Ambient Displays: A Designer's Synopsis

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ABSTRACT
Research in the field of ambient displays has burgeoned within the past several years, but a coherent view of the design space has yet to be articulated. We present a synopsis of key design dimensions for ambient displays based on a survey of existing ambient displays. This paper presents our findings, referencing representative work for each design component, and in the process introduce research areas and display designs not yet investigated.

Keywords
Ambient displays, user interface design

INTRODUCTION
Ambient displays present information in the periphery of the user's attention, cultivating a design paradigm that does not assume nor require explicit attention or interaction from the user. The Dangling String [8], one of the first ambient displays, hangs from a motor whose speed corresponds with the ongoing network traffic. The motor spins faster as the network traffic increases, creating a combination of noticeable sound and motion from a distance, yet these movements are not distractive or disruptive for casual observers.

The Dangling String is just one example of the many unique displays created [1-9]. Although ambient display research has blossomed, a coherent, concise overview of the design space has yet to be articulated. We present a designer's synopsis of key design dimensions for ambient displays, charting the design space for these displays and suggesting areas for future research in the process.

OVERVIEW
Despite the artistic and physical diversity of existing ambient displays, there are elements of every ambient display that hold constant. In general, there is a data source whose data are optionally processed (summarized, filtered, etc.), then translated into output by the display. Figure 1 shows the relationships between these steps. Though most ambient displays assume passive use, users can potentially interact with the system by modifying the data source, the type of processing performed on the data, or the display itself. In the rest of this paper, we discuss each step of this model, suggesting future research for ambient displays.

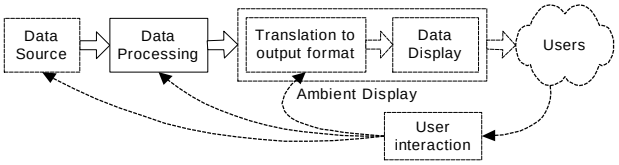

Figure 1 - Overview of an ambient display

DESIGN DIMENSIONS
Data Source
Data sources drive the ambient display and may consist of one or many input channels; comprise personal or public data; be communicative (connecting people to people) or informative (connecting information to people); or be contextual in nature. The Water Lamp [2], for example, presents a single input channel (e.g., water projection on the ceiling) of semi-public, context-free, informative data about web site accesses. Audio Aura [5], on the other hand, offers multiple input channels of private and public data that are sometimes context-aware. Specifically, it uses a headset to play layers of sounds that give information about (private) email or (public) activity.

With the exception of Audio Aura, contextual information has rarely been exploited in the design of ambient displays. Further, great potential exists for displays like the Digital Family Portrait [6], which are aimed for home use.

Data Processing
Ambient displays process data to provide useful information in the user's peripheral attention, reducing the need for deep analysis and focus. In addition, ambient displays often preprocess data due to the limited and unique display modes (such as moving water or spinning string). Data can be summarized, aggregated, trended, or otherwise manipulated. The Digital Family Portrait, for example, displays trends to give users an overall feel of the activity level and health of a remote family member over the previous month.

Historical or predictive data fit naturally with ambient displays, providing awareness of temporal activity. Histories also allow users to "see" what they may have missed, while predictive information foreshadows future events. Music Monitor [7], for example, incrementally introduces instrumental voices into the bass, harmony, and melody lines to gradually transition to the new state. Despite these examples, however, few ambient displays provide either histories or predictions.

Translation to an Output Format

The affordances of the output media impact the way the display uses and maps data. Abstraction is a key element of this process. Most ambient displays cannot precisely render most data, unlike, say, a pixelated monitor displaying text. A less precise, more abstract data display may also result in more aesthetically pleasing displays, and help to hide specific or private information. As an example, Audio Aura "displays" and summarizes email information as ocean waves rather than providing a detailed representation of these data. Currently, there exists little to no end-user support in existing displays for selecting data sources or modifying data mappings to the output media.

Data Display – Choices in Media, Form, and Location

A major design decision is the media through which the data are displayed. Ambient displays may target any combination of the senses, but as [9] points out, the choice of media should consider the context of use. For example, if the display is intended for use in a visually demanding environment, it should probably target one of the other unoccupied senses.

