

Developing Usable Context-Aware Mobile Computing: Three levels of interactivity

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Abstract: Context-aware computing describes the area of applications that adapt according to environmental measures and it promises a smooth interaction between humans and technology. To find how this can be achieved, I separate applications into three levels of interactivity, personalization, passive context-awareness and active context-awareness. I propose to investigate which approach is appropriate for the different types of applications. It is my hypothesis that personalization-oriented applications are relevant at an early state of mobile device adoption but as the user gets experienced, context-aware applications are more relevant and useful. Finally I describe research already conducted and propose further studies to support the hypothesis.

Keywords: Ubiquitous computing, context-aware computing, mobile computing

1 Introduction

Being a part of ubiquitous computing, context-aware computing has been an active research area for over a decade. The concept of context-aware computing describes infrastructures that include sensor information from its surrounding environment, physical as well as electronic, in the computing applications. The collected information creates the *context* that comprises the interaction between humans and computing units; the applications change according to its present context. The decreasing size and increased specialization of computing devices make independent context variables essential to well functioning and usable technology. Context-awareness is the attempt to relate the technology to the actual situation and environment it is part of. Examples of context-aware applications include the tour guide that adapt its content according to location and time of day (Abowd et al., 1997) as well as the more recent WAP application that shows the user's state to defined acquaintances on a mobile phone (Schmidt et al., 2000).

Though many different approaches have been taken to facilitate the development of applications, most applications have been developed from the

knowledge of what is technologically possible. From creating a widget mode (Dey et al., 2001) and describing a blackboard model (Winograd, 2001), to characterizing context into several classes (Chen and Kotz, 2000, Schmidt et al., 1999), researchers have attempted to structure the complex nature of context sensing into categorizations and models. Context in itself is not easy to describe in terms of technical categories and some researchers even claim that it is impossible (Greenberg 2001). The present project description therefore investigates the human factors and obstacles of developing context-aware mobile computing.

2 Problem Statement

The main question within my research is how the user's experience of context-awareness in mobile computing devices depends on the presence of individual pieces of context information rather than the quality of the measured context. Quality, in this regard, is considered to be the preciseness of the sensor information. What will also be considered is *how* relevant context information is discovered and implemented into application in a way that facilitates the user's task in a positive manner. More specifically, I will attempt to determine when active or passive context-awareness in a device is more

appropriate to the user than personalization, and in which cases one is to prefer over the other.

My initial hypothesis is that personalization is relevant at an early state of mobile device adoption but as the user gets experienced, context-awareness in limited versions, is relevant and useful. This context-awareness should be developed in gradual steps, implementing only a few measures and leave it to the user to be able to change or 'turn off' these intelligent features.

3 Conceptual Framework

I have defined three levels of interactivity for context-aware applications: personalization, passive context-awareness and active context-awareness. *Personalization* describes the approach where applications let the user specify his own settings for how the application should behave in a given situation; *passive context-awareness* presents updated context or sensor information to the user but lets the user decide how to change the application behaviour, where *active context-awareness* autonomously changes the application behaviour according to the sensed information (Chen and Kotz, 2000).

The concepts will be used throughout the research and it will work as a foundation for my studies of user behaviour and context-aware technologies.

3.1 Related Work

While some researchers differ between the levels of interactivity, they rarely agree on where to separate them. Cheverst et al.'s 'push' approach is described in the same terms as our definition of passive context-awareness, while their pull approach falls in a category between personalization and passive context-awareness (Cheverst et al. 2001). Another distinction is provided by Brown and Jones, who define the levels of 'interactive' and 'proactive' (Brown and Jones, 2001). Interactive applications cover our definitions of both personalization and passive context-awareness where proactive is defined almost identically defined to active context-awareness. None of this research however, considers the difference in users' perception of the different levels.

4 Research Approach

Besides a literary review of the concepts, ubiquitous computing, context-awareness and evaluation methods of user experience, several case studies are

to be carried out. Qualitative research involving interviews of users as well as observation will be conducted to find data to support my hypothesis. Furthermore, context-aware applications will be developed according to the suggested design based on the initial case studies. The applications will be tested on users and supply knowledge of which approach of design is better: personalization or active context-awareness.

