure, we propose the *Awareness-Model Card (AMC)* technique. This section outlines the conceptual background, while the next presents the technique.

Infrastructure Awareness

The awareness model presents 'focus' as what an object is interested in, and 'nimbus' as the information that an object projects about itself [1]. Awareness of object A in relation to object B happens when A's focus meets B's nimbus; i.e. when A is interested and has access to what B projects about itself. The problem of invisibility of infrastructures, modelled in terms of awareness model, is presented in figure 1A. Here there are two obstacles to awareness, first the user (U) focuses on different things than the infrastructure (I) in itself, and second the infrastructure's invisibility (shown in dashed lines) keeps the user from sporadically confronting it.

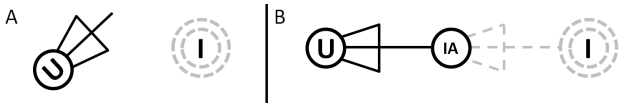

Figure 1. Infrastructure Awareness' awareness model.
(The circle represents the object's nimbus. The cone represents the object's focus and its orientation.)

An Infrastructure Awareness (IA) system seeks to overcome these difficulties by providing awareness to the user about one or more properties of an infrastructure. To achieve this, the Infrastructure Awareness system extracts data from the infrastructure's nimbus and translates it into information that the user is interested in and can pick up using technologies like ambient displays. This is shown in figure 1B.

Design Approach

A range of participatory and user-centred design methods provide tools and resources to foster stakeholders' creativity in the design process [4]. For example, Pictive [12] is an early example of using paper based techniques to facilitate users' implication in the design process. Mackay discusses in further details how paper and video prototypes help identify possible solutions [10]. As open thinking can be hard to instigate for participants not familiar with such methods, designers proposed to use different sets of visual elements such as elements of the *Interactive Thread* [9] or IDEO cards [7] to engage participants in generating ideas.

More recently, Halskov and Dalsgård have proposed inspiration cards [5] to both frame the ideas of participants and bring various sources of inspiration into the design process. They introduce two types of cards; so-called 'domain cards' describing findings from domain studies, and 'technology cards' illustrating applications of technology. By combining such cards, their workshop activity aims to develop new design concepts.

Central to all these previous techniques is that they all address a design process for something very specific and visible. Our focus is, however, slightly different since we are not only interested in what technology to use for the awareness system, but rather which elements of the (invisible) infrastructure are interesting to the users. For this purpose, the AMC technique retain card mapping between two different domains. But rather than using domain and technology cards, we propose to generate awareness systems ideas by using *focus* and *nimbus* cards.

THE AMC TECHNIQUE

The objective of the AMC technique is to construct an awareness model through a participatory card matching activity. Figure 2 illustrates the overall flow of the technique.

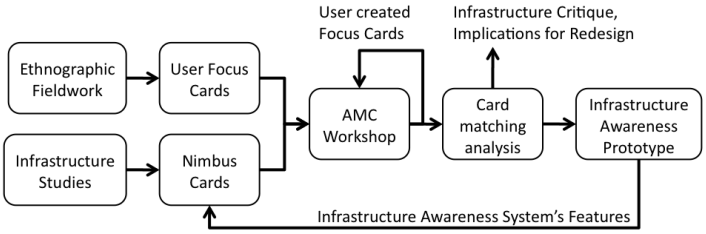

Figure 2. The AMC technique in the design process.

Card design

The AMC technique uses two types of cards: focus cards and nimbus cards. Based on preparatory domain analysis and field studies, designers initially create a deck of focus cards. Focus cards represent users' interests in the context of a given activity. Using information from the infrastructure developers, designers also create a deck of nimbus cards. Nimbus cards highlight different features of both the underlying infrastructure and the awareness system. We used cardboard cards with a title, a description, optionally a related image, and free space for comments. All cards also belong to a category for inspiring participants to generate new cards within a given category, or to identify missing categories.

Presentation

The introduction to the AMC activity starts with a short description of the workshop activities, the infrastructure, and the current state of the awareness system being designed. Thereafter, the focus cards are presented for 1 or 2 minutes, and participants start exploring them.

Co-creation and Matching

In the first phase of the workshop, participants are invited to challenge the focus cards. Participants start by exploring the cards in order to refine or discard them, or even create new ones describing interests related to the application domain. Then, participants organize focus cards in a hierarchy and in categories. The hierarchical organization leads to define the

relevance of focus cards from the participants' standpoint. The categorical organization leads to identify missing categories as well as topics which are more salient than others.

During the second phase of the workshop, focus and nimbus cards are matched. Participants group one or more focus cards with a nimbus card, if they considered the nimbus card provides for information related to the user cards. The cards are attached to a cardboard and participants are encouraged to describe how the matching occurs. In this stage participants and designers can discuss new nimbus cards that would match focus cards.

Closure

The final phase organized the matching cards in three categories *matched*, *missed*, and *discarded*. The *matched* category consists of matching focus and nimbus cards, implying that users' interests are matched by a representation of the infrastructure information. Designers can use matched cards to investigate awareness efficiency, and to identify improvements. The *missed* category consists of groups of focus and nimbus cards that match but where one of the two elements of the nimbus is missing. Either the awareness system display information not available from the infrastructure or the infrastructure provides elements of interests that are not displayed by the awareness system. Designers can leverage this information to inform the new features of the awareness system, or to critique the infrastructure. The *discarded* category consists of focus or nimbus cards that could not be matched, as well as focus cards that were out of scope (e.g., "provide a centralized purchasing system").