Media choices also influence the number of discrete pieces of information that may be displayed (bandwidth), the refresh rate for a display, and how transitions are made between the background and foreground of the user's attention. A display employing changes in temperature, for example, has both a low bandwidth and low refresh rate when compared with a traditional CRT. Slow refresh rates can be desirable if the media leave a "residue" and create a history. The Water Lamp, for example, leaves a residue of water ripples after the lamp has been tapped by a solenoid. More work is needed to fully explore how different media can leave traces of activity in their wake.

One or many output channels can be employed. When multiple channels are used to represent a single data source, opportunities exist to represent the same data at varying levels of abstraction. The Information Percolator [3], a display that uses air bubbles rising in columns of water, produces both aural and visual effects. It is a pixelated display that can provide precise information visually, while it supports an abstract aural awareness of activity via the bubbles. There is ample room, however, to explore displays with varying levels of abstraction in their representation. One could imagine a "self-describing" ambient display, for example, where the sum of individual, precise data points paints a broad, abstract picture from afar, similar to scatter plots.

Users and Interactivity

Ambient displays can target a spectrum of users, from individuals to select groups to the general public. Audio Aura presents mostly private information to a single user. Sunset Boulevard presents billboard-sized images to an audience of thousands of random commuters, controlled by garage-door-opener button votes [1].

While most ambient displays are simple output displays, user interaction represents another design dimension. Interaction may be implicit (e.g., contextual, as in Audio Aura), or explicit as in the clock in the ambientROOM [4]. The majority of displays, however, offer the user limited to no interaction. For displays with particularly abstract representations of data, interactivity allows users to retrieve more specific information. For example, imagine that as users walk closer to the Dangling String, they hear whispered the names of the machines with the highest loads.

CONCLUSIONS

In this paper, we have consolidated past work in ambient displays to create an overview of the design space of this field. In the process, we have identified areas for future research. In particular, this synopsis suggests the need for exploration of: end-user tools to configure ambient displays; context-aware displays; lightweight communication between multiple users of one or more displays; use of histories and predictions in ambient display output; media choices that result in historical residue; self-describing displays and other uses for gradients of abstraction; more interactive options for ambient displays.

REFERENCES

1. Crane, M., MacDonald, D., Minneman, S., and Winet, J. Sunset Boulevard: 200 MHz in a 35 mph Zone. Exhibited at the SIGGRAPH '97 Electronic Garden.
2. Dahley, A., Wisneski, C., and Ishii, H. Water Lamp and Pinwheels: Ambient Projection of Digital Information into Architectural Space. In *Summary of CHI '98*, 1998, pp. 269-270.
3. Heiner, J.M., Hudson, S.E., and Tanaka, K. The Information Percolator: Ambient Information Display in a Decorative Object. In *Proceedings of the 12th annual ACM Symposium on User Interface Software and Technology*, 1999, pp. 141-148.
4. Ishii, H., Wisneski, C., Brave, S., Dahley, A., Gorbet, M., Ullmer, B., and Yarin, P. ambientROOM: Integrating Ambient Media with Architectural Space. In *Summary of CHI '98*, 1998, pp. 173-174.
5. Mynatt, E.D., Back, M., and Want, R. Designing Audio Aura. In *Conference Proceedings on Human Factors in Computing Systems*, 1998, pp. 566-573.
6. Rowan, J., Mynatt, E., Rogers, W., and Jacobs, A. Digital Family Portraits: Providing Peace of Mind for Extended Family Members. To be presented at CHI'01.
7. Tran, Q. and Mynatt, E. Music Monitor: Ambient Musical Data for the Home. In *Proceedings of the HOIT2000 Conference*, 2000, pp. 85-92.
8. Weiser, M. and Brown, J.S. Designing Calm Technology. http://www.ubiq.com/hypertext/weiser/calmtech/calmtech.htm
9. Wisneski, C., Ishii, H., Dahley, A., Gorbet, M., Brave, S., Ullmer, B., and Yarin, P. Ambient Displays: Turning Architectural Space into an Interface between People and Digital Information. In 1998, pp. 22-32.