The SenseChair: The lounge chair as an intelligent assistive device for elders

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Abstract
The elder population is rising. In the United States, the number of those needing assistance far exceeds the number of care facilities available to help the aging population. This creates a great incentive to help elders remain independently in their homes.

Our group is exploring how robotic technology, designed in forms as familiar as home appliances, might be used to assist elders and those who provide care. We have designed the SenseChair, an intelligent assistive lounge chair that brings assistive technology to elders in a comfortable and familiar fashion. The SenseChair takes information about a sitter's behavior and the environment and provides information ranging from ambient displays to explicit notification. It serves as a research platform to understand how we can help elders stay independently in their homes, and offer them physical, social, and emotional support.

Keywords
Interaction design, product design, elders, user research, ethnographic research, furniture, assistive robotics

Problem statement
Our Project on People and Robots [1] is researching the design of compelling robotic products for the aging

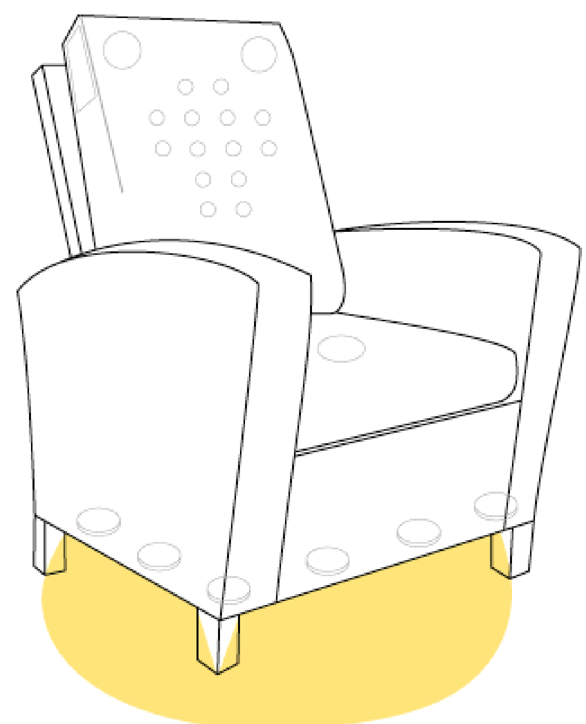


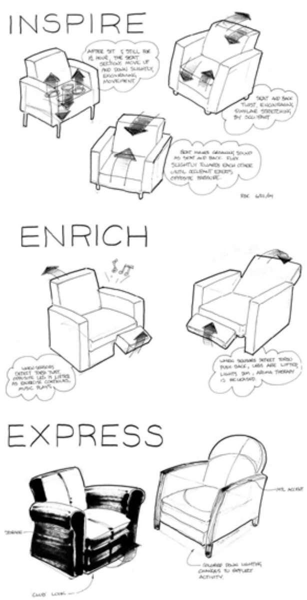
Figure 1. Schematic diagram of the SenseChair.

population. Specifically, we are interested in the design of products that allow elders to lead fulfilling and safe lives independent of institutional care. We believe that as designers, we can shape future robotic products to be more appropriate and sensitive to the human experience.

Our definition of "robotic" is suitably broad. Rather than adhering to a strict technical perspective of *what a robot is* or *should be,* we mine the field of robotics for technologies that might be of service to people in their everyday lives. Our intention is to transfer, and in some cases translate, these technologies from the domain of computer science and engineering research into the context of daily life. We are particularly interested in considering new and different forms for robotic technology: how those technologies can fit into existing product forms, such as a chair.

In 2001, we conducted ethnographic research focused on well and declining elders' relationships to products [2]. We reasoned that by understanding what breakdowns occur with existing products and what common wants and needs are currently unmet or poorly addressed, we might understand how to best design robotic technology to address the needs of this audience. We identified 53 opportunities where robotic technology could benefit elders and clustered them into five areas: health and wellness, social and emotional support, managing the household, leaving a legacy, and chairside and bedside.

