Challenges in Designing and Implementing Adaptive Ambient Notification Environments

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Ubicomp/ISWC'16 Adjunct, September 12 - 16, 2016, Heidelberg.

ACM 978-1-4503-4462-31609...$15.00
DOI: http://dx.doi.org/10.1145/2968219.2968552

Abstract
Ambient notifications can support people in their daily activities, providing courses of action and relevant information in context. A key aspect of ambient notifications is the unobtrusive provision of information, embedded into the users' environment. The number of services which are providing notifications on numerous devices, both mobile and embedded into the environment, is increasing. Therefore, is important to find unobtrusive ways for notification, avoiding redundancy, and the appropriate detail of information and alert level. In this work, we describe some of the challenges that arise when designing ambient notification environments and provide alternative approaches by describing specific scenarios and use cases for these kind of systems.

Author Keywords
ambient notifications; smart homes; ubiquitous computing; context adaptivity; activity recognition; ambient assisted living

ACM Classification Keywords
H.5.m [Information interfaces and presentation]: Miscellaneous

Introduction

The demographic change is a challenging factor that will have decisive influence on the design of future human-computer interaction. The United Nations Population Fund projects the percentage of people aged 60 and older to 21.8% in 2050 from formerly 11.5% in 2012. Furthermore, 33 countries will have 10 million people aged 60 and older in 2050 [10]. With this change in age distribution, also questions arise of turn closer attention to people with illnesses such as depression, dementia and age-related physical and cognitive limitations. This will increase the need for assistive systems that take into account the specific requirements of the elderly as well as ease tasks in health care to allow for a longer independent life. We envision an ambient notification system, which assists elderly to live longer in their homes with notifications for upcoming tasks, calls and other every-day routines.

Generally, assistive technologies have the potential to create a safer and more accessible home environment, which can help to maintain personal independence when cognitive and physical constraints are progressing. Technology can help when challenges arise in daily routines and everyday necessities that might not be performed alone. A system that unobtrusively and comprehensively offers a range of options is preferable over direct instructions, which can be perceived as an intrusive dictation. However, suitable ambient notification mechanisms for providing unobtrusive and calm support to ease continuation of learned routines in everyday-life have not yet been sufficiently explored. Further, integrating a variety of different notification mechanisms in home environments will also raise a set of new challenges. To avoid redundancy and select the most appropriate way of notification in the user's current context, it is necessary to implement a fine-grained inter-device communication on top of an activity recognition and plan deduction component, which is shared across all services in the home environment.

Related Work

Visual, auditory or tactile alerts, distributed over different platforms, generally draw attention away from the main task to events that take place outside of user's focus. For example, in case of email notifications, the majority of users decide to enable notifications because it creates awareness of what is happening [6]. Only a quarter of the participants in the author's field study interrupted their primary task after an incoming notification. Since the primary value is to create awareness, the authors suggest to take timing and urgency of the conveyed information into account to minimize unwanted disruption.

Serna et al. modeling the progression of Alzheimer's disease for cognitive assistance in smart homes using the ACT-R theory [9]. It can be used as a basis for the plan recognition component for ambient assistance to detect dangerous situations proposes a cognitive model for pervasive assistance.

A recent system that aims to support independent living with reciprocal ambient audio awareness is *SonicAIR* [1]. It connects the soundscapes of friends or family members and thereby explores how this might reduce the isolation of seniors living independently. Instead of using microphones, the system uses sensors in embedded devices to produce a sound on the other end. Ramos et al. identified 'different types of forgetting' by using diary studies, focus groups and interviews of elderly people. Furthermore, the authors investigated which tools are being used to prevent and overcome the problem of forgetting. In correspondence with our approach, they suggested to integrate reminder systems directly into every-day objects [8].

Figure 1: Ambient lightning pointing towards the door.

Figure 2: User interacts with a Lorm communication glove.

The related work consistently suggests that handling attention and minimizing disruption is essential to calm down ubiquitous computing environments. This directly brings us to the challenges of designing and implementing ambient notification environments.

Exemplary Scenarios

We now present two possible scenarios of the envisioned system. Afterwards, we discuss the challenges for designing and implementing the system.

Scenario 1: Motivating for physical activity
Bob likes to go for a walk in the park after lunch if the sun is shining and temperature is just right. In the park there is his favorite café were he likes to stop to get a coffee. While the system is in learning phase, it collects information about relevant locations, people and objects in order to compile a personal behavior history. Data can be entered by Bob himself using a user interface, or by the system using sensors in relevant objects (e.g. a walking stick or coffee cup) and in Bob's clothing (e.g. his jacket). The learning phase is being executed before his cognitive ability declines. If Bob's behavior changes for the worse, for example staying on the couch watching TV instead of going to the park, this will be detected by the system. At this point, the system changes from the learning phase to the executive phase. By showing different possible courses of action using fitting stimuli, the system tries to motivate Bob to go back to his usual behavior. For example, audio signals (e.g. chirping birds) or ambient lighting could be used to point towards the door (see Figure 1). Another option could be gaining Bob's attention by letting the walking stick emit auditive or visual cues. If not all environmental conditions are met, for example when it is raining, the system could suggest talking the umbrella or alternative actions (going to the swimming pool).

