The Georgia Tech Aware Home

Julie A. Kientz
College of Computing
Georgia Institute of Technology
Atlanta, Georgia 30332
julie@cc.gatech.edu

Ed Price
Interactive Media & Technology
Georgia Institute of Technology
Atlanta, Georgia 30332
ed.price@imtc.gatech.edu

Shwetak N. Patel
College of Computing
Georgia Institute of Technology
Atlanta, Georgia 30332
shwetak@cc.gatech.edu

Elizabeth D. Mynatt
College of Computing
Georgia Institute of Technology
Atlanta, Georgia 30332
mynatt@cc.gatech.edu

Brian Jones
Interactive Media & Technology
Georgia Institute of Technology
Atlanta, Georgia 30332
brian.jones@imtc.gatech.edu

Gregory D. Abowd
College of Computing
Georgia Institute of Technology
Atlanta, Georgia 30332
abowd@cc.gatech.edu

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Abstract
The Aware Home Research Initiative (AHRI) at Georgia Tech is devoted to the multidisciplinary exploration of emerging technologies and services based in the home. Starting in 1998, our collection of faculty and students has created a unique research facility that allows us to simulate and evaluate user experiences with off-the-shelf and state-of-the-art technologies. With specific expertise in health, education, entertainment and usable security, we are able to apply our research to problems of significant social and economic impact.

Keywords
Aware home, smart home, home, aging in place, children, sensors

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
The Aware Home Research Initiative (AHRI) is an interdisciplinary research endeavor at the Georgia Institute of Technology that addresses challenges facing the future of domestic technologies. A unique and critical resource in this activity is the Georgia Tech Broadband Institute Residential Laboratory (Aware Home), a three-story, 5040-square-foot (470 m^2) home that functions as a living laboratory for interdisciplinary design, development and evaluation (see Figure 1). The two main floors of the Aware Home have identical floor

Figure 1: Outside view of Aware Home

Figure 2: Floor plan of the first and second floors of the Aware Home

plans (see Figure 2), and are designed to be two, independent, 3-bedroom, 2-bathroom apartments.

The home was designed from the ground up with accessibility, computing, and sensing balanced with aesthetics. Indirect and diffuse lighting along with a low-sheen floor provide ideal conditions for computer vision applications while also reducing glare for the residents. Conduit through the walls and between floors combined with a drop ceiling hide equipment and sensors and allow easy installation of new technologies.

The Aware Home research spans several complementary themes. In particular, we have developed applications that support several different scenarios for families or individuals living in a home. These applications cover the themes of aging in place, busy families, and children with special needs. In addition, we are also working on developing the building blocks to create highly distributed sensing and perception technology, developing awareness of human activity in physical environments. In this paper, we describe each of the above research themes and completed or ongoing research projects that exemplify the main goals of each theme.

Collaborations

The Georgia Tech Aware Home is an interdisciplinary effort on campus, with faculty members representing many different areas and colleges. These areas include Computing (HCI, computer vision, activity recognition), Electrical and Computer Engineering, Psychology, Industrial Design, the Health Systems Institute, and Architecture. We also have many collaborations with industry and various funding agencies, including the National Science Foundation, the National Institute on Aging, the National Institute of Mental Health, the Cure Autism Now Foundation, the Georgia Tech Broadband Institute, Georgia Tech Venture Labs, Intel Corporation, Motorola Labs, Hewlett-Packard, Mitsubishi Electric Research Labs, Siemens Research, and Visteon. We hope to expand our collaboration with additional industry and academic institutions, as well as increase our collaboration internationally.

Designing Applications for People

When designing technology for a home setting, the most important priority is ensuring that it meets the needs of the people who live there. Not only must one consider the proper function of the technology for the target population, but also understand what is aesthetically acceptable for that population. Thus, research in this space, must be multidisciplinary, involving not only computer scientists and HCI researchers, but also industrial designers and psychologists as well as experts in the space (*e.g.* gerontologists or therapists).

The applications spaces and specific projects described below fit one of the two scenarios: supporting aging in place and supporting busy families. These application spaces include social communication, memory aids, everyday home assistants, and health monitoring.

Supporting Aging in Place

There are many reasons why elderly people may wish to remain in their own homes for as long as possible [7]. The AARP in the United States conducted a study that indicate that senior adults strongly prefer maintaining as much independence as possible and that they want to stay in their homes. Seniors and their families also must consider the cost of assistive care

Figure 3: Digital Family Portrait

Figure 4: Memory Mirror

Figure 5: Technology Coach

facilities in the United States - estimated at nearly $60,000 per year for 1 adult.

