# Explorations and Experiences with Ambient Information Systems

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## ABSTRACT
We have developed a series of ambient information systems and used each in our research lab for extended periods of time. The systems use technologies such as RFID, RSS, and Phidgets to help present information on devices ranging from tangible and tactile objects such as children's toys to peripheral displays running on wall-mounted LCDs. This article describes the motivation, design goals, and implementation issues for four systems: Ambient Trolley, Pirate Island, AuraOrbs, and InfoCanvas. A key capability provided in most of the systems is the consolidation of multiple types of awareness information into one display. We conclude the article with reflections on our experiences and questions about how one would evaluate such systems.

## Categories and Subject Descriptors
H.5.m [**Information Interfaces and Presentation**]: Miscellaneous.

## General Terms
Design, Experimentation, Human Factors.

## Keywords
Ambient information system, ambient display, peripheral display, evaluation, RFID, Phidgets, LCD

## 1. INTRODUCTION
Within the Information Interfaces Lab at Georgia Tech, we have been exploring the design and use of a variety of ambient information systems [7] over the past few years. Our approach to each project has begun with the identification of a need or problem by people in our local community. We have coupled work on addressing these problems with a desire to explore the use of new technologies. The projects described herein, for example, have employed Phidgets, RFID tags, RSS feeds, and flat panel picture frame style displays.

One of the common threads across all the projects is that each has focused on communicating *awareness information* to our lab inhabitants. Awareness information is sometimes called "discretionary information" and it involves information that is important to people but is not their primary focus at that time. For example, information about tomorrow's weather forecast, traffic on the ride home, or a colleague's presence in the office can all be considered awareness information. Information like this has become much more available recently because of widespread network access and increased distribution of data by information providers, much of this occurring through the WWW.

All of the systems described here have been deployed in our lab and have been in use for extended periods of time. We believe that only through long-term use like this can one adequately understand the benefits, problems, and general issues of such systems.

In the sections that follow, we describe four particular systems developed, the Ambient Trolley, Pirate Island, AuraOrbs, and the InfoCanvas. The sections explore motivations for the project, design rationale, technologies employed to build the system, and some reactions to its use. We conclude by reflecting upon our experiences with all the systems and the further research questions they raise.

## 2. AMBIENT TROLLEY
The Georgia Institute of Technology has trolley service between various locations around campus and to the subway station in a nearby neighborhood. Our lab is located a moderate distance from the main campus, so many people use the trolley to commute to classes and meetings held there. Fortunately, a trolley stop is located directly in front of our building and thus it receives a lot of use by our lab members. Trolleys, shown in Figure 1, are scheduled to arrive every 5-10 minutes, but due to surface street traffic, trolley arrival times are inconsistent and one cannot plan on a trolley being at a stop at a predetermined time.

Because our lab is on the third floor and it has no view of the trolley stop, it is difficult to know when a trolley is nearby and thus when one should rush to meet it. The first ambient information system we describe is an attempt to help people gain

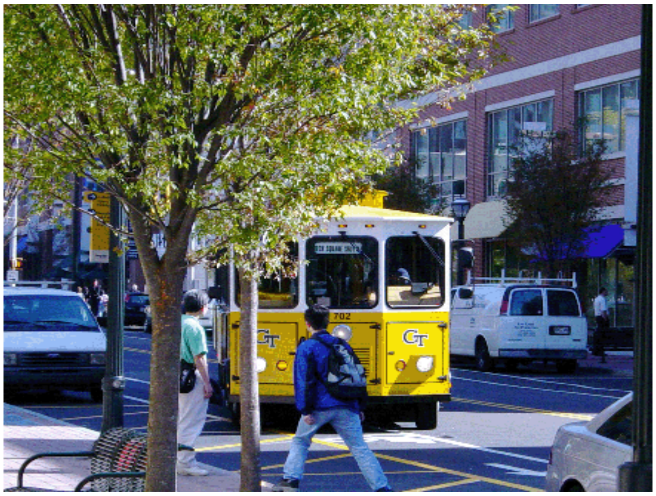

**Figure 1: Actual trolley running on campus.**

an awareness of the trolley's position and suggest a good time to leave the lab to meet the trolley.