USING THE AMC TECHNIQUE

The AMC technique was used in the design of the ambient displays system for the P2P biology grid. First, two design workshops were conducted to discuss and mock-up the display system, and then one workshop using the AMC technique was done in order to refine the design. In the AMC workshop, four molecular biologists (one post doc and three PhD students) and two designers participated. Two of the biologists participate in the overall project of building the P2P computational grid, and have experience in developing bioinformatics software. All of the participants have taken part of some of the previous design workshops and had an overall understanding of both the infrastructure and the concepts of an awareness system.

The designers brought an initial set of cards consisting of 19 nimbus cards and 11 user focus cards. The nimbus cards detailed features of the infrastructure (15 cards) or the awareness system (4 cards) like "[grid] capacity", "tasks executed", "contribution levels", and "job progress". The user focus cards represent users' interests like "resource availability", "latest publications", and "how quickly will I have my results?". During the co-creation and matching stage 15 new user focus cards were created showing interests like "projects explanations" and "calendar of upcoming events".

In the matching stage, participants created 11 *match* groups all of which had matching features of both the infrastructure and the awareness system. Moreover, 4 nimbus cards where *discarded* as irrelevant for the user interests. Participants *discarded* 9 user focus cards (5 new) as not related to the infrastructure, and 4 (2 new) of them were categorized as *missed*.

Results and Discussion

Overall, the AMC technique proved instrumental in re-framing the understanding of participants' interests through their use of focus cards. This helped them to draw implications for the (re)design of both the awareness system and the infrastructure.

More specifically, our first observation was that by letting participants review, correct, create, and classify focus cards, the technique helped the designers to gauge the interests of the participants. We were able to refine our understanding of the participants' interest and identify elements we missed during the field work. Moreover, the focus card helped to prioritize participants interests in the following order:

1. Ongoing activity in the lab – What is going on? What are the latest publications?
2. Get and understand results – How do others do procedure X? Am I missing something?
3. Experimental procedure – Resource availability and location. Colleagues expertise.
4. Publicizing results – Exceptional results. Decoded RNA & DNA.

While we initially identified experimental results as the most important thing that biologists wanted to share with each other, the AMC workshop revealed that their interest was stronger in day-to-day activities and discussions.

As for the topical organization of focus cards (figure 3), it led to a new category we had missed; namely communication. This led to the generation of a whole set of focus cards focusing on aspects like explanations about ongoing project, Tweets, MBI emails (a mailing list dedicated to resources in the laboratory), updates about last week's activities, and an overview of upcoming events. By grouping focus cards in categories, we could also identify how some interests were redundant or deeply related and thus select focal points from different categories.

Our second core observation was, that the mapping of focus

Figure 3. Topical organization of focus cards

cards to nimbus cards defined an awareness model we could rely on for the re-design of our grid awareness system. We were able to identify both what worked, as well as identify potential breakdowns in the awareness our system was creating. This included, amongst other things, the following issues:

- which of the infrastructure features being shown, but not relevant (e.g. bidding activity);
- which of the infrastructure features not being shown, but relevant (e.g. the data used to execute a task);
- which elements of interest the awareness system could display to engage people even though not supported by the infrastructure (e.g. latest publications).
- which elements of the infrastructure were missing to answer users' interests (e.g. sharing of results).

Note that we mixed both infrastructure cards and awareness system cards in the set of nimbus cards. This combination proved to be useful to identify which interests were correctly made visible by the ambient display. It also made it easy to recognize infrastructure properties that matched participants' interest but were not visible on our ambient displays. However, by mixing these cards, we also made it more difficult for participants to know what was coming from the infrastructure and what was external to it.

CONCLUSION

In this paper, we have proposed the AMC technique: a card matching activity specifically crafted for designing awareness system for invisible infrastructures. The AMC technique helps match the interests of users to the information the infrastructure can provide, the focus and the nimbus respectively, according to the awareness model. This technique provides three benefits: 1) evaluate how existing infrastructure awareness systems match users' interests; 2) identify which of the users' interests the infrastructure awareness system does not take into account; 3) identify elements of redesign in the infrastructures themselves so that they could be better adopted by their users. We have demonstrated its use through the design of an ambient display system for providing awareness and motivating adoption of a volunteer P2P grid. The use of this technique provided important insights into the further redesign of this display system.

We discussed the AMC technique in the context of grid infrastructures, but as its name hints, the technique could be appropriated for the design of awareness systems in other contexts, such as in design for sustainability for e.g. saving energy. Future improvements include defining a more generic set of awareness cards that could be instantiated to specific application cases. This generic set could rely more heavily on the abstractions from the Awareness Model proposed by Benford and Fahlén, including concepts like space, objects, media, aura, adapters and boundaries. This set of abstractions could also be used as lenses to analyse the outcome of the AMC sessions. Finally, we seek to explore the notion of interaction in infrastructure awareness systems, as a way to trigger reflection and better support adoption of infrastructures.

ACKNOWLEDGEMENT

This research has been funded by the Danish Agency for Science, Technology, and Innovation under the project "PC Mini-Grids for Prediction of Viral RNA Structure and Evolution", #09-061856.

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