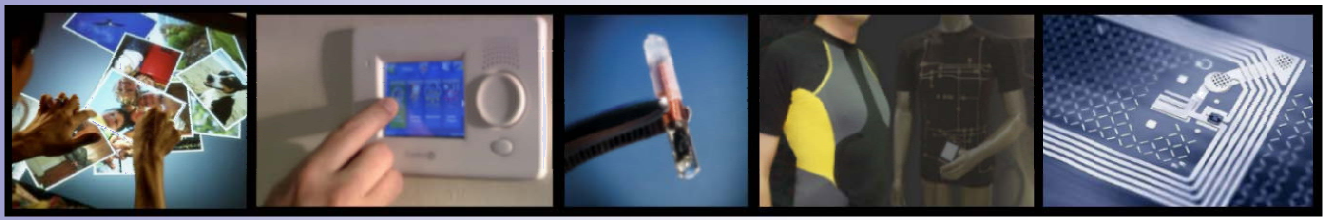
UBIQUITOUS COMPUTING:

ETHICAL and SOCIAL IMPLICATIONS of EMERGING TECHNOLOGIES to the ELDERLY



SENIOR: Social Ethical and Privacy Needs in ICT for Older Citizens: a Dialogue Roadmap

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Currently published SENIOR Deliverables which provide context for many aspects of this technology-focused discussion paper, include:

- Report of the Launching Workshop
- Report of the Social Anthropological Workshop
- D1 1 Environmental Scanning Report

On the Cover

Pictured, from left to right:

- Microsoft Surface™ tabletop computer: http://www.microsoft.com/surface/index.html
- Smart Home Controls: http://www.i-rooms.co.uk/products_services.htm
- Verichip: http://parallelnormal.com/2008/05/30/verichip-headed-down-the-tubes/
- VitalJacket: http://gizmodo.com/381964/vitaljacket-heart-monitor-and-t+shirt-in-one
- RFID Tags: http://www.electronicdata.com/Items.aspx?catId=c01

Contents

Independent and Connected

Imagine a day in the life of Samuel and his wife Lily, aged 80 and 74, respectively. Samuel has been retired since his mid-60's, and Lily has been a homemaker and mother of 3 children since she and Samuel were married in their early 20s. Samuel has a history of high blood pressure as well as adult-onset diabetes, each of which is controlled with oral medications. Lily is fairly healthy, although arthritis has begun to cause her some pain and affect her hand strength in opening jars and the like. In addition, Samuel has begun to notice that Lily has difficulty remembering some of their conversations and is always losing objects, but he cannot really be sure if she wasn't always a little disorganized, or if this is something new. Lily and Sam's three children have been out of the house since they left for college. Their son lives in a town about 20 kilometers from his parents, but both their daughters live about 600 kilometers away, and do not get an opportunity to visit often. Between all the children, there are 7 grandchildren, all of whom are school age and already using email and the Internet for communicating with their friends or doing research for school projects. Sam and Lily own their own home, where they have lived together since their children were quite young. The house is itself rather old, and is laid out with the kitchen, dining and other living spaces on the ground floor. So far, neither Sam nor Lily has fallen on the stairs, but Lily's arthritis has begun to make navigating the stairs painful. Samuel was very successful in his career and, as a result, in addition to owning the family home and the land it is built upon, the family has numerous investments whose performance Sam monitors online.

- *Sam gets up early and goes to the bathroom, stepping on a* ***scale***[1]*, which gathers information about his weight, temperature, glucose levels, blood pressure, and other vital measurements that his doctor wants to keep track of, and which are sent via his* ***home's wireless network*** *directly to his physician's office.*
- *By the time Sam reaches the kitchen, the coffee is already brewed and waiting to be poured.*
- *He checks the morning headlines on the* ***PC/touch screen that is embedded in the kitchen table***[2] *while he waits for Lily to wake and join him.*
- *When Lily gets up, at 7 a.m.,* ***sensors***[3] *on her side of the bed register that she has gotten up, and automatically turns on the bathroom light, dimming it up slowly.*
- *After dressing, Lily joins Samuel, turning on the kettle to boil water for her morning tea. The stove is enabled with a* ***safety sensor****, automatically turning itself off after the water has boiled.*
- *Lily and Sam check their email together, enjoying a photo from one of their grandchildren with the new puppy which has been added to the family, and they choose the option to forward it to their* ***digital photo frame*** *on the table in the front hall.*
- *All of these movements through the house are monitored by a* ***network of motion sensors***[4]*, recording where Sam and Lily have gone in the house, how long they were in each place. Each such movement was uploaded to a central server and compared this to their typical daily routine. At 8:30 in the morning, given that both Sam and Lily followed their usual routines within a "reasonable" time frame, each of their children receives* ***an email or a text message*** *saying "Mom and Dad are up".*