In the Ambient Trolley project, we built a novel physical interface to indicate to building residents the amount of time before the next Trolley arrives at the stop outside our building. We modified an O-gauge model railroad trolley car to run along a 6-foot length of track suspended from the ceiling near the entrance to our lab (see Figures 2 and 3). Small labels at the midpoint and two endpoints of the track indicate the amount of time estimated until the trolley arrives: 8, 4, and 0 minutes from left to right. The trolley's position is updated every 60 seconds to reflect the new arrival estimate. In the event that the estimate is greater than 8 minutes, the car is positioned at the left-most endpoint. To meet the bus, users typically must leave their desks when the model indicates 2 minutes.

The trolley car is controlled from a PC hidden nearby. A Phidgets [2,3] interface board is used to control various lights and motors on the trolley car, as well as relaying input from endpoint switches to the controller application. At regular intervals, the application retrieves a simple web page containing estimated arrival times based on GPS data provided by NextBus [4]. The


**Figure 2: Ambient Trolley up-close.**


**Figure 3: Configuration of Ambient Trolley showing tracks and positional markers used to indicate distance from trolley stop.**

HTML is then parsed for the next predicted arrival and this value is used to reposition the trolley. The controller application itself is rather plain, allowing a user to start or stop the display, indicating the current arrival time depicted by the trolley, and providing access to diagnostic functions like moving the trolley car along the track manually.

We experimented with several positioning mechanisms to determine which provided the most reliable visual estimates of the indicated time. In the original prototype, user intervention was required to calibrate the amount of time needed for the trolley to move from one end of the track to the other. In practice, this proved problematic as users were not able to consistently indicate the same endpoints—in effect, each time the display was restarted the physical positions of 0 and 8 minutes changed. To address these concerns, we added hardware switches to fixed endpoints of the track, and calibration was handled entirely by the controller application. The trolley could then be repositioned by moving the motor in the appropriate direction for a duration equal to $1/8^{th}$ of the total end-to-end calibration time multiplied by the absolute difference in previous and current values. For example, if the estimate changes from 5 to 3 minutes, the motor must run for $1/4^{th}$ the total calibration time.

Unfortunately, this did not solve all of our positioning problems. Users noted that the trolley seemed to "drift" from its calibrated positions. Typically, this meant that the trolley failed to reach the 0 endpoint when it should have. We noted that there was slight variation in the speed of the motor in the forward and reverse directions, causing some of the faulty motion. Additionally, drift tended to occur when the motors were moved for long durations. Over the course of a day, these small drifts compounded and became perceptible enough that the display was considered unreliable.

Two solutions were attempted. In the first, we attached a light sensor to the underside of the trolley car and added a series of white and black markers to the track bed. The idea was that the light sensor would be able to detect the exact locations of all non-end point values (1-7). However, this proved impractical due to changing ambient lighting conditions in our lab throughout the day. The final solution returned to the timed positioning approach, but enhanced the algorithm by adding special cases. If the new value is either of the extremes (0 or 8), the trolley is moved until the corresponding end switch is tripped. Due to more drift observed on longer motions, if the new value is greater than half the distance of the track, the trolley first repositions to the far end and moves back to the new position. All other cases rely on the original strategy where a short burst in the corresponding direction is used to approximate the value. Anecdotally, the trolley display now seems to depict arrival times reasonably well enough to be usable. Remaining discrepancies are no worse than those caused by inaccurate GPS predictions.