After more focused user research we designed and built the SenseChair—an armchair with pressure sensors in the seat, back, arms, and legs (Figure 1) — as a robotic assistant for elders' homes. The sensors both detect activity and allow occupants to physically express their intention. In addition, an array of vibration motors, lights, and speakers provide rich communication modalities. The chair is capable of expression through several different "personalities" and provides information ranging from ambient displays to explicit



notifications. To illustrate how the SenseChair accomplishes this goal, consider the following scenario:

Joan usually goes to her chair after breakfast. Last night, she left the chair on a setting that relays community information. Each time someone enters a public area in the community, her chair responds with gentle vibration movements.

Today Joan is restless, and fidgeting quite a bit. She could use some distraction and social support. She explicitly interacts with the chair by tracing an input pattern in the armrest to increase the interaction with the community. In addition to the gentle vibration, she chooses to hear abstracted sounds that represent public spaces in her building.

The chair senses her movement patterns and offers community information in the form of abstracted audio files, or simply soothing sounds like old football games. Joan drifts off to sleep in the chair. Based on the time of day (dusk) and her inert position in the chair, the chair responds with a gentle glow underneath. This serves as a nightlight and supports her low vision.

After a period of inactivity, the chair motivates Joan to stretch. She has been spending longer and longer periods of inactive time, and the chair makes note of these subtle changes in quality of mobility. Her legs are moved in alternating fashion and the resistance she provides is measured. As a result, Joan feels more energetic and alert, and has less residual pain from day to day.

This scenario highlights the full scope of the capabilities were are envisioning for the SenseChair. These include the ability to monitor and learn the behavioral patterns of the owner, to provide multi-modal interaction with the chair and expression by the chair, and ultimately, to receive data from beyond the immediate environment so as to function as an embodied social awareness system.

Each of these capabilities are being developed in turn. We consider the SenseChair not as a complete product, but rather as an ongoing platform for research into designing technologically enabled support mechanisms for elders. Key in this research is an awareness of the preferences and values of elders, particularly in relation to issues of privacy and agency. As such, we are open to the notion that the ideas expressed in our framing scenario may change as we continue to interact and receive feedback from elders. This requires a highly interactive design and development process, with the constant involvement of the public and the re-evaluation of our activities. In this paper we present the work we have pursued to date towards constructing our first functional prototype.

Project Participants

A team of interaction designers, product designers, computer scientists, and a mechanical engineer conducted this project. Funding came from two National Science Foundation grants. Our team consists of two Design/HCII faculty members, one Robotics/HCII faculty member, one Design faculty member, two doctoral candidates in design, two doctoral candidates in HCI, one undergraduate mechanical engineering student, one product design student, and one staff member in design at the university.

Project Dates and Duration
Development of the SenseChair has taken 18 months to date, beginning in January of 2004 and building on early ethnographic research on elders and caregivers. Currently, we have a functional prototype. We will continue to refine this prototype through field testing, placing the working chair in homes of elders for an extended period of time by the end of 2005.

Design Process
The design process to date can be broken into the following phases: early user research to identify broad opportunities and needs; later user research focusing on one specific opportunity; sketching and ideation; concept validation; and prototype development, including form, hardware, software, and interaction design.

Early user research
In September 2001, we conducted ethnographic research with elders and their caregivers in two Midwestern cities. We focused on elders' relationships with products, and how these relationships changed as physical and cognitive decline set in [2]. We found that as people age, their life space contracts. As physical and/or cognitive decline takes place, elders spend more time and conduct more activities in their homes, until ultimately, the home subsumes all physical, social, and caregiving activities. Along the way, many breakdowns with products occur.

From the 53 opportunitiy areas we identified, we chose chairside and bedside as a promising opportunity area. As elders become less mobile, they spend much of their day in a favorite spot: a lounge chair in front of the television, or a chair with a view of the home or the neighborhood.

Later user research
In order to learn more about elders' relationships with their chairs, we conducted a second round of research exploring how elders use and feel about their dominant chair [3]. We wanted more detail on the activities elders conducted while seated in their favorite chair. We used a directed storytelling approach, asking, for example, what activities were conducted in the chair the previous day. Two main themes emerged from this round of research: elders had a strong attachment to their favorite chairs, and elders frequently used their chairs as a "command center" (Figure 2).