[1] Telemedicine is a fast growing field, with a wide range of health monitoring sensors available to track numerous health conditions, and in many form factors, from scales, to skin patches, to standalone table-top devices, to monitors embedded within garments. Standards for, and interoperability of such systems is a key concern, as is the underlying network of medical support personnel who will review the information collected, and how such support is managed under varying reimbursement schemes. This paper does not delve into this vast area, which encompasses a complex network of health monitoring products and supporting services, but recognises that management of chronic health conditions are a key component of the support required for the elderly through ubiquitous technologies.

[2] In May 2007, Microsoft introduced a "surface computing" device, which is not expected to reach the home market for some time. According to the initial marketing of, the "Milan" device (now renamed Microsoft Surface™) is expected to appear in retail environments.

[3] Sensors that respond to someone getting out of bed to gently dim a light was developed by the Bath Institute of Medical Engineering (BIME) as part of a project for the University of Bath – a smart house designed for individuals with dementia. This model environment also used specialised sensors to monitor if a bath was left running too long, or if a cooker was left on too long, with a focus on ensuring the safety of an individual, aiming to ensure they would be able to live independently for as long as possible.

[4] As an example, the QuietCare system is currently available in the US and in the UK/EU, though statistics on uptake of such systems are not yet available.

Ubiquitous Computing: An Overview

This brief glimpse into the morning routine of an elderly couple reveal just a few aspects of daily life that can be enhanced by technologies that are already available, or which are expected to be in production in the near future. Some of these technologies do not look much different from those with which we are already familiar in the desktop computing world. However, many of them are invisible, operating in the background of the environment, providing essential safety, health and communication support to individuals whose bodies may be affected by chronic medical conditions or whose minds are affected by early stages of Alzheimer's disease or other dementia.

It is these seemingly invisible technologies that are the hallmark of ubiquitous computing, a movement that has been defined as a technological shift from computing that takes place on personal desktop machines to that in the periphery, embedded in the environment in a way that is nonintrusive and yet supportive. The idea of ubiquitous computing (alternatively called pervasive computing, calm technology, or ambient intelligence, with some nuance in definition and scope) originated in the late 1980s with Mark Weiser of Xerox's PARC (Palo Alto Research Center), where the humanities and social sciences were deemed to be crucial in understanding how to create this invisible technology.[5] The PARC team had a vision that foresaw a multiplicity of computers for each individual, each performing specific tasks, often integrated into the environment with many others.

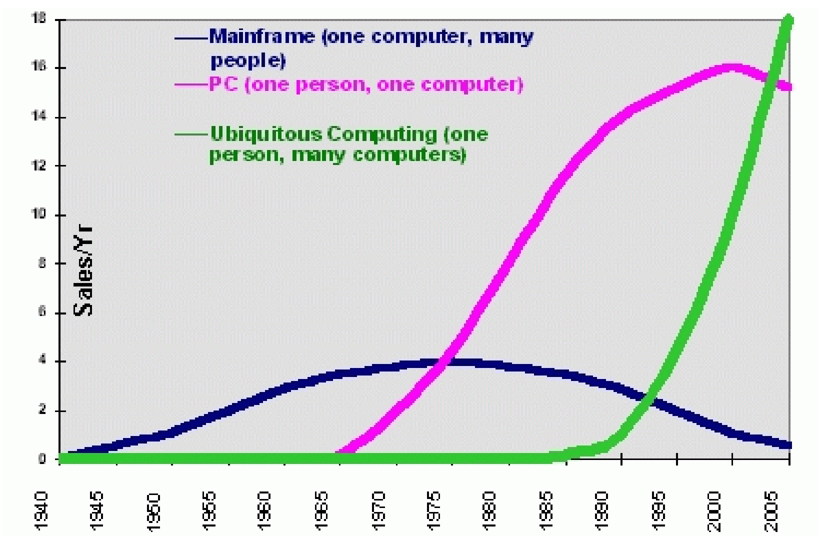

Figure 1: Weiser's projected proliferation of computers through ubiquitous computing[6]