The Ambient Trolley appears to be a fairly self-explanatory representation of the information being portrayed and most passers-by appear to “get it.” Unfortunately, the GPS data driving the system is only moderately reliable and this can undermine people’s confidence in the display. Ambient information systems are clearly prone to this kind of problem. In terms of interest and appeal, many viewers smile or chuckle when observing the Trolley for the first time, a fact that is pleasing to us as designers. Viewers have commented, however, that the blue cord connecting the Trolley to the computer does detract from the aesthetics of the system.

## 3. PIRATE ISLAND

Our next system, Pirate Island, is an attempt to explore how fun and playfulness can be combined with useful information conveyance. A child’s LEGO-like construction set for a pirate island makes up the setting of this physical display. Figure 4 shows the island. Various aspects of the island have been motorized to provide animation to represent transformations in awareness data being monitored.

This project and the two others described later in the article illustrate one of the primary design goals of our work with ambient information systems, a desire to consolidate multiple pieces of awareness data within one system. Many ambient displays developed previously have focused on one particular nugget of information. In contrast, we wanted to explore whether multiple data streams could be combined into one coherent display and whether people viewing the display could easily digest all the different information.

**Figure 4: Pirate Island Information Display.**

Each of the four moveable parts on Pirate Island (circled in Figure 4) communicates a different piece of information and they are drawn from three fundamental information types: continuous values, categorical values, and binary values. Both the cannon, on the far left, and the compass in the middle of the figure are able to communicate continuous values. The cannon rotates on a continuum of 180 degrees in relation to the current temperature value. The compass is a simple clock, portraying the hour of the day. The pirate climbing the ladder, to the right, signifies a simple binary value, in this case the presence of precipitation. He faces the ladder when the value is 0 (sunny conditions) and outward when the value is 1 (rain is occurring). Finally, the flag above the pirate illustrates categorical values and currently is mapped to traffic conditions. The flag stands upright when traffic is normal, at 45 degrees to the right when traffic is slightly congested, and at 90 degrees when traffic is severely congested.

Pirate Island uses Phidgets to help control the display, much like the Ambient Trolley. The application program controlling Pirate Island is minimal. It exposes the actual values being depicted by the physical display and allows a user to start and stop the Phidgets.

## 4. AURAORBS

Another type of awareness information sometimes communicated to people through peripheral or ambient displays is presence information. Communicating the presence/absence of colleagues or friends has been a common theme in CSCW applications [5], one example of which is video-based media spaces. Transmitting video, however, raises numerous privacy concerns. Some researchers suggest that the video stream be filtered to mask out potentially sensitive information [1]. Our next system adopts this strategy by using an ambient information display to communicate presence information.

In a shared community like our lab, it is not uncommon for someone to wonder whether another (absent) person has been there recently, whether they have been in yet that day but stepped out, and so on. Similarly, people may wonder whether an office with a closed door simply means the person is not present or if the person is present but working privately.

We have built an ambient information system that communicates people’s presence along with a few items of local interest such as weather forecasts and traffic conditions. The system’s interface runs on a large 42 inch flat panel display on the wall of our lab as shown in Figure 5. It uses abstract geometric shapes and colors to represent the awareness information. We use RFID technology to identify people’s presence and RSS feeds to gather the weather and traffic information.

RFID uses radio frequency signals to identify objects. An RFID system consists of two primary components - a tag and a reader. We use passive tags that have no battery of their own and make use of the incoming radio waves broadcast by a reader to power their response. Each member of our lab has a tag such as a key fob, a card, or a flat disk and each tag has a unique signal that identifies it to the reader.

**Figure 5: AuraOrbs display deployed in the laboratory.**

In the AuraOrbs system, we have mounted an RFID reader on the pole of a wire shelf near our lab entrance. Lab members swipe their RFID tag past the reader when they enter and exit the lab. Software running on a computer connected to the reader detects each swipe event, determines who the person is, and updates the information display. The display control system also monitors the RSS feeds and updates the view as appropriate to the most recent information received.