Figure 2. The chair as command center: an example from our research.

Elders used many different kinds of chairs and sofas. The most common was a heavily padded recliner. Elders had many different reasons for choosing a favorite chair. Many were from previous homes, chosen from other possessions to take to a smaller home in a retirement community. Some selected a chair based on assistance it could offer, such as the ability to recline or lift the sitter to standing. In many cases, chairs had been augmented with headrests, pillows, or blankets to pad them and to increase comfort.

The notion of the chair as a hub for all activities is especially important to elders who have mobility problems. Favorite chairs were frequently used as a “command center,” surrounded by objects that elders need throughout the day. These items include telephones, remote controls, lamps, reading materials, medications, notes, schedules, kitchen timers, baskets for crafting supplies, flat surfaces to hold paperwork and glasses, and other items. Activities performed in the chair included talking on the phone to socialize and manage schedules; reading mail, books, newspapers, and magazines; watching television; resting, relaxing, and napping; and crafting such as knitting. Many elders mentioned that they would sit still for too long, causing them discomfort and pain.

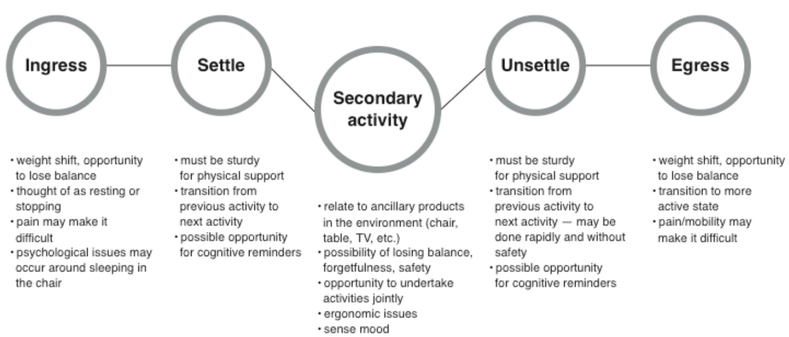


Figure 3. Chair activity model from the ideation phase.

We decided to augment the command center with technology that supports current activities as well as enabling elders to perform new ones. One issue identified in this work is to take into account how long the elder has been sitting, and make sure that she is not too sedentary or entirely immobile.

Secondary research

Our secondary research explored chairs as places to sit and to control activities, such as vehicle cockpits and command centers. Mandal’s *Homo Sedens* [4] is a basic primer for understanding how people sit and remain comfortable. Part of our design process comprised surveying classic chairs such as recliners and club chairs, sitting in a variety of chairs, and noting the points of tension during the ingress and egress process. Through many seating trials on recliners, armchairs, and others, we learned that the spine must be held in an upright position, that pressure compression should be in the fleshy section of the derriere rather than the legs, and that the chair should have rounded edges, adequate ventilation, and adequate means of balancing body heat. Aesthetics must also be balanced with designs that accommodate for changing abilities.

We generated lists of activities and items kept around the favorite chair. These included active, reflective, consumptive, and communicative activities, and issues of ingress, egress, body position, and weight distribution. We also culled images from our interviews of people sitting in their favorite places, noting what items always, sometimes, and never appeared in these locations. We then created a chair activity model to describe ingress, egress, and activities conducted in the chair to guide our design (Figure 3).

Sketching and ideating

In the ideation phase, the team generated hundreds of sketches and scenario concepts. After thematically clustering the concepts around different user needs, we prioritized the concepts based on the match to the user need, technical feasibility, and personal research interest. This process helped narrow the field to just 22 concepts that spanned a large range of user needs and clustered into three high-level categories: communication and reminders, staying active, and sensing intervention.