4.1 Research Already Conducted

The literary review has so far given rise to The Context Information Model, a model that facilitates the initial design of context-aware functions within consumer oriented mobile devices (Barkhuus, 2003a). It separates high level contextual information from low level sensor information and suggests designing features from the users' point of view and real needs instead of from the developers' knowledge of what is possible.

To find what context measures that are in play among mobile communication today, an exploratory case study has been conducted and analysed (Barkhuus, 2003b). It consists of qualitative interviews with high level mobile phone users and attempts to find the context information or 'cues' that make up the situation that mobile communication takes place within. The findings show that four different measures are important to the situation: identity, location, relative time and social situation. The study concludes that mobile telephony can benefit from certain context-aware features but that users inquire a lot of context information and adapt according to the features available.

4.2 Planned Studies

To test the user's preference of personalization versus passive and active context-awareness, I plan to conduct an experimental study involving the development of sample applications. It will be developed on the basis of the results from the context measure case study, meaning that the gathered context measures will be studied in relation to the three levels of interactivity. It will involve user testing of possible context aware applications, attempting to find if users prefer personalization over active context awareness.

I will have the opportunity to apply the gathered knowledge within Cross Roads Copenhagen¹, a project, which aims to develop location based mobile services and technologies. Within this project, the aspect of context-awareness is essential and actual large-scale implemented applications will be candidate for further study. My contribution to this project should be to suggest and implement the proposed context-aware technologies that I have studied so far.

5 Conclusion

What I hope to accomplish with my research is to contribute to a theoretical framework of how context-awareness can be implemented in mobile communication technology. I will attempt to provide further knowledge into the area of ubiquitous computing by demonstrating how the user's experience of technology is affected by the implementation of context-awareness in mobile technology. It will also be suggested how context-aware computing can be designed with the user in mind without attempting to technically define the overall situation.

My goal is to show how technology can facilitate the task but in a way where the user still has a sense of power. The technologies today provide endless opportunities for active and intelligent applications and services; however, keeping the user's complex sense of the situation in mind, it is important to realize that technology is not capable of predicting just any possible situation and that it has limitations in regards to awareness of the overall interpreted context. I thereby aim to bridge the studies of human behaviour with more technology oriented designs of context-aware applications in order to contribute to the many aspects of human-computer interaction research.

References

Abowd, G. D., Atkeson, C.G, Hong, J, Long, S., Kooper, R. and Pinkerton, M. (1997), Cyberguide, A mobile context-aware tour guide. *Wireless Networks*, 3, pp 421-433.

Barkhuus, L. (2003a), Context information vs. sensor information: A model for categorizing context in

context-aware mobile computing. In *Proceedings of Fourth International Symposium on Collaborative Technologies and Systems*, pp 127-133.

Barkhuus, L. (2003b), How to define the communication situation: Determining context cues in mobile telephony, in proceedings of *Context '03*, Stanford, June 23-25, 2003.

Brown, P. J. and Jones, G. J. F. (2001), Context-aware retrieval: Exploring a new environment for information retrieval and information filtering. *Personal and Ubiquitous Computing*, 5(4): 253-263.

Cheverst, K., Davies, N. and Mitchell, K. (2001), Investigating context-aware information push vs. information pull to tourists, in *Proceedings of Mobile HCI 01*.

Chen, G. and Kotz, D (2000), A survey of context-aware mobile computing research Paper TR2000/381, Department of Computer Science Dartmouth College.

Dey, A. Abowd, G., and Salber, D. (2001), A conceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications. *Human-Computer Interaction*, 16(2-4): 97-166.

Greenberg, S. (2001), Context as a dynamic construct. *Human-Computer Interaction*, 16(2-4): 257-269.

Schmidt, A., Beigl, M. and Gellersen, H. (1999), There is more to context than location. *Computer and Graphics*, 23: 22-32.

Schmidt, A., Takaluoma, A. and Mantyjarvi, J. (2000), Context-aware telephony over WAP. *Personal Technologies*, 4(4): 225-229.

Winograd, T. (2001), Architectures for context. *Human-Computer Interaction*, 16(2-4): 401-419.

¹ Cross Roads Copenhagen is a collaboration between The IT University of Copenhagen, Nokia, Denmark's Broadcast and several other private companies.