The AuraOrbs display follows the style of an abstract painting. Figures 6 and 7 show two example system views. Each person in the lab is represented by a unique-colored sphere. When an individual arrives and badges in, their sphere appears at a random position on the display. When the individual leaves and badges out, their sphere changes into a circle outline of that same color. The radius of the circle then begins to slowly shrink and will eventually disappear after two hours. This visual representation allows viewers to determine who is "in" and whether a person was recently present but has now stepped out. If a person badges out and then back in shortly thereafter, a new sphere is created. Thus, a number of hollow circles means that a person has been in and out frequently in the recent past.

The background color of the view portrays weather information. The left edge of the background indicates temperature, more specifically, today's forecasted or measured high as compared to tomorrow's forecasted high. If tomorrow's high temperature will be much warmer, then the left edge of the display is bright red. If tomorrow's temperature will be much colder, the left edge will be blue. The color is smoothly interpolated between these two extremes to encode the forecasted difference with an in-between purple color indicating a high temperature tomorrow equal to today's high. The right edge of the background is used to encode tomorrow's forecasted conditions. Yellow indicates sunshine, gray indicates clouds, and black means rain is coming.

The number of wavy lines through the display simply indicates the number of traffic incidents on highways frequented by several members of the lab. More lines indicate more accidents and a likely slower commute home.

We designed the display to be simple and to allow a viewer to quickly learn the relevant information at a glance. The background colors have natural correspondences and were intuitive to all. The number of wavy lines is easy to detect as well. Learning the mapping from sphere colors to individuals took about a week of use with a reminder legend posted next to display. Thereafter, the legend was removed and lab members were able to remember the mappings. This symbolic color-to-person mapping provides a level of privacy in that only our lab members who know the mappings can determine details of any individual's presence. In our case privacy like this is not a

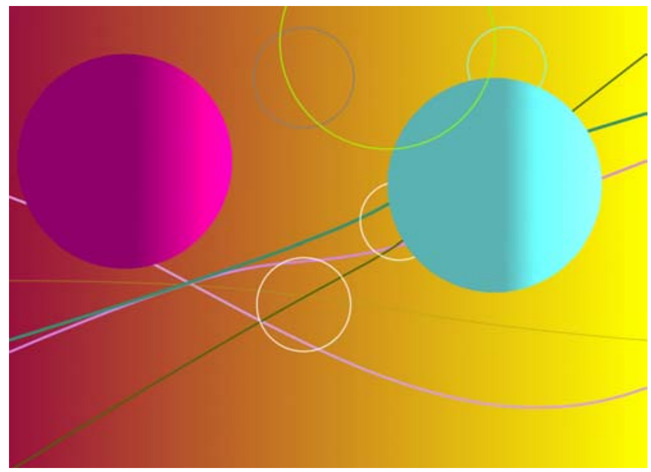

**Figure 6: Example AuraOrbs display showing two people present (pink and blue spheres) and five recent departures (circle outlines). The display also indicates that tomorrow will be moderately warmer than today (reddish left edge) and sunny (yellow on right). Five traffic incidents (wavy lines) have recently occurred on local roads.**

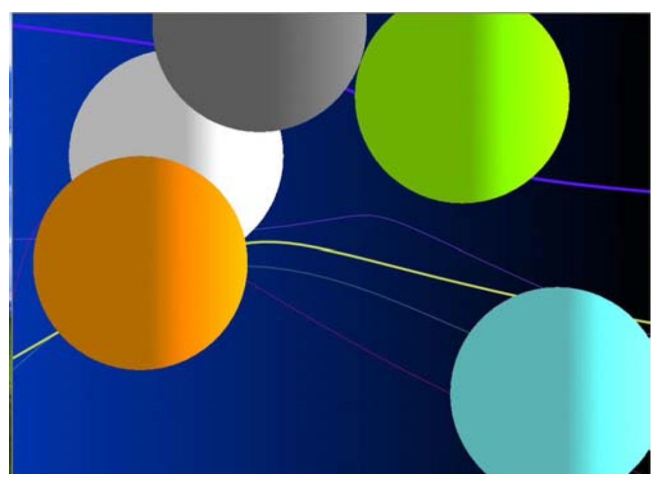

**Figure 7: Another example AuraOrbs display indicating much different weather than that of Figure 6. The display shows that tomorrow will be much colder than today (blue left edge) and rainy (black on right). Five people are present.**

concern, but one could easily imagine situations where tracking of specific people's movements by outsiders would be problematic.