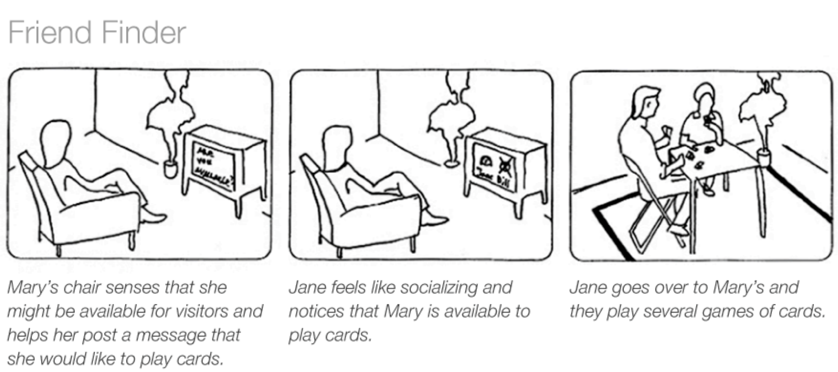


Figure 4. Example concept shown during concept validation.

Concept validation

In order to better understand the intersection between our observation of elders' needs and elders' perception of their own needs, we evaluated the 22 concepts in a concept validation session. The goals of this session were to ensure that our concepts would be readily accepted by our target audience, to gain additional insight on perceived needs, and to understand how particular aspects of technology might best meet these needs.

Each concept was documented in a black and white, cartoon-style storyboard (an example is shown in Figure 4). The scenario text, rather than addressing the technology, focused on how the chair met a specific need and offered a high-level view of the interaction between the elder and the chair. For each storyboard we created a lead question and a series of follow-up questions to help explore elders' needs.

Ten elders living in a retirement community evaluated the concepts. They provided feedback and shared stories about related issues and experiences.

The validation session helped us to validate and prioritize specific functions for the chair. The activities where elders desired assistance included the following: *scheduling*, for assistance with medication schedules, social schedules, appointments, and television shows; *socializing*, for lowering the barriers to impromptu socialization such as meeting a dinner partner; *exercising*, for staying active instead of sitting too long and getting stiff; and *controlling devices*, for assistance with remote controls, lights, telephones, and timers. One idea was to have interdevice control, for example, the ability to mute the TV when the phone rang.

Technology issues also emerged from this session. For example, many elders were concerned that the technology used in the chair would be too "smart" and would take control away from them. Many had relinquished some control of their lives already to caregivers and family members. They did not want to continue this trend with technology in their homes. This is consistent with other research showing that not providing people a sense of control over technology can be psychologically and physically debilitating [5]. Privacy was also a concern, in terms of understanding who might have access to the information the chair collected about them. Finally, many elders were concerned with becoming too dependent on assistive technology. For example, an elder's friend had used an electric scooter as an assistive device, and failed to walk independently again.

Four working scenarios emerged to define the initial functionality of the SenseChair: falling asleep after dark, where the chair would gently wake its occupant and remind them to go sleep in their bed; falling asleep in an uncomfortable position, where the chair would sense the non-ergonomic position of the occupant, and use an ambient notification to get them to shift position; using the SenseChair to control devices in the environment, and conveying, through the chair, basic public information about the surrounding community.

Form development

As functional concepts emerged, our gradually shifted to sketching forms that could reinforce the chair's function and be readily accepted by our audience. It was important that the chair not project the stigma of disability, but one of vitality and currency.

The SenseChair uses the classic club chair as a principal visual reference (Figure 5). It has large, embracing arms and a high back that provides head support. Knowing that our users would frequently sleep in the chair, we designed a supportive seat geometry that maintains users in a stable seated position, greatly reducing the potential of users falling out. The front edge of the seat is lower than normal and the middle of the seat is higher. This configuration allows users to sit higher while their feet can still touch the floor. This geometry makes it easier for users to enter and exit the chair with diminished strength and/or balance. The higher seat surface also resulted in additional space under the seat for the computer and wiring access. The form of the chair was tested with early foam core models, and final patterns were sent to a local furniture maker for fabrication.

Figure 5. The SenseChair prototype.