There are several main issues that must be addressed when designing for seniors in the home. First and foremost is maintaining the safety of the individuals. This can be done through preventing accidents, whether by removing physical hazards or indicating when a stove or oven was left on, or through detecting and addressing accidents, such as detecting when an elderly person falls and calling emergency services for him or her in the event of an accident. Another important aspect of supporting aging in place is helping senior adults with daily activities, such as reminders to take medication or help individuals with learning various technologies they need, such as a blood glucose monitor. Lastly, technology to support aging in place should facilitate communication to others outside the home. This can be to help coordinate various family members and caregivers checking in on the senior adult, but also to help combat isolation that might be felt by senior adults living alone. Below are three applications being developed and evaluated to support seniors living independently in their home.

• **Digital Family Portrait [8]** –The Digital Family Portrait (see Figure 3) reconnects family members by providing a qualitative sense of a distant relative's well-being while striking a reasonable balance between privacy and the need for information. Like a traditional portrait, it is designed to be hung on the wall or propped on a mantle, blending with household decorations. Instead of a static frame, the digital frame changes daily, reflecting a portion of the person's life. From general measurements of activity to indications of the weather, the portrait attempts to capture the observations that would naturally occur to someone living next door or in the same home.

• **Memory Mirror** - Memory Mirror reflects the use of specified objects during a period of time (e.g., 24 hours of a day). As a person uses an item, it is visually posted to the mirror and is recorded in a history log. If an item was previously used, the mirror reflects details of the previous number of usages. The memory mirror (see Figure 4) also warns of possibly lost items that have yet to be returned. The uses RFID (radio frequency identification) technology, which is being rapidly adopted by industry as "active barcodes" for tracking inventory and tagging objects with digital information.

• **Technology Coach [6]** - The Technology Coach (see Figure 5) provides ongoing feedback to assist older adults in using home medical devices for the first time, or for the one hundredth time. The system "watches" the use of the device via different tracking technologies and provides appropriate guidance. We are evaluating the use of conceptual and procedural feedback for both short-term and long-term use of the device and are developing new techniques for modeling complex chronological tasks and new methods for recognizing actions with the device using optical sensors.

Supporting Busy Families in the "Sandwich Generation"
The modern culture of families in the United States has moved toward a model where the adults living in a home both work full-time jobs. Often, this family will have young children as well as elderly parents that they must care for, earning them the nickname, the "Sandwich Generation." These families are often very busy and have many things requiring their attention. In the Aware Home, we are developing technologies to

Figure 6: Cook's Collage

Figure 7: Family Video Archive

Figure 8: Baby Steps

help families manage busy schedules, care for loved ones from both generations, care for individuals with special needs, and make life at home more enjoyable. Below we list ongoing and completed projects aimed at supporting busy families.

• **Cook's Collage [13]** - The Cook's Collage provides a visual summary of recent cooking activity along a kitchen countertop. The motivation is that while you are cooking, you may be interrupted by a phone call or a child who needs attention. The Cook's Collage aims to help you remember where you were while cooking so you can resume after interruption. The current design emphasizes the temporal order of cooking events. Visual snapshots are arranged as a series of panels similar to a comic strip, ending with the most recent action highlighted in yellow. Figure 6 shows the cook's collage display as a cook prepares a punch recipe.

• **Personal Audio Loop [12]** - The Personal Audio Loop (PAL) is a continuous audio buffering application that serves as a memory aid for individuals. PAL resides on a mobile phone and always provides access to the last 15 minutes of audio in a person's life. This helps the user answer questions such as: "What were we talking about?" or "What was that person's name?" We have conducted several studies in the lab and the real world to determine whether the device is usable, useful, and ubiquitous. Additional analysis has looked at the privacy and social acceptability of such a device.

• **Family Video Archive [2] & Context Cam [9]** - The Family Video Archive (Figure 7) is an application that helps in organizing and retrieving home videos. The Family Video Archive enables people to add footnotes to video files with metadata and use this data to find meaningful scenes, creating a web of interwoven connections between segments. We have also developed the ContextCam, which automates the capture of the metadata about the scene being recorded using sensors, GPS, and prediction models.

• **Bufferware [3]** - BufferWare is a space-based table-top application that allows you to save the last few minutes of audio and video when you least expected to need or want to save things. This could be a conversation you might want to save for later reference, or footage of your child's first steps that you were unable to capture otherwise. Bufferware does not inherently archive information, which provides a balance of social, technical, and practical concerns of capture applications.

• **Baby Steps [4]** – Baby Steps (Figure 8) is a project motivated by the need for the early detection of developmental delay, which helps affected children get better treatment and intervention. We are working on a digital repository for new parents to keep track of various milestones in their child's development that are indicators of typical cognitive development (for example, babbling by age 6 months, or holding and shaking toys at age 3 months). The system we are developing will also proactively ask parents to look for various milestones and provide prompts for parents to talk to their pediatrician if milestones have not yet been met.