Aesthetics were also a concern in the design of the display. Since it is so large and prominent in our lab, we wanted a scene that would be attractive and appealing. While individual artistic tastes vary widely, the display has largely been viewed favorably.

The AuraOrbs system is implemented using MFC, OpenGL, and XML DOM libraries. A simple control interface allows users to manage the visual mappings and add new individuals and RFID tags. Details of monitored data such as forecasted temperatures and traffic incident locations can be overlaid on the display. Furthermore, changes in data are logged and a time slider allows a user to quickly go back-and-forth in time to rapidly see movements and changes in data. Although we have not implemented it yet, one can easily imagine a touch or voice interface that would allow this type of more in-depth information to be summoned on demand.

Lab members appear to enjoy having the AuraOrbs display running in the lab and find the information it communicates useful. The chief problem with the system is people forgetting to swipe in or out when arriving or departing. Other, more automated tracking technologies could help this problem, however. The display clearly has piqued the interest of outsiders and we have fielded many questions regarding its purpose. One observer commented that he does not know the mappings of colors to individuals (as is appropriate for someone outside the lab), but the background color weather mappings are still useful.

## 5. INFOCANVAS

The InfoCanvas is an ambient information system that communicates information via a flat panel LCD that has had the bezel removed and replaced by a picture frame. The system thus acts like an electronic picture in which the scene can be controlled and made to change. An example of the InfoCanvas running in an office is shown in Figure 8. A variety of scenes exist, most exhibiting a kind of clip art style.

The main idea of the system is that different objects in a scene can be set to represent different items of awareness information of interest. When the underlying data being monitored changes, then

**Figure 8: Example deployment of InfoCanvas.**

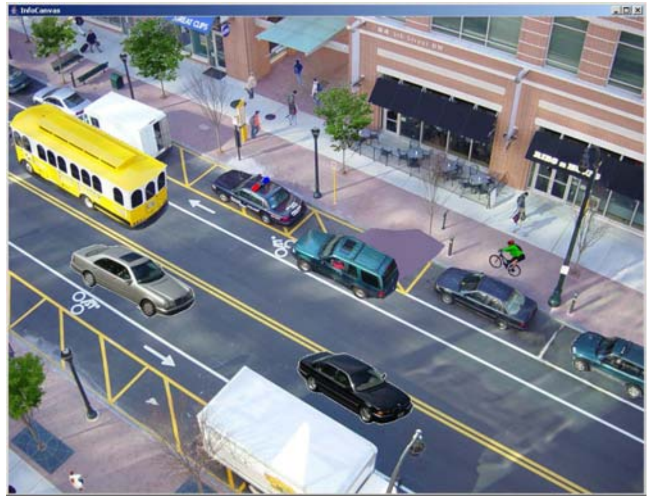

**Figure 9: Sample InfoCanvas scene. Colors, appearance, and positions of objects such as the cars, lights, people, trees, etc., all indicate the present state of information of interest.**

the corresponding object's representation in the scene is updated appropriately. Objects can change appearance, color, position, and size, or can be made invisible to represent different data states. For instance, in the example scene shown in Figure 9, the number of cars on the street could indicate stock performance that day or the level of traffic on a drive home. The position of the bicyclist could indicate tomorrow's forecasted high temperature or the current time of day.

Details about the system are described elsewhere [9], but a more recent longitudinal study of the system deployed for use by eight local technology workers uncovered some interesting findings [8]. For instance, the use of seemingly strange abstract, symbolic mappings such as a crab's position on the beach representing a stock value was appreciated and often adopted by participants. A key factor in this was that the person using the display was able to personalize the mapping from data of interest to an object of choice. This personalization made the representation more meaningful and relevant to the individual.