The SenseChair has a traditional wood structure covered with fabric webbing and foam cushioning. We selected a firmer than normal foam for increased user stability and ease of ingress and egress. The foam was covered with upholstery batting and fabric for surface softness and a more traditional hand. Experiments with motors and sensors drove the type of batting and positioning of these components for maximum efficacy. We borrowed extensively from traditional chair construction so that it would have a familiar and reassuring feel and comfort. While we were intent on adding features that technology enables, we were wary of making the technology fundamentally change the traditional ways of using a chair.

Sensor development

Sensor development began with the creation of a smart slipcover made of pressure sensors sewn out of conductive fabric (Figure 6). The sensors detect what parts of the chair the user is touching, and are strategically placed throughout the seat, back and armrests of the chair. Sensors are constructed of a conductive silk organza, which is 80% metal and 20% silk. The fabric sensors are composed of two pieces of conductive fabric, with an insulating rubber mesh sandwiched inbetween. The sensors are only capable of binary signals, so subsequent iterations of the sensing package will utilize inexpensive, off-the-shelf pressure sensors, designed to be inserted directly into the cushions of the SenseChair itself.

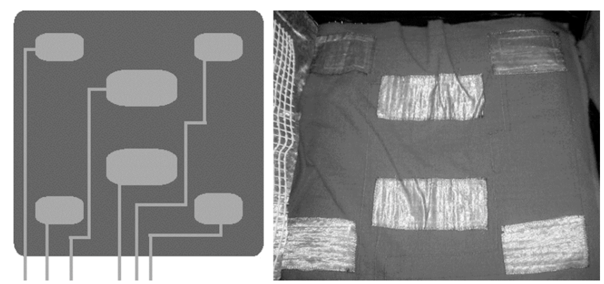


Figure 6. Seat sensor layout and prototype made of conductive fabric.

Hardware development

Additional hardware development for the SenseChair includes a set of actuators made of 18 vibration motors and 8 halogen lamps (Figure 7). The halogen lamps are located under the chair and arranged in a circular array. The vibration motors are primarily located in the back cushion along with a few in the seat cushion. Four large vibration motors create cushion-wide signals. Two of these motors are located at the top of the back cushion, and two are located in the seat cushion. The small vibration motors are configured in a t-shaped array in the back cushion to conform to the human form. These motors create local vibrations that are highly expressive in nature.

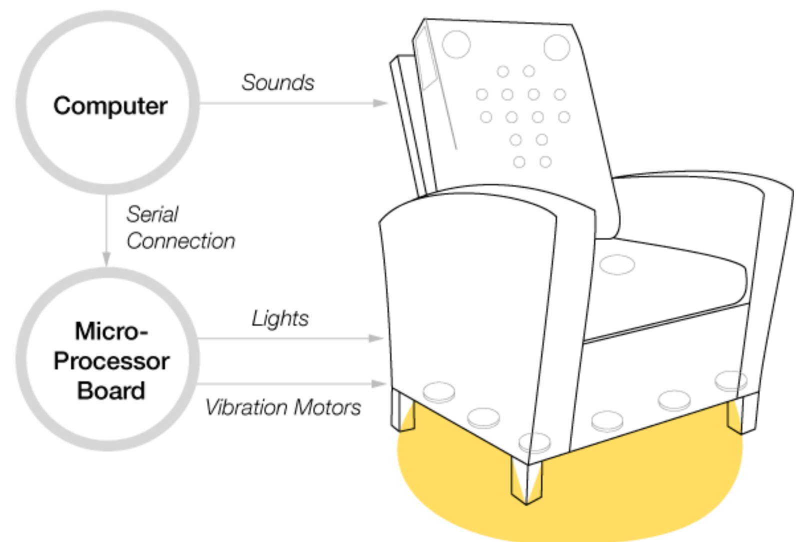


Figure 7. SenseChair hardware layout.

The SenseChair is also is also equipped with stereo speakers that are located on the both sides of the back cushion. The speakers are directly connected to a computer.

The actuators are controlled by a custom-design microprocessor board located in a compartment embedded in the structure of the chair. This programmable, self-powered microprocessor board independently runs programs that define the behavior of actuators based on the sensory input. These programs are created in using SenseChair Authoring Software. The speakers are also driven by the authoring software.