Designing Technology Building Blocks

In order to support some of the applications designed for people as described above, the basic building blocks of a technology infrastructure are needed to sense various activities. For example, the Digital Family

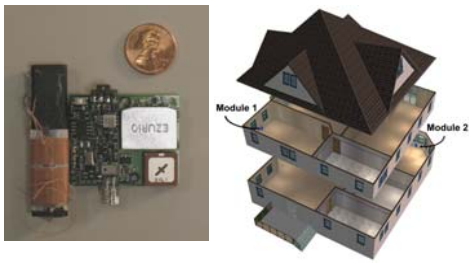

Figure 9: PowerLine Positioning

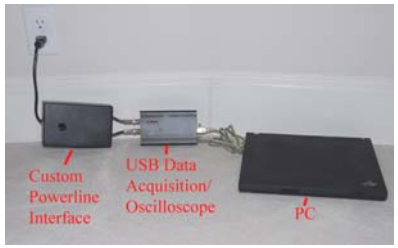

Figure 10: PowerLine Event Detection

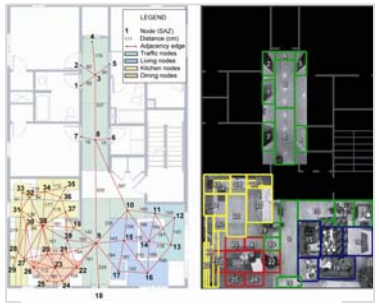

Figure 11: Activity Characterization

Portrait requires a sensing system that can indicate activity within a home and the Technology Coach uses a computer vision system that can detect where a user makes a mistake. General safety and peace-of-mind are other reasons why you may need in-home sensing. Below we describe several ongoing projects that form the technology building blocks for the applications described above and other potential applications.

• **PowerLine Positioning [11]** – PowerLine Positioning (Figure 9) is the first example of an affordable, whole-house indoor localization system that works in the vast majority of households, scales cost-effectively to support the tracking of multiple objects simultaneously, and does not require the installation of any new infrastructure. The solution requires the installation of two small plug-in modules at the extreme ends of the home. Simple receivers, or positioning tags, listen for these signals and wirelessly transmit their positioning readings back to the environment. PowerLine Positioning is capable of providing sub-room-level positioning for multiple regions of a room and has the ability to track multiple tags simultaneously.

• **PowerLine Event Detection [10]** - Activity sensing in the home has a variety of important applications, including healthcare, entertainment, home automation, energy monitoring and post-occupancy research studies. Many existing systems for detecting occupant activity require large numbers of sensors, invasive vision systems, or extensive installation procedures. This approach (Figure 10) uses a single plug-in sensor to detect a variety of electrical events throughout the home. This sensor detects the electrical noise on residential power lines created by the abrupt switching of electrical devices and the noise created by certain devices while in operation. We use machine learning techniques to recognize electrically noisy events such as turning on or off a particular light switch, a television set, or an electric stove.

• **TrackSense [5] -** While commercial solutions for precise indoor positioning exist, they are costly and require installation of additional infrastructure, which limits opportunities for widespread adoption. We have developed a self-contained solution to precise indoor positioning that requires no additional environmental infrastructure. Evaluation of our prototype indicates this system can deliver up to 4 cm accuracy and 3 cm precision in rooms up to 5 m^2, as well as 2 degree accuracy and 1 degree precision on orientation.

• **Activity Characterization** – Within the ceiling of the Aware Home are 10 pin-hole cameras capable of performing computer vision techniques. We are exploring the use of these cameras for the use of "activity characterization" (Figure 11). Rather than try to recognize specific activities, we are working toward using low-resolution camera images to infer higher resolution motion-data than motion sensors alone would provide. The characterization of activity can be used to inform applications of the "mood" of the home, *i.e.*, are the inhabitants very active and busy today? Or are things more calm and relaxed?

Conclusions and Future Work

The Aware Home Research Initiative at Georgia Tech is an ongoing project that enables researchers to explore what it means to develop technology for residents in a "living laboratory" setting [1]. One key approach to our research is to first look at the actual needs of potential inhabitants of the smart home through

formative evaluations of the design requirements and social implications of technology. We believe being well-informed about the needs of the users facilitates designing practical technology that can actually be used in real homes. The applications we develop advance Human-Computer Interaction by showing examples of human-centered applications that meet the needs of real users and are feasible to deploy in a real home setting. In addition, the novel technology building blocks enable designers to make interesting technology designs a reality. In the future, we are working toward developing a 5 year strategy that will include expanding upon our efforts to cover treating cancer in home, energy conservation and sustainability applications, and the early detection of social and behavioral disorders. We also plan to increase our efforts in making many of the applications and technology building blocks a reality through commercialization efforts.

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