With a goal to make a computer "so imbedded, so fitting, so natural, that we use it without even thinking about it," [7] the PARC team developed prototype devices which included an interactive display board, a handheld tablet and a pen-based computer. Although these efforts generally focused on office environments, the concepts they pioneered have been expanded to reach well beyond the workplace and into home and community life. At the time, there were numerous technological constraints which have since been largely overcome, including issues related to power consumption, sensor size and cost, and communication. In addition, Moore's Law has

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[5] Weiser, Mark, "The World is not a Desktop", 7 November 1993. http://www.ubiq.com/hypertext/weiser/ACMInteractions2.html
[6] Weiser, Mark, Ubiquitous Computing, 17 March 1996. http://www.ubiq.com/hypertext/weiser/UbiHome.html
[7] Weiser, Mark, 17 March 1996. http://www.ubiq.com/hypertext/weiser/UbiHome.html

continued to hold true (i.e., capacity of integrated circuits doubles about every two years)[8], with advances towards the presumed limit to semi-conductor scaling by the year 2020. Other key technological improvements that act as enablers of ubiquitous computing include:

- Enhancement of both wireline and wireless networking technologies, which is increasing the accessibility and affordability of broadband networks, the growth of optical fibre networks, and the development of Bluetooth technology, enabling multitudes of wireless signals to coexist effectively within a crowded landscape.[9]

- RFID technology has emerged to provide low-cost methods of identifying individual objects at short-range.

- A new, more robust Internet Protocol (IPv6) is emerging to enable exponentially more objects and systems to be identified over a global network (IP addresses under IPv4 are expected to be exhausted by the year 2010; 3.4×10^{38} addresses will be available under IPv6).

- Sensors and actuators have been reduced in size and cost and expanded in their range of application (measuring and responding to gasses and odours, vibrations, acceleration, pressure, sound, temperature, visible, infrared, and low light).

- Geolocation systems (GPS) have become much more accurate, and are becoming affordable at a consumer level, used routinely for personal vehicle navigation and entertainment.[10]

- Micro-electromechanical systems (MEMS), tiny mechanical devices that are built onto semiconductor chips and measured in micrometers, are used to make pressure, temperature, chemical and vibration sensors, light reflectors and switches as well as accelerometers for airbags, vehicle control, pacemakers and games.[11]

By integrating wireless technology and the Internet, ubiquitous computing allows for the unknowing engagement of technology in everyday objects and activities. Unlike personal computers, ubiquitous devices are extremely tiny, even invisible, and communicate through interconnected networks.

Building on this research, universities and research organisations around the world have continued to explore possible applications of ubiquitous computing (see Annex D). However, ubiquitous computing still has a long way to go before all the various contributing elements are brought together in a cohesive way that serves to create an actively supportive, safe and inclusive environment for the elderly.[12] Today, most of these hidden

[8] "Moore's Law", *Intel*, http://www.intel.com/technology/mooreslaw/

[9] Note that issues related to communications technologies will be reviewed in greater detail in a separate paper on the topic of Ubiquitous Communication, also published by the SENIOR consortium.

[10] As an example, in a GPS-based game of geocaching (www.geocaching.com), participants search for (and hide their own) a hidden cache using a personal GPS unit, based upon location coordinates and other clues divulged on a central website.

[11] A 2004 study utilised an ambulatory activity recorder, based upon MEMS accelerometers and magnetometers, to monitor level of mobility in the frail elderly. Noury, N., et al., "ACTIDOM - A MicroSystem based on MEMS for Activity Monitoring of the Frail Elderly in their Daily Life", TIMC-IMAG Laboratory, Grenoble, France, Engineering in Medicine and Biology Society, 2004.

[12] In his book Everyware: The dawning age of ubiquitous computing (2006), author and futurist Adam Greenfield projects that ubicomp will take 100 years to "emerge to its fullness" but observes that "the time is apt for us to begin articulating some baseline standards for the ethical and responsible development of user-facing provisions in everyware."

systems are generally single-purposed and often task-oriented (turn on a light, turn off the gas, sound an alarm, make current computing environments less obtrusive).

A significant exception to this is found in the area of domotics, where a complete, integrated network of sensors is built into a home or building to create a "smart home" environment, controlled centrally, and usually focused upon the home's environment (safety from invasion or fire, heating and cooling systems, preprogrammed lighting selections, entertainment system controls, etc.). For new homes, or those undergoing major remodeling, building in the elements required for a smart home is done quite effectively, with wiring added prior to completion of walls; however, for older homes, retrofitting requires the use of RF technologies which have advanced dramatically in the past decade as RFID in the supply chain has driven significant levels of research in the area.

