CONTEXT-AWARE ENVIRONMENTS FOR INDEPENDENT LIVING*

Ted McFadden [1,2] and Jadwiga Indulska [2]

CRC for Enterprise Distributed Systems Technology[1] and
School of Information Technology and Electrical Engineering, The University of Queensland[2]
mcfadden@dstc.edu.au, jaga@itee.uq.edu.au

Abstract
The range of pervasive computing technology available for use in healthcare continues to evolve, allowing for an increasing variety of wireless sensors, devices, and actuators to be cost effectively deployed in smart, context-aware environments. One area that is of compelling interest for the application of this technology is independent living of the elderly. An independent living environment needs to support an individual's healthcare needs and activities of daily living (ADL), while extending social interaction, environment control, and information flow to care giver and family communities. This must be done without compromising an individual's medical care, safety, privacy, or security and should allow an individual to maintain maximal independence. Continuing variations in cognitive and physical capability must also be considered. Current context-aware pervasive computing environments only partially address these requirements.

This paper surveys current pervasive computing research activities in this area and introduces research on an architecture for a pervasive computing infrastructure to realise independent living environments. The infrastructure will allow context-sensitive adaptive interfaces to assist individuals with tasks and provide alternate modes of interaction with common devices such as phones, microwaves, and televisions. It also considers the community policies that define what access rights, degree of control, and interactions, caregivers, friends, and family have with the environment in normal and extraordinary situations. These policies will influence the context-aware behaviour of the independent living environment and can be used to shape interface adaptation, trigger social or care specific interactions, guide daily tasks, and support health-care or other sophisticated independent-living applications.

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Introduction

In many countries, such as Australia, the percentage of elders in the population continues to increase. This ageing population, with increasing longevity (Booth and Tickle, 2003), will place increased demands on health-care systems and require greater assistance from health-care and family member communities to live outside of full-time care facilities.

From a social perspective maintaining an independent lifestyle is important to the quality of life of elders (Hirsch et al., 2000) and decreasing independence can have a profound impact on the quality of life of family caregivers (Consolvo et al., 2004). From an economic viewpoint, maintaining independence can help contain health-care costs by reducing the health-care episodes requiring intervention, hospitalization, or ultimately placement in full-time care facilities.

It is desirable to use increasingly available pervasive computing technology to support the independent living of the elderly. Pervasive computing describes environments where ubiquitous computing devices "vanish into the background" (Weiser, 1991) assisting individuals with their activities and goals, not forcing a focus on the use of the technology itself. Many pervasive components such as location sensors, motion sensors, cameras, home-automation and security systems are already being deployed in homes. Newer generation mobile phones and computing devices with wireless networking capabilities are expanding the usage scenarios, processing power and communications capabilities of these components. Services that make use of the context information reported by these components, such as location, identity, activity, temperature, and heart rate, may be designed to provide individualised assistance to the elderly in home environments. It is important that these services work in concert to support the individual and their care community in an unobtrusive and natural fashion.

In this paper, we describe the current state of the art in providing IT-technology based support for independent living. We also show how such support can be further increased by an integrated context-aware environment for independent living (CAE-IL) which (i) can process and utilise contextual information created by sensors and appliances, (ii) ensures the required level of security and privacy, (iii) utilises user profiles and preferences when making any decisions about the help required by the elderly, (iv) provides multimodal interfaces to the services and selects appropriate mode of interfaces depending on the need of the elderly, and (v) allows remote and flexible adaptations of caregivers roles and responsibilities.

The structure of the paper is as follows. Section 2 surveys current research in the area of smart home environments and applications for independent living while Section 3 presents the requirements for a CAE-IL and a new architecture that meets these requirements. Section 4 concludes the paper.

Independent Living Research

Many research projects have focused on developing specific assistive technologies for the elderly or developing a better understanding of the issues associated with use of technology by elders. For discussion purposes, they will be grouped in this paper around four broad categories: application of sensors to support independent living, remote accident and health monitoring, activity of daily living (ADL) support, and social interaction support. In addition to discussion of the existing solutions, we also describe further issues which need to be addressed to support independent living.