Software development

The SenseChair Authoring Environment has been designed as a graphical environment to build, visualize, and run sensor-actuator behaviors (Figure 8). The functions are grouped under three sections: Build, See, and Run. The Build panel allows users to define actuator patterns. These patterns include combinations of lights, vibration motors, and sound clips that loop with fixed time intervals. Users of the authoring environment can construct, label, and save these patterns, which are stored in an XML format. The See panel provides users with visualizations of actuator patterns that are retrieved from the XML structure, and patterns that are temporarily constructed in the Build panel. The Run panel connects the Authoring Environment to the microprocessor through serial communication, and uploads actuator pattern definitions that are retrieved from the XML file. The SenseChair Authoring Environment is built using the Java programming language.

Interface and interaction design
Interaction design has addressed both input and output signals. For input, beyond the simple position and time in a seated pose, we have explored the use of a fabric controller to provide the sitter with some additional control over devices in the home. To manage the occasions that elders directly interact with the chair (for example, in the device control scenario) we are designing a fabric controller. This device will achieve interaction with the chair as a common element for the control of many devices. The controller will also possess generic functionality that can be easily extended to different devices. For the initial development, we focused on a controller that worked for a TV, lights, and a timer.

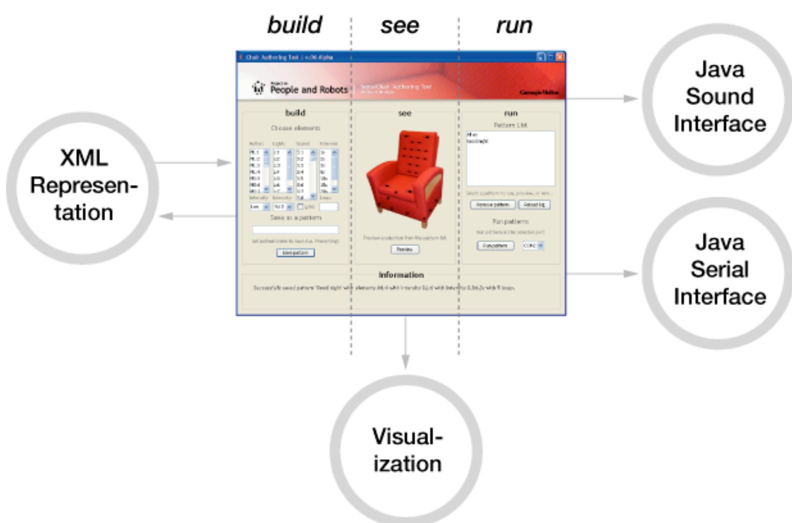


Figure 8. Structure of the SenseChair Authoring Environment.

Several rounds of concept generation and evaluation led to a sunken ring design containing a confirmation button in the center of the ring (Figure 9). The entire controller is made of washable fabric and serves as an arm cover for the chair. In addition, we created a second cover for the other arm with buttons that allows users to target the device they want to control.

The interaction design has progressed by designing sounds and speech commands along with vibration and light patterns. Early sketches were created in Flash, and later sketches have been created using the SenseChair authoring software. Sound, lights, and vibrotactile output are sequenced together to create distinct expressions for different users and different alerts. Each expression is a set of patters of lights and vibration motors, together with sound. These patterns can increase and decrease in intensity over time as the expression is "played back" through the chair. The lights mounted under the chair can be modulated or turned on and off at full force.

We are currently exploring issues of sound design. Specifically, we are conducting further research on what kind of sound expressions are most appropriate and compelling: spoken alerts, sound effects, or ambient sounds found in nature.