The system was viewed most favorably by people in the middle of a spectrum of information consumers. At one extreme, people who normally kept aware of very few pieces of discretionary information just did not have a basic need for it. At the other end of the spectrum, people who wanted to know precise details about many different information items, such as current prices of 10-20 stock values, did not find the symbolic representations detailed enough and they used the display as a simple alert to gather more detailed information from other sources. In between these two extremes were the majority of study participants who identified 5-15 items of information that they typically maintain awareness of from day-to-day. These people found the system to be both useful and enjoyable on the whole.

## 6. DISCUSSION

One of the key questions that has emerged from our experiences building and using the systems above is how to evaluate the systems. Ambient information systems are not meant to assist some finite, concrete task that can be easily measured and assessed as is often the case for other computer applications. Rather, an ambient information system's success seems to lie in some combination of 1) effectiveness in promoting awareness in some data of interest and 2) a level of enjoyment and satisfaction in the person or persons who are using the system.

Studies of systems in this space are challenging because any explicit evaluation efforts of an examiner draw more attention to the ambient system than it would normally receive, thus its peripherality is compromised and one must question whether realistic use is being examined. While certain aspects of an ambient information system such as its perceptual affordances can be measured in a laboratory study [6], we feel that evaluations of systems as a whole must be longer-term examinations of actual use in real-world situations. It is important to study deployed working systems in their proper context to understand how they are being perceived and how they are affecting the people in that environment.

Another problem or challenge with ambient information systems is that they typically consist of special purpose hardware and software that is difficult to create and can malfunction or break easily. Therefore, we conclude with another important question that must be answered for this field to grow — How do we transition ambient information systems from special purpose "toys" to more everyday information appliances?

## 7. ACKNOWLEDGMENTS

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## 8. REFERENCES

[1] Boyle, M., Edwards, C. and Greenberg, S. The Effects of Filtered Video on Awareness and Privacy**.** In *Proceedings of CSCW '00,* Philadelphia, PA, December 2000, 1-10.

[2] Elliot, K. and Greenberg, S. Building Flexible Displays for Awareness and Interaction. In *Proceedings of the UbiComp '04 Workshop on Ubiquitous Display Environments*, Nottingham, U.K., September 2004.

[3] Greenberg, S. and Fitchett, C. Phidgets: Easy Development of Physical Interfaces Through Physical Widgets. In *Proceedings of UIST '01*, Orlando, FL, November 2001, 209-218.

[4] NextBus. Available online: http://www.nextbus.com/predictor/publicMap.shtml?a=georgia-tech

[5] Pederson, E. R., and Sokoler, T. AROMA: Abstract Representation of Presence Supporting Mutual Awareness. In *Proceedings of CHI '97*, Atlanta, GA, April 1997, 51-58.

[6] Plaue, C., Miller, T. and Stasko, J. Is a Picture Worth a Thousand Words? An Evaluation of Information Awareness Displays, In *Proceedings of Graphics Interface '04*, London, Ontario, May 2004, 117-126.

[7] Pousman, Z. and Stasko, J. A Taxonomy of Ambient Information Systems: Four Patterns of Design. In *Proceedings of AVI '06*, Venice, Italy, May 2006, 67-74.

[8] Stasko, J., McColgin, D., Miller, T., Plaue, C., and Pousman, Z. *Evaluating the InfoCanvas Peripheral Awareness System: A Longitudinal, In Situ Study*. GVU Tech Report: GIT-GVU-05-08, Georgia Tech, Atlanta, GA, March 2005

[9] Stasko, J., Miller, T., Pousman, Z., Plaue, C., and Ullah, O. Personalized Peripheral Information Awareness through Information Art. In *Proceedings of UbiComp, '04,* Nottingham, U.K., September 2004, 18-35.