Examples of sensor environment research include Chan et al., (2002) where an infrared (IR) sensor system was developed to monitor patients' nocturnal mobility in an assisted-care facility to support future health care applications. The sensor offered coarse-grained location information and during initial testing at a hospital showed good agreement with information manually recorded by nursing staff. Helal et al., (2003) describe an ultrasonic based location sensor system designed as part of an independent-living research home that promises more precise location information but would require an individual to wear two transmitting beacons. In Sixsmith and Johnson, (2004) thermal-imaging sensors were used as location and motion sensors for use in an automatic fall detection system. In focus group studies to evaluate the desirability of the system, it was noted that a lack of understanding of how the technology worked influenced acceptance of the system. For sensor environments, consideration has to be given to the privacy issues, such as how precisely and to whom location information can be reported or how much extra information a thermal (or video) image might contain. Also important, are the social implications of certain technology designs, such as the use of location sensing pendants or badges that would have to be worn at all times. Hirsch et al., (2000) describe a reluctance of elders to use technologies that have an assistive stigma associated with them.

Several projects investigate health and accident monitoring in an effort to take system capabilities beyond the first generation, personal response systems described by Doughty et al., (1996) that were often a manually activated emergency call button worn on a pendant by the individual. CSIRO's Hospital Without Walls (Wilson 2000) initiative undertook to monitor blood pressure, heart rate, and fall sensing. A low-power wireless monitoring device worn by the individual transmitted heart rate and fall sensor data, and included a panic button. (The CSIRO PERSiMON research stream extends the sensor and communication capabilities in a new wireless monitoring device.) Jimison et al., (2004) investigated the feasibility of monitoring the computer interactions of elders to gauge cognitive health. This particular work focused on using computer games, but in principle is extensible to other computer or device (e.g., television remote control, microwave) interactions. In Das and Cook (2004) an episode discovery algorithm is run over collected environmental sensor data to identify longer term trends that may be indicative of deviations from routine related to health care conditions that may require intervention. The success of these types of systems is dependent on the ability to accurately interpret sensor events in context to obtain appropriate assistance for an individual in normal and emergency circumstances while not triggering false alarms that result in unnecessary disruption and intrusion into an elder's life. This better positions the system for acceptance as it is seen as a safety net that does not prematurely compromise independence.

Research on assisting with ADLs focus on mimising an elder's day to day dependence on family and professional caregivers. Examples include a computer-controlled microwave oven (Russo et al., 2004) that is equipped with a radio frequency identity (RFID) reader that can assist with cooking foods packaged in containers with RFID tags. It works in conjunction with the other services in the smart home environment described previously (Helal et al., 2003) and thus can track the location of individuals throughout the house and prompt them on a nearby video display when a meal is ready, or a cooking step, such as stirring, is required. Elders with various impairments (e.g. poor vision and hearing, memory difficulties) took part in a usability study with the majority stating it would be desirable to have such a system in their homes. Pollack et al., (2003) developed a mobile robot that had an on-board planning system to aid in prompting elders about daily activities such as eating and taking medicine. The planning system used inputs from the robot's sensors to determine when certain events had likely occurred. Additionally, as the robot was equipped with highly accurate position sensors, it could help elders navigate from one location to another. The robot has been field tested at a retirement community. ADL applications such as these are highly dependent on the context information (e.g. location) available to them and can benefit greatly from being fully integrated into the home environment where they can utilise context information provided by the other components (sensors and higher-level services) to affect their operation.

The manner in which ADL services interact with elders needs to be flexible and take advantage of multiple methods of communication. Perry et al., (2004) discuss the implementation of a telecare system that supports multimodal user interaction via audio, video, input device, or by observation of environmental sensors. Morris et al., (2003) note that common, familiar surfaces such as refrigerator doors and tabletops could be exploited as interfaces.

