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Attention Management in Ubiquitous Computing Environments

Abstract Ubiquitous computing environments offer users an increasing variety of information, services, and communication occasions. Designing such environments in a manner that facilitates users in the selection of attention-worthy events and actions becomes increasingly necessary in order to avoid overloading the limited human abilities to process incoming stimuli. This workshop presents a selection of papers describing research for the development of attention-aware ubiquitous computing environments.

Keywords Attention management · Ubiquitous Computing

1 Introduction

One of the challenges of ubiquitous computing is the coordination of different devices so that their interventions with users take into account ongoing (inter)actions and avoid cognitive overload. The mechanism that humans use to control cognitive load is attention. Attention acts as a filter of incoming information. Attention can either be controlled voluntarily by the subject, or it can be captured by some external event. Voluntary control is referred to as endogenous, top-down, or goal-driven attention. Attention captured by external events is referred to as exogenous, bottom-up, or stimulus-driven attention. For example, if one reads some text one is applying endogenous attention, however a sudden noise may attract attention through an exogenous process. In order to limit cognitive overload it is important to model users' attentional states (as guided by endogenous and exogenous processes) and adjust devices' behaviour to this state. To this end, devices of different complexity levels must gain a coherent understanding of users' past and current (inter)actions, goals, preferences, social relationships, etc. Through this attention awareness cognitive load may be minimised by addressing issues such as: interruption management / notification optimization, individual versus group interaction, just-in-time information selection, customable information visualisation.
Whilst "disappearing", i.e. minimizing cognitive load, has been the chief objective of ubiquitous computing, true adaptation to human cognitive abilities requires a better understanding of the reactive, deliberative, social, and aesthetic processes controlling attention allocation and of how they can be supported by technologies. Improving such understanding is the primary objective of this workshop on Attention in Ubiquitous Computing Environments. The variety of research issues covered in this field is well represented by the papers in this workshop. We have broadly organised them into three areas: (1) detection of user attention, (2) attention-aware information presentation, and (3) support of shared and individual attention in collaborative situations.

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2 Detection of Users' Attention

As discussed in [3], in order for a system to be respectful and supportive of users' attentional choices it needs to detect and model users' attentional states. The system needs therefore to determine the user's goals and current tasks, establish the user's attentional focus, and be aware of what is happening in the environment; as well as detecting and evaluating possible alternative attentional states for the user.
Two aspects in the detection of the user's attentional state are particularly important. First, it is necessary to capture and model those events – i.e. user's (inter)actions, changes in the environment – that are relevant when defining the user's current and alternative attentional foci. Second, it is necessary to capture these events in a manner that is unobtrusive.
A methodology for modelling users' current attentional states is proposed by Maisonnasse and his colleagues who evaluate "the spread of attention over a group of interacting persons and entities" and collect the results in "a matrix that captures the allocation of attention for each individual over nearby entities". This attention matrix can then be used to guide the interactive behavior of devices in pervasive environments.
Pallotta and his colleagues propose to capture peoples' motion in order to extract information about their attention and intentions and, they suggest that abnormal situations, i.e. when motion is not following expected patterns, may be used as triggers for more attention-demanding interventions by the system.
Detecting unusual patterns in the environment as a signal of possibly attention-worthy situations is a strategy also used by Kulakov & Davcev who concentrate on the case of video processing for surveillance tasks and propose a

"General Learning System capable of learning sequences or time-series of signal patterns" which implements a model of attention for the recognition of significant entities in life video-captured sequences. Their model builds upon an earlier Behavioral Model of Visual Perception. The objective is having a system capable of detecting, and correctly reporting unusual events occurring in real-time that might not have been included in the training data.
Finally Yokohata and colleagues sketch two contextual elements that may intervene in the definition of users' foci: location and preferences.

3 Attention-Aware Information Presentation

On the basis of their knowledge of the attentional state of the user, devices can make an informed decision on the best strategies for interaction. Time and modality of interaction, as well as cueing, may determine the quality of the communication and the level of cognitive load imposed to the user.
For example, Cheng and his colleagues note that "Resource intensive task-focused top-down processes essentially screen out bottom-up activation of attention, leading to sensory events being effectively ignored". In these situations, they propose to use cuing mechanisms to engage the user in a voluntary shift of attention. They discuss the role of cues for attention management in visual displays along four different dimensions: (Locus of control, Spatial cue information, Semantic cue information, Timing of the cue) and provide scenarios exemplifying the effects that priming may have in several situations.
As resource-intensive, task-focused processes may impair top-down attentional mechanisms, so can large-scale environments, which may overload the user's sensory mechanisms possibly resulting in the user missing important information. The latter problem is address by Koceski and his colleagues who propose a set of visualization guidelines for attention support in navigation systems for large-scale environments. Such environments typically force "the navigator to integrate the information provided by successive viewpoints into a coherent mental representation of the traversed environment". The guidelines proposed by the authors aim at optimizing "the usability of the displayed information by directing the users' attention to the highest priority data."
The issue of appropriately timing interactions is addressed by Gievska who proposes that the most suitable time for interrupting an user may be evaluated using Bayesian networks by "inferring the state of several hypothetical (non-observable) variables: Interruption Relevance, Sensitivity to Interruption, Individual Differences, Environmental Conditions and Urgency of interruption." Gievska proposes that these variables are related to categories within an Interruption Taxonomy that she also introduces. .Finally Rudman and Zajicek focus on the evaluation of attention aware systems, which demand a new approach when determining the key indicators for success in the system.

4 Support for Shared and Individual Attention in Collaborative Situations

An aspect of attention management that is becoming increasingly critical is the support of shared and individual attention in collaborative situations. Heider and Kirste address the problem of information presentation in multi-display environments for the support of collaborative problem solving and teamwork. In order to make appropriate decisions about display allocation the system must consider users' diverging interests as well as the dynamic changes of foci within the community. The authors report results in which automatic display management reduces the number of interactions and minimizes the users' cognitive load.
Supporting attention in collaborative situations normally also involves mediating the communication amongst participants in order to minimize disruption whilst ensuring that important messages are timely recognized.
Maisonneuve proposes a model of attention in communication based on a visual search model. The mechanism proposed by the author mirrors both bottom-up and top-down processes. The visual features guiding bottom-up processes are mirrored with 7 salient features that could attract the receiver's attention in communication. Top-down control is mirrored by an intention profile that models how the user's context mediates attention allocation in communication.
Intelligent notification and interruption in pervasive or ubiquitous environments is also addressed by Mei and Easterbrook who emphasize "the social or organizational dependencies among different actors in the process of completing a task."

6 Conclusions

Whilst the research community has increasingly recognized the enormous potential of attention aware systems [1, 2, 4] the issues related to design of such systems in ubiquitous computing environments need to be further addressed in a homogenous manner. This workshop represents a first effort in this direction.

References

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