The Sense Lounger: Establishing a Ubicomp Beachhead in Elders' Homes

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ABSTRACT
In this paper we describe the Sense Lounger, a method for simply and cheaply turning a lounge chair into an initial "ubicomp" device in a home; providing a beachhead for transforming the home into a rich ubicomp environment. The Sense Lounger employs fabric sensors sewn into a chair's slipcover and force sensors on each leg to detect both an occupant and their activity. Drawing insights from user needs, we developed the Sense Lounger to (i) fit into the home and lifestyle of elders, (ii) assist and add value to the lives of elders, (iii) provide a platform for expanding assistive devices within the home environment. The current Sense Lounger prototype can be used to detect signs of life, patterns of use, posture, and sitting duration.

Keywords
Interaction design, design studies, assistive technology, eldercare, aging in place, ubicomp

ACM Classification
H.5.m Information interfaces and presentation (e.g. HCI)

INTRODUCTION
For many years researchers have explored the promise of ubiquitous computing (ubicomp) technology in the home; however, both users and product development companies have been reluctant to bring these developments into homes. Resistance comes from privacy concerns, cost, aesthetics, ease of use, and the inconvenience of instrumenting entire homes. People will continue to resist using ubiquitous computing technology in their home until they can see that the benefits easily outweigh their concerns.

Elders provide one of the most interesting demographics with respect to ubiquitous computing technology for two reasons. First, declines in their cognitive and physical abilities provide an opportunity for ubicomp systems to add real benefits to the quality of their lives. Second, the percent of elders in the population is growing. The US Census Department has predicted that the elderly population in the United States (65 and older) will double from 34 to 68 million by the year 2028 [8]. Elders also present a real challenge to the ubicomp community in that they are quite resistant to new technology in the home.

Figure 1. The Sense Lounger (left) exposed view of Sense Lounger's sensors (right)

As people age, their physical world begins to shrink, resulting in them spending more time at home. In addition, they often require assistance to keep up with the tasks of daily living. They receive some assistance from family, friends, and health care workers, but technology may also be able to play a positive role in their lives. Acceptance of ubiquitous computing devices and environments offer elders an opportunity to live in their homes longer.

Resistance to ubicomp systems in the home comes from their expense, invasiveness, lack of user control, complication, difficulty to operate, and lack of aesthetics appropriate to a home. Many people resist the idea of cameras in the home due to privacy concerns. Others will not purchase, install, or even allow the large number of devices and technologies required for a room level system. Room-based technology can also appear "too smart" and autonomous for an elder audience that is already ceding much control of their lives to family members and healthcare workers. However, technology that comes into the home through their much loved and frequently used chair may provide an opportunity for convincing elders of the benefits of larger ubicomp systems.

RELATED WORK

Related work falls into the areas of (i) acceptance of ubicomp systems, (ii) whole house systems, and (iii) smart furniture. Abowd [1] identified and explored issues of privacy, control, visibility and security with respect to ubicomp. Additionally, Forlizzi et al. discovered how social attributes and cultural judgments can also influence elder's willingness to accept assistive devices [2]. We have designed the Sense Lounger with these factors in mind.

Many ubiquitous computing research and industry projects involve room-level or whole-home systems [4,5]. These homes employ multi-camera vision setups and/or large sensor networks. These systems involve the acceptance of a lot of technology into one's home and can be intimidating. Projects with a smaller footprint include The Digital Family Portrait [7]. This remote display of an elder's activity in the home appears much less invasive and expensive. We see our Sense Lounger as one potential input device for this or related activity communication systems.

A project at MIT has developed a Sensing Chair, which uses two relatively expensive pressure sensor sheets placed on the seat and back of an office chair [10]. Their chair senses posture. Fay *et al* have developed a Smart Couch, which uses load cells to recognize the occupants sitting on it [2]. Our approach differs in two distinct ways. First, we focus on maximizing the value of inexpensive sensors, and second, we do not require users to replace a chair that may have high sentimental value.

The majority of work in this area employs a technology first approach. Our work, however, benefits from combining the methodologies of design and technology research. We have also adopted the research goal of making ubiquitous technology that conforms to Raymond Lowey's MAYA design philosophy of "Most Advanced Yet Acceptable" [6]. This can be tricky to achieve when designing for any audience, and especially elders because they frequently have barriers to the acceptance of technology. Throughout this paper we will discuss these barriers that we have discovered and how we have designed our technology to overcome them.

NEEDS ASSESSMENT

We began by reviewing the findings of a previous ethnographic study of 17 elders living independently in their homes [3]. This work focused on the private home as the context, and looked specifically at how problems with products and the environment provided signs of decline and a need for assistance. This previous study identified five major opportunity areas to assist the aging population. The area of most interest to us was "chairside and bedside."