Scenario 2: Supporting vision and hearing decline
In the past year Alice's vision and hearing declined. Nowadays she is unable to read small text on displays without her glasses and she sometimes misses phone calls because she did not hear the ring tone. She wears a wool cardigan that supports her in her daily routine. The cardigan is connected to the envisioned system and can detect touch, twist and pressure. This allows Alice to interact with the cardigan, for example to call for help. The system forwards the call to her family members. Also, when sitting in front of the TV, the cardigan can use tactile feedback to inform Alice about events such as incoming phone calls. By simply pulling on the cardigan, Alice is able to answer incoming calls. Apart from body-worn tactile interfaces the system can display hints for optional or necessary actions using ambient notifications on objects in her environment.

The system learns her habits and is able to, depending on her current context, use different notification channels. Because the type and degree of the physical impairment differs for every user, the system is able to adapt to the needs of the user and selects appropriate input and output channels. Further, by analyzing the user's input, the system is able to adjust the sensitivity of the input methods by adapting it according the needs of the user. Even if Alice's vision and hearing further declines, the system will be able to support Alice in an optimal way by using specialized user interfaces for deafblind people. Currently, deafblind people use the communication system Lorm that is based on a tactile finger alphabet. This system can be connected to the envisioned system using sensors and actuators in the form of a communication glove [3] (see Figure 2). The envisioned system can translate messages into the tactile Lorm alphabet and therefore enable deafblind people optimal support in their everyday life and the ability to stay connected with family and friends.

Challenges with Ambient Notifications

In the following we will investigate different challenges respective designing and implementing adaptive ambient notification environments as well as physical constraints which have to be considered.

Designing ambient notifications

The design aspect is important to create consistent and esthetic notification environments which unify different modalities and multiple devices with diverse technical capabilities. Aesthetic, functional, economic, and social dimensions must be considered to form a pleasant ambience for a particular context. As an example, audio notifications can be designed such that they form an ensemble playing. Non-speech audible notification cues, which might be personalized and dependent on the current location, can be embedded into background music as proposed by [11]. Although the information of the notification is transported into the environment, by design, the user perceives it as possibly relaxing music without causing a disturbance. Similarly, it is conceivable to further unify and integrate by adding mood across different modalities. The design challenge is to embed notifications creating an interplay of different forms of notifications that is meaningful and unambiguous. At the same time, the holistic representation and possible notification flows should meet the same demands, which are required for the acceptance of other objects in living environments. For a particular information, a representation must be chosen that suits best the current attentional demands and task priority of a user. Thus, the design of notifications highly depends on the user's context and is ideally chosen at runtime by individually outweighing the benefits and attention costs for the user [2]. Design guidelines addressing the aforementioned situational awareness for ambient notifications should be derived using the user centered design approach.

Implementation

Ambient notifications should be implemented as calm and peripheral interfaces, suggested by [2]. The information is represented continuously over a longer period of time allowing the user to comprehend the information in-depth and to detect patterns and trends. State changes can be perceived implicitly in the ambient notification environment. Part of the implementation of ambient notification environments is a context recognition and a plan deduction component, which can be realized by instrumenting the environment and by using sensors assessing the cognitive and physiological state of the user. For example, gaze detection including fixations and saccades are an indicator for reallocation of attention and can be used for deriving context information for notification management [5]. The notification management and coordination across different modalities can be implemented with a publish and subscribe messaging transport protocol. It it necessary to identify a set of well-known models from psychology that rely on practically observable data in a living environment, which can in turn be used to select adequate presentations and adapt notifications at runtime.

Psychological constraints

Understanding the cognitive load, the remaining attentional capacity, and the task prioritization of a user is a crucial prerequisite to make context available in an ambient notification system. Representations of notifications that reduce distraction of the current main task require a measure of the attentional costs, which the user possibly has to pay. The psychology of perception yields evaluations approaches for outweighing benefits and costs of notifications in terms of various aspects. The general tradeoff that has to be made lies between the utility an individual user has with the access to additional digital information and the scarcity of his attention, referred as the attention-utility-tradeoff [2]. Experiments using eye-trackers and body-worn sensors have

been conducted to assess the impairment of the primary task, such as in [5]. Horvitz used a Bayesian model to infer the probabilities of which degree an interruption pays off in terms of information value for the user [4]. The author also considered attention to be the most limited resource of the user. However, ambient notifications are different as they are not supposed to attract the users' attention directly. Visually, the detection of events is more efficient if these are located within the spotlight of attention [7]. Thus, notifications at the peripheral level are suited to create ambient notification environments to prevent unwanted distractions and disruptions.

Summary

In this paper we discussed challenges in designing and implementing a system that enables adaptive and ambient notifications. This system assists elderly people with decreasing health state to live longer in their homes. It should consist of a learning phase in which the users' habits are entered by the users themselves or automatically by interacting with smart objects. If the system detects negative change in the users' habits, it will switch to the executive phase and notifies the users in an ambient way about possible courses of action. The system should be adaptive and adjust itself according to the users' needs. We introduced two exemplary scenarios and discussed emerging challenges, for example the design of ambient notifications, technical difficulties in the implementation and psychological constraints.

Acknowledgments: This work is supported by the German ministry of education and research (BMBF) within the DAAN project (13N13481) and by the DFG within the SimTech Cluster of Excellence (EXC 310/2).

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