Solution details
The SenseChair supports communication, information, and mobility in the favorite spot in the home. It collects data using sensors, and expresses signals using light, sound, and vibration. It can remind, warn, or help the

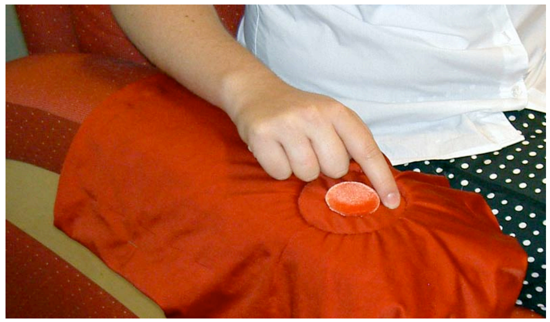


Figure 9. Fabric controller.

elder with a variety of tasks. It can provide a sense of the environment for people who are less mobile. It can also control appliances in the vicinity of the chair. The SenseChair has several personalities: it can act as a coach, a colleague, or an entertainer. It relies on the position and pose of the sitter for input, and provides multimodal output ranging from ambient to explicit notification.

Product form
The SenseChair relies heavily on the image of the traditional club chair, so as to introduce technology in a familiar and comfortable form factor.

Product function
The SenseChair is designed to provide non-invasive feedback, alarms and notifications to the owner of the chair. Our initial functional scenario for the SenseChair is to monitor sitting position and lack of activity (dozing off) in the chair. Although sleeping in the chair might seem benign, from our interviews it became apparent that taking naps in the chair were often not desired, particularly in the evening. Participants reported that falling asleep in the chair disrupted their normal sleep routines. In this scenario, the SenseChair facilitates normal sleep routines by taking note of when sitters are napping in the chair and encouraging them to go sleep in their beds. Future versions of the software will employ machine learning techniques to allow for more sophisticated awareness of the activities in and around the chair and subsequently more sophisticated functionality. However, for now our functional scenario addresses a single but common situation for elders.

Interaction (*input)*
The need for direct user input to the chair is limited. One explicit design criteria was to not have the chair appear or be perceived as "another piece of technology." Other than turning the chair on and off, there is often no need for participants to make adjustments to the chair for it to function properly. Rather, the chair functions almost entirely based on immediate environmental sensing, specifically the distribution of body weight across the surface of the chair measured by pressure sensors and the length of time since the last substantial body movement. This data is augmented by the time of day, which is taken from the computer housed within the chair. By correlating the time of day with the data about movement, we are able to simply discern if the participant has fallen asleep in the chair after dark prompting the chair to respond accordingly. We will continue to explore the widget as an interaction mechanism for device control in the environment surrounding the SenseChair.

Interaction (output)

The SenseChair is capable of several types of output. Activating the sensors in certain patters results in vibration motors oscillating singly and in groups, sounds playing, or lights mounted under the chair to be turned on singly and in groups. Each of these types of output can be modulated. The motors can be turned activated either uniformly or individually to create patterns of vibration. The design of the vibration patterns is informed by previous research on vibro-tactile displays [6].

Sound, lights, and vibrotactile output are sequenced together to create distinct expressions for different participants and different alerts. Each expression is a set of patters of lights and vibration motors, together with sound. These patterns can increase and decrease in intensity over time as the expression is "played back" through the chair.

Future Work

We view the SenseChair as an ongoing project investigating the application of robotic technologies to existing product forms in the home. Our future work with the SenseChair can be grouped into five areas: 1) integration of sensor package, 2) increasing the capability of the authoring tool, 3) application of machine learning algorithms to improve the ability of the chair to respond to user behavior, 4) use of the widget to control household appliances, 5) providing community activity as input data to the chair, and 6) placing the chair in the homes of elders for long term field studies. We are currently pursuing 1, 2 and 3, so that we can place the chair in elder's homes in the later Summer/early Fall of 2005 for evaluation.

Conclusion

This design research sketch has presented the SenseChair, an intelligent assistive product that brings technology to elders in a comfortable and familiar fashion. The SenseChair addresses a need identified and validated in our ethnographic research with elders and caregivers. The SenseChair takes information about a sitter's behavior and provides information ranging from ambient displays to explicit notification. It serves as a research platform to understand how we can help elders stay independently in their homes, and offer them physical, social and emotional support.

Acknowledgements

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