Interviews

In order to learn more about elders' relationships with their chairs, we went to an assisted living facility in suburban Pittsburgh and interviewed 7 elders (4 women and 3 men) about their chairs. We interviewed them about their furniture and asked where they spend their time. We were also interested to learn if they had a dominant chair and to gain insight into activities they conducted while seated.

We used a directed storytelling approach, asking them, "How did you use your chair yesterday?" We focused on elders living in assisted living facilities because they have moved and are able to reflect on their lives before and after the transition. Generally, as elders move, they relocate to smaller spaces. As a result, they must reduce their furniture and belongings, increasing the value of the items they choose to keep with them. The elders we interviewed had moved from particularly large homes (3-4 bedroom) to 1-2 bedroom apartments, and had to reduce their possessions.

Themes

In synthesizing the data, several themes emerged. We chose to focus on two: chair attachment and the command center.

Chair Attachment: Interviews revealed that elders have a strong attachment and sense of personal history with their dominant chair, which has developed after many years of use. We saw that as their requirements for a chair changed, they would augment their existing chair with cushions, headrests and slipcovers instead of buying a new one.

Figure 2. Chair as Command Center

Chair as Command Center: Elders frequently used their chairs as a "command center", surrounding it with objects needed throughout the day. Figure 2 offers an example of a chair surrounded by a telephone, lamp, remote controls, baskets of reading material, and supplies for craft projects.

Developing and Evaluating Elder's Needs

Based on our interviews we developed a list of daily needs a smart chair might support. These needs include autonomy, exercise, keeping a schedule, communication, safety, education, and entertainment. In order to validate that our observed needs matched the elder's perceptions of their needs, we conducted a focus group session with six elders living in different assisted living facilities. We generated a set of twenty-two concepts scenarios showing both where these needs were and were not met. The scenarios focused on the interaction between the user and the chair and not the specific technology. During the focus group, we shared the concepts one at a time and asked the elders if they had similar experiences.

Design Implications

This design research had a tremendous effect on the technological design of the Sense Lounger. Perhaps the most significant finding was that we would not be able to replace the elders' existing chair with a new technological one. The focus group confirmed our observation that elders have a strong relationship with their current chair. In addition, it revealed elders' resistance to spending money on technology and to accepting new items into their homes. However, this research showed us that we could augment their chair with technology, so long as it met some requirements. Three of these most important requirements are that this technology be simple, robust and comfortable.

We developed a set of seven requirements for the sensors based on our interviews and the focus group. By following these design requirements, we can build home sensors to assist elders that are more likely to be accepted.

- **Adaptable.** Sensors should be easily integrated into any type of chair, recliner or sofa and mustn't damage them.
- **Comfortable.** Sensors need to be comfortable to sit on.
- **Durable.** Sensors need to withstand everyday use including sitting, spilling, and cleaning.
- **Safe.** Since these sensors are going to be so close to the user's body, the user cannot be in danger from them.
- **Aesthetic.** Sensors need to fit into the home aesthetic.
- **Natural.** Sensors need to preserve the existing human-chair interaction, the basis of the current user-chair relationship.
- **Affordable.** Sensors need to be inexpensive in order to get realistic acceptance from elders.

Applications

We see the Sense Lounger as a system that can be used for many different applications. We want to build from the existing notion of the chair as the place the user spends their time and performs activities, by building technology that supports their current activities as well as enabling them to do new ones.

One simple application of the Sense Lounger measures how long someone sits in the chair. In our focus group we got a positive response about a chair that gave the user a subtle clue (backrub) that they had been sitting in the chair for "too long". This application resonated with the elders in the focus group because they admitted to sitting still too long which caused them to feel stiff. Knowing how long someone spends in the chair is a simple and useful activity monitor for family members and caregivers.

In addition to detecting presence, the Sense Lounger will be able to sense the occupant's activity for context sensitive applications. For example, if the lounger knows the user's schedule and detects that the occupant is taking a nap in their chair, it will be able to wake the occupant from their nap in plenty of time to make an appointment.

SENSE LOUNGER DESIGN

We decided that the design that best met these requirements was a "Smart Slipcover" that went over the chair, and force sensors which slipped under the legs of the chair.

Smart Slipcover

This slipcover has custom built conductive fabric sensors sewn into it. These sensors detect which parts of the chair the user is touching, and are strategically placed throughout the seat, back and armrests. This information is then used to determine the posture of the chair's occupant.