The final research category to be considered is that of support for elders' social interactions and family community. Mynatt et al., (2001) describe a digital family portrait, by which a picture of a remote family member is situated in a dynamic video frame that provides qualitative icons representing a remote person's daily life. This can be used by family members to check on an elder at a glance. Portraits of others may also be placed in the elder's home to provide a two-way awareness and connection. An alternative system, the CareNet display (Consolvo et al., 2004) surrounds a digital portrait with icons that expand to provide detailed information relevant to the elder's care. It is designed to increase communication between members of the caregiver community, who can have varying degrees of responsibility, and allow for better coordination of care related activities. In both of these projects, appropriate sensor technology was not available to automatically update the displays. They were updated manually after interviews with test subjects. Social support and other applications that involve communities (e.g. family, friends, and health-care professionals) must take into account the specific, dynamic, roles of community members, privacy considerations in sharing information, and the preferences of individuals concerning the operation of the system. To be effective they also require environments with adequate sensor instrumentation.

Integrated, Flexible Environment for Independent Living

The representative research initiatives described above highlight some of the key research areas for successful use of pervasive computing technology in independent-living environments. However, these research components independently do not create a viable independent-living environment. It is necessary to address the issues identified in the previous section and integrate all of the components into a flexible, extensible environment. This environment must accommodate a range of sensors, services, and fully consider caregiver community interaction. We are beginning research on such a CAE-IL architecture, as illustrated in Figure 1. It includes processing of context information from a variety of sensors, appliances, and services. It supports mediating access to actuators (e.g. oven controls) by an elder (or other system components.) It features explicit privacy and security management. User and community preferences and profiles aid services in making context-sensitive operating decisions, such as when to make an emergency call for help. Interface adaptation can be configured to dynamically support alternative multimodal methods of interaction for applications and household devices (e.g. ovens, televisions, phones). The architecture supports adding new applications as plug-ins, so as new independent-living services are added they immediately take advantage of existing facilities such as interface adaptation. Management of system configuration, caregiver rights and responsibilities occurs through adaptive interfaces appropriate for health care and family community members who are not technology specialists. This architecture should provide elders with a cohesive environment to support their independent living.

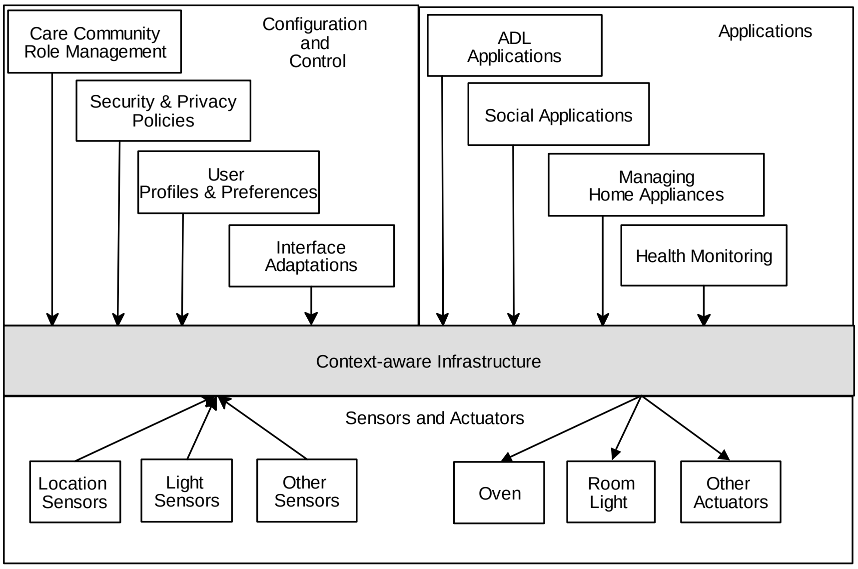

Figure 1: Context-aware Environment for Independent Living Architecture Overview

Conclusion

In this paper we have examined the potential for pervasive computing technologies to be applied to the domain of independent living of the elderly. We have surveyed current research efforts and identified independent living environment requirements and areas for continuing research. We then described the need for an integrated, flexible context-aware environment for independent living (CAE-IL) and introduced new research on a CAE-IL architecture.

CAE-IL systems will help realise government and industry ageing in place policies and initiatives. Future industry standardisation would drive down cost, and provide opportunities to economically offer CAE-IL compatible home appliances, devices, and support services. It is hoped that the future use of such CAE-IL systems will indeed provide for an improved and extended quality of life for elders and their families, while realising a genuine cost savings over institutionalised care.

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