For more detailed discussions about the current state of the various technologies which are contributing to the evolution of ubiquitous computing, see Annex A. See Annex B for a discussion of markets for these technologies as they specifically apply to the needs of senior citizens.

Ubiquitous computing technology in an ethical and social context

Ubiquitous computing, encompassing a broad range of applications and technologies, can be looked at through a number of lenses, when examining the ethical implications and the effects it may have on social inclusion. Technologies, an engineer might well state, are agnostic as to their ethical use or misuse, and the ways in which technologies are applied to solve certain problems or serve certain market segments define how they perform on an ethical basis. However, many of the technologies that contribute to ubiquitous computing are, by their nature, capable of either supporting key ethical principles or contributing to misuse in one or more ways, some of which are examined below:

Freedom from harm

For the most part, technologies which are simply monitoring the environment in a passive manner, or which only are employed when called upon, are expected not to present any significant harm to the user. However, technologies may be used without consideration of the physical harms that might be undiscovered or contemplated, though with lessons learned (e.g., as with asbestos or leaded paint) and with the heightened levels of safety and testing requirements in developed countries, it is far less likely that materials or technologies with broad negative health consequences could occur. Recently, a study completed by doctors at the Medical Center at the University of Amsterdam indicated that RFID tags could have a deleterious effect upon medical equipment and pacemakers leading them to end their report with the following:

> *"In conclusion, in a controlled nonclinical trial setting, RFID technology is capable of inducing potentially hazardous incidents in medical devices. Implementation of RFID in the ICU and other similar health care environments should require on-site EMI tests in addition to updated international standards."* [13]

[13] Togt, Remko van der, Erik Jan van Lieshout, Reinout Hensbroek, et al., "Electromagnetic Interference From Radio Frequency Identification Inducing Potentially Hazardous Incidents in Critical Care Medical Equipment", *Journal of the American Medical Association*, Vol. 299, 25 June 2008, pp. 2884 - 2890.

This is of particular concern since RFID is widely used in medical settings for asset tracking (of the very medical equipment with which it may interfere), medications and patients of all ages. As examples:

- Companies have developed identification systems using RFID tags that can be placed in a patient's chart, wristband or under the skin (e.g., Verichip[14], Gentag[15], NEC Unified Solutions[16], AeroScout[17], SurgiChip[18], Radianse[19], CenTrak[20]). Focusing on RFID-based infant protection, Verichip has released the Halo and Hugs systems[21] to provide security against infant abduction in hospital birth wards.

- RFID technology is being used to track medical equipment. ASD Healthcare[22] offers a medication-dispensing cabinet that monitors the expiration dates of medicine. Clearcount Medical Solutions[23] has a sponge management system to eliminate the risk of misplaced sponges. Other companies involved in medical device tracking include Radianse[24], 3M[25], WaveMark[26] and Phillips[27].

Some have expressed concerns about Wi-Fi signals in classrooms[28], where children may be affected by the large number of signals. While we may not see any effects on adults, whose skulls are fully developed, might this change in a world in which every manufactured object emits radio frequencies?

Respect for human dignity

In general, questions of dignity vs. stigmatisation have a profound effect upon decisions made by individuals when purchasing any material goods. Social status is quickly inferred by our appearance, the size and aesthetics of our homes, and the physical form of the many objects and artifacts with which we fill our homes.[29] If a ramp is built in order to give us better access to our home's entrance, the external appearance of the home gives immediate messages about the health condition of its resident. If a medical monitoring device, with a blood

