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Active Environments: Sensing and Responding to Groups of People

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ABSTRACT

Most environments are *passive* – deaf, dumb and blind, unaware of their inhabitants and unable to assist them in a meaningful way. However, with the advent of ubiquitous computing – ever smaller, cheaper and faster computational devices embedded in a growing variety of "smart" objects – it is becoming increasingly possible to create *active* environments: physical spaces that can sense and respond appropriately to the people and activities taking place within them. Most of the early UbiComp applications focus on how *individuals* interact with their environments as they work on *foreground* tasks. In contrast, this paper focuses on how *groups* of people affect and are affected by *background* aspects of their environments.

Keywords

Ubiquitous computing, intelligent environments, social issues, computer supported cooperative work.

INTRODUCTION

Computers are becoming smaller and cheaper, connectivity is expanding in both the wired and unwired domains, and the growth of digital content is outpacing the capabilities of current indexing systems. These trends are ushering in an era of *ubiquitous computing* [5], in which we have computing and communication capabilities available in all kinds of environments and situations beyond the "traditional" model of sitting at a desktop computer workstation. Under this new model of computing, human-computer interaction issues evolve into issues of *inhabitant-environment interaction*. Many of the early applications of ubiquitous computing focus on how these new capabilities will affect an *individual*'s interactions with his or her environment. However, much of our time is spent in shared physical spaces, so it is important to consider how an environment might effectively sense and respond to *groups* of co-located people. This paper raises a number of issues for what might be called "UbiGroup" applications, and describes research that address some of these issues.

Many of the computer applications we are familiar with today are used in the *foreground* of our attention, e.g., checking stock quotes on our web-enabled telephone or using a word processor application on a laptop computer to create a short conference paper. However, as computers become smaller and cheaper, they will increasingly be embedded in a variety of objects that do not typically require, and often do not permit, our focused attention. Such applications will operate in the *background*, at the periphery of our attention; they will affect aspects of our environments, but not necessarily assist us directly with the task(s) at hand.

One example of this type of application is MUSICFX [4], a system embedded in a fitness center environment that is aware of who is working out and what they generally like to listen to, and uses this knowledge to determine the best music to play at any given time. While MUSICFX affects aural aspects of a group environment, another project seeks to affect visual aspects: the Projected Realities proposal [3] calls for pictures or artwork that would be projected on large public displays to reflect the mood of the local population. Finally, Sunset [1] affects both the visual and aural aspects of a group environment, creating a "drive-by interactive drama" in which a large public display shows a vignette – a sequence of pictures accompanied by a soundtrack of "insinuating muzak" – that is influenced by the number of passersby (or loiterers) pressing buttons on their keyfobs and garage door openers.

In general, these and other new environment-affecting applications must be able to sense their contexts, determine the preferences and goals of their inhabitants, and respond appropriately. The remainder of this paper discusses these functions in more detail, and highlights issues that arise in the ways that various applications implement them.

CONTEXT SENSING

The context for the Sunset project consisted of people passing by the Billboard Live club on Hollywood's Sunset Boulevard who were detected by monitoring for transmissions from radio key fobs and garage door openers. The Projected Realities proposal includes a number of potential environmental sensing capabilities, e.g., "ventrovers" that could listen and peak into rooms in an apartment complex and a network of linked security cameras and monitors, although the longer range context was inferred by other means (described in the next section).

Unfortunately, in many contexts, detecting *that* one or more people are present is often not as useful as identifying *which* people are present. Both the Sunset and Projected Realities projects could be extended in interesting ways were they to include the capability to identify the current set of inhabitants. In the fitness center environment affected by MUSICFX, the music is tailored to the preferences of the specific people working out, not to the number of unidentified people. In a workplace environment, temperature and/or lighting levels might respond to the number of people present, but adapting to the preferences of those specific people would likely result in a more hospitable environment [2].

Although some progress has been made in computer vision and speech recognition systems for identifying the faces or voices of different people in a room, many systems, including MUSICFX, that rely upon the accurate identification of different people in a physical space utilize some kind of badge or tagging system. Greater progress in the area of automatic identification is one factor that would enable more widespread deployment of environment-affecting applications, although the privacy concerns of people who might be identified in an increasing number of contexts would have to be addressed.

PREFERENCE AND GOAL DETERMINATION

Once an environment becomes aware of whom its inhabitants are, the next step is to associate preferences or goals with these inhabitants. This might be done *explicitly*, by querying inhabitants about their preferences or goals, or it might be done *implicitly*, by inferring these from the environmental context and/or some observable actions taken by the inhabitants. In either case, these preference or goal determinations might be done in one or more different times and/or places than the environmental context in which the response system is embedded.

Nothing explicit was known about the particular preferences or goals of people passing the Sunset displays. However, it was assumed that passersby would prefer viewing (and participating in) potentially engaging entertainment rather than blank screens. The Projected Realities project collected responses to "cultural probes" that included pictures and or textual material, from which inferences were made about the concerns and activities of the inhabitants of an apartment complex. In MUSICFX, explicit determination of musical preferences was accomplished by asking fitness center members to fill out an electronic enrollment form to specify one of five levels of preference for each of 91 genres of music.

An implicit determination of musical preferences could be accomplished by tracking a person's purchases at an on-line music store or tracking which Internet radio stations a person listens to. However, privacy concerns may dampen people's enthusiasm for participating in such a system. In general, there is a tradeoff between implicitly inferring preferences, which may be inaccurate and perceived as invasive, and explicit requests for preference information, which may be burdensome and imposing (and therefore not used by some/most inhabitants).

RESPONDING APPROPRIATELY

Once an environment has some knowledge (or, at least, presumption) of the preferences and goals of its inhabitants, it can adapt itself in response. Sunset responded to the activity of its passersby by altering the pacing, segues and selection of its vignettes. In Projected Realities, various public displays would respond to the inferred collective mood of the residents by projecting images representing that mood. MUSICFX responds to the musical preferences of the fitness center inhabitants by choosing music that is likely to please them.

CONCLUSION

Two themes common to all these applications is their focus on environmental aspects on the periphery of inhabitants' attention, and their responsiveness to the group of inhabitants rather than single individuals. As computers permeate more aspects of our environments, we expect to see new capabilities for sensing and responding appropriately to inhabitants, which will provide for more engaging, entertaining and hospitable environments in a broader variety of contexts.

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