We conducted a design exploration of many different conductive materials and evaluated them based on how they met the sensor requirements described above. We looked at materials such as conductive foam, mesh, paint, and tin foil. While all inexpensive, these materials vary in terms of durability and comfort. Conductive foam is comfortable to sit on, but is thick and loses its shape after sitting on it. Tin foil is extremely inexpensive and highly conductive but not durable. Painting conductive paint on fabric is a very fast way to build a sensor, but isn't very conductive and requires many coats that become hard when dry. Conductive mesh, such as that used in window screens, is too inflexible to work with or sit on.

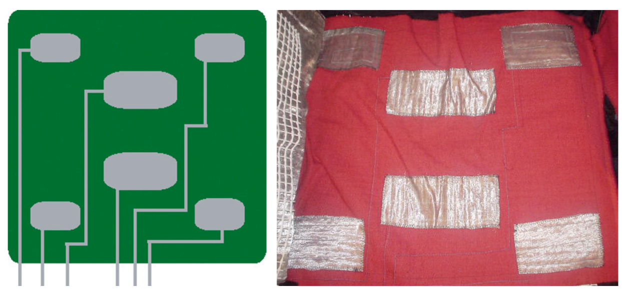

Figure 3. Final seat sensor layout sketch (left), prototype made out of conductive fabric and conductive thread (right)

The Sense Lounger uses the same conductive fabric used in [9], metallic Silk Organza, which is 80% metal and 20% silk. The conductive fabric was sewn onto a piece of fabric with a conductive thread. The fabric and thread were used to draw a "circuit" on a regular piece of fabric, with conductive thread as the wire traces.

The fabric sensors are composed of two pieces of conductive fabric that sandwich an insulator, rubber mesh, of the same size. This insulator separates the conductive pieces so they only touch when enough pressure is applied. The amount of pressure is dependent on the insulator's thickness. After experimenting with different types of insulators, we chose one that is activated when there are five or more pounds on the sensor.

Sensor Layout

After choosing materials, the next challenge was to determine the arrangement of sensors on the chair. In order to determine which parts of the chair should have sensors, we videotaped a member of our team sitting in a chair performing the activities our elders reported doing: reading, talking on the phone, and watching television. We then analyzed these videos to see which parts of his body touched the chair during these activities. From this investigation, we decided to put sensors in the back, seat and armrests of the chair.

Throughout this design exploration, we wanted to make the sensors general enough to accommodate different body sizes while reporting the body position of the chair's occupant. We were looking for such body positions as: crossing a leg, sitting forward in the chair without touching the back, and sitting back in the chair. After making initial sketches we made paper, and then fabric, prototypes to get a sense for the physical size and placement of these sensors. Figure 3 shows the final layout of the seat sensor.

Force Sensors

In order to learn more about the chair occupant's posture, the Sense Lounger has force sensors attached to the bottom of the chair's legs. These sensors are able to collect data the binary sensors can't, such as which side of the chair the occupant is leaning on, by analyzing the pressure information for each leg. The force sensitive resistors we chose are quite small, 2mm x 2mm and are able to measure up to 3 kilograms of force.

Current Status

Both the smart slipcover and the force sensors are interfaced to a PIC16F76 and a serial interface to a PC. The PIC is a low power (5V @ 5mA) and inexpensive chip with a 10MHz clock crystal. We wrote an OpenGL visualization of the sensor data that can be displayed in real time or can be generated from the sensor log files. An example of this visualization with someone in the chair is in Figure 4.

These sensors are currently able to detect the presence of someone sitting on them, and are able to calculate how long they have been sitting there. In addition to detecting presence, we are able to use the raw sensor data in order to detect the posture of the person sitting in the chair. It is also able to detect if the person is sitting still in the chair, or if they are moving around.

CONCLUSION AND FUTURE WORK

Future work includes exploring different techniques for the user to explicitly interact with their chair, or the "Human Chair Interaction." We are currently exploring an input device that is sewn into the armrests of a chair, which enables the user to control devices in the home. We currently see several opportunities here, including device control, tactile displays, or visual displays. We also plan on using machine learning to recognize the occupant's activity. We believe that recognizing activity is the first step in developing context sensitive interactions between the user and the chair, as well as monitoring applications.

We have described the Sense Lounger, a unique sensing solution which we feel will help ubicomp be more widely accepted in the home. We see this as technology that will enable aging in place through realistic

Figure 4. User in Sense Lounger (left) and visualization of real time sensor data (right). Visualization colors triggered sensors white, and colors the legs according to their pressure.

technology for elders. Our methodology of combining design and technological research, and the MAYA principle, has helped us design a unique and useful system.

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