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14 "RFID Tags", *Verichip*, 2006. http://www.verichipcorp.com/content/company/rfidtags#implantable
15 "RFID Diagnostic Smart Skin Patch Technology", Gentag, 2008. http://www.gentag.com/applications.html
16 "Location Tracking Services", NEC Unified Solutions, 2007. http://www.necunifiedsolutions.com/Downloads/PDFs/188453_RFID_Healthcare.pdf
17 "T3 Tags", AeroScout, 2008. http://www.aeroscout.com/content/t3
18 "SurgiChip". SurgiChip, Inc., 2008. http://www.surgichip.com/index.htm
19 "Patient Tracking", Radiance, 2008. http://www.radianse.com/patient-tracking.html
20 "InTouch Care", CenTrak, 2008. http://www.centrak.com/CenTrak_PeopleTracking.asp?menuid=p6
21 "Infant Protection", Verichip, 2008. http://www.verichipcorp.com/content/solutions/infant_protection
22 "Cubixx", ASD Healthcare, 2008. https://www.asdhealthcare.com/display.aspx?cid=Cubixx.cms
23 "SmartSponge System", Clearcount Medical Solutions, 2008. http://www.clearcount.com/product.htm
24 "Asset Tracking", Radianse, 2008. http://www.radianse.com/asset-tracking.html
25 "RFID Tracking System", 3M, 2008. http://solutions.3m.com/wps/portal/3M/en_US/rfid_tracking_solutions/home/products/rfid_tracking_system/
26 "Hospital Solutions", WaveMark, 2008. http://www.wavemark.net/hospitals.html
27 "Phillips announces new RFID asset tracking solution", *Phillips Healthcare*, 2008. http://www.medical.philips.com/us/news/content/file_1361.html
28 In May 2007, Panorama, a BBC investigative programme, claimed to have monitored high levels of radio frequency radiation in UK classrooms. Although not a scientific study, the programme gave high visibility to the issue and generated a lot of discussion and concern. More recently (July 2008), the director of the University of Pittsburgh Cancer Institute in the US issued a memo to his staff encouraging adults to use hands-free devices, and to have children use mobile phones only for emergencies due to concern over possible linkages to brain tumors. Subsequent to that announcement, there has been broad discussion in the media, given that there are no conclusive studies supporting the cancer/tumor concerns expressed. The Director of the Institute, Dr. Ronald B. Herberman, conceded this point, stating that "really at the heart of my concern is that we shouldn't wait for a definitive study to come out, but err on the side of being safe rather than sorry later".
29 Birdwell-Pheasant, D., Lawrence Zúñiga and D. Berg, *House Life: Space, Place, and Family in Europe*, 1999. See also Chapman, D. *The Home and Social Status: International Library of Sociology I: Class, Race and Social Structure*, 1955.

pressure cuff, is on one's kitchen counter, this too gives immediate cues to a visitor as to the state of the senior citizen's health. At times, medical necessity overcomes the desire to avoid the stigmatisation associated with having such cues apparent to others, but the desire *not* to provide such cues is strong and can create resistance in the potential user, slowing the demand for such products and, in turn, inhibiting the willingness of industry to invest in their development.

Over the past decades, global efforts to provide greater accessibility to public buildings and resources initially resulted in architectural changes that were costly, unattractive and in many cases stigmatising to those who would benefit from them. Over time, a universal design approach (also known as design for all or inclusive design) emerged to drive design, embodied by the following principles[30]:

- *Equitable use*. The design is useful and marketable to people with diverse abilities.
- *Flexibility in use*. The design accommodates a wide range of individual preferences and abilities.
- *Simple and intuitive*. Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills or current concentration level.
- *Perceptible information*. The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
- *Tolerance for error*. The design minimizes hazards and the adverse consequences of accidental or unintended actions.
- *Low physical effort*. The design can be used efficiently and comfortably and with a minimum of fatigue.
- *Size and space for approach and use*. Appropriate size and space are provided for approach, reach, manipulation and use regardless of the user's body size, posture or mobility.

> Universal design is the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.
>
> *–Ron Mace, architect and designer, University of North Carolina*

From an ICT perspective, there have been several responses to addressing the need to ensure accessibility to technologies, including:

- Recently, WCAG 2.0[31], which is focused upon access to web-based systems[32]. In addition, as industry becomes increasingly involved in the issue of technology accessibility, many of them do not necessarily look beyond the web paradigm when contemplating the meaning of e-inclusion.[33]

- Building upon universal design, ICT developers from the University of Washington, have suggested that "assistive technologies are built on the assumption that it's the people who have to adapt to the technology. We tried to reverse this assumption, and make the software adapt to people."[34]

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[30] The Center for Universal Design, NC State University, 2008. http://www.design.ncsu.edu/cud/about_ud/udprincipleshtmlformat.html#top

[31] Web Content Accessibility Guidelines 2.0, W3C Candidate Recommendation, 30 April 2008, www.w3.org/TR/2008/CR-WCAG20-20080430/

[32] In the US, Section 508 legislation sets the standards for accessibility to technology-based systems, which does extend beyond web and PC-based systems, but does not provide a broad framework that anticipates future/emerging technologies. http://www.section508.gov/

[33] "Public Policy", *Oracle*, http://www.oracle.com/global/eu/public-policy/fs/new-e-inclusion-policy.html

[34] Gajos, K., D. Weld, and J. Wobbrock, "Association for the Advancement of Artificial Intelligence", University of Washington, 15 July 2008, From "For Your Eyes Only: Custom Interfaces Make Computer Clicking Faster, Easier." *ScienceDaily*, http://www.sciencedaily.com /releases/2008/07/080715152316.htm

As with assistive technologies for the disabled, there is a great danger of introducing ageism at many levels as industry aims to address the needs of the elderly, focusing upon the specific issue of chronological age of an individual, and thereby unnecessarily categorising him/her. When examining how technologies can be used as an effective tool to extend the physical abilities or social reach of an individual, the needs should be examined within the context of clinical, physical, cognitive, social, or other requirements.

However, given that in its purest incarnation, ubiquitous computing solutions would literally be unseen: do such technologies represent the best solution possible to eliminate the stigmatisation presented by many assistive technologies? If this quality of near invisibility supports a right to human dignity, does this same quality raise other ethical issues or challenges?[35]

Informed consent

One of the most challenging ethical areas for ubiquitous computing is in providing an effective method of informed consent to the user of the technology. Designed to recede into the periphery, the sensors, networks and databases are meant to be unseen by the user, and actions taken based upon sensed changes in the environment, passive behaviours or specific actions of the subjects in the environment. Many questions arise from this:

- Assuming that the outward actions and responses of the system are meant to be "calm" and not demand that the user take particular notice of the system, how does the user even know that the system is indeed taking action (recording data about the environment, medical condition, behaviours, etc.)?

- It may be that the primary user is aware of the system and its actions, but to what degree does this now obligate the user that he/she inform others who come into the environment?

- The actions of a system, as it is designed, may be rather benign. However, if the system collects information and stores it elsewhere (in a central database), how does one know what safeguards are in place to protect those data, and to ensure against later misuse or design changes or function creep? For example, suppose an application involves video recordings which are submitted to an intelligent video content analysis, which only engages human monitors if an exception is identified by the application (e.g., a person falling to the floor). What preventative measures should be taken to ensure that the individual is given the level of privacy they expect (e.g., that captured video content is destroyed within an appropriate period of time, and no back-ups are retained)?

- If such systems seem simple in their presentation to the user, they are likely to be highly complex in their processing and application of computer-driven decision-making. How can all the possible implications of the operation of the system be made plain to users? Will this result in engineers making decisions about what the user "needs to know"?

[35] Can ubiquitous technologies such as the "Presence Lamp" developed by Intel provide much needed social connections in a manner that enables the elderly user to feel connected to loved ones in a non-intrusive manner? The Presence Lamp in a senior citizen's home is connected to a sensor in the sofa, or the senior's favorite chair, with a companion lamp similarly installed in the home of the senior's care-giver or family member. When the elderly person sits in the chair, the light turns on in the other location, inviting interaction.

- Further, if proportionately fewer senior citizens are less technology-savvy than their working-age counterparts, how can one predict the extent to which they may be able to fully understand the technical implications of such systems, without a firm grounding in the underlying principles of technology that engineers take for granted (wireless signals, sensor collection devices, databases).
- Of great significance for those senior citizens who are beginning to suffer from dementia, perhaps yet undiagnosed, are the implications of informed consent. As the individual's ability to comprehend and/or recall newly introduced information waxes and wanes over days or even over the course of a single day, how can one hope to achieve informed consent?
- Finally, can informed consent be taken to an extreme? As pharmaceutical products have become commonly advertised in recent years, required to provide terrifyingly detailed lists of possible side effects associated with their use, can the issue of informed consent ultimately prevent the uptake of new technologies that may not yet work consistently, but are still deemed to provide value to the user? For example, if a sensor-laden rug measures one's gait on a daily basis, and does not detect any significant changes in the user's balance or strength, but a fall occurs nonetheless, what sort of liability might the manufacturer face? To alleviate any liability concerns, legal disclaimers must reveal that not all falls will be prevented, and that the company will not assume liability for any injuries. If such disclaimers are made, would you invest in the rug for your ageing parent or yourself?

One of the key conclusions from the "Bled Exploration of issues and guidance" on Ethics and e-Inclusion: Contribution to the European e-Inclusion Initiative[36] with regards to this issue for the Ageing population was the following:

> *Informed consent is vital, choices available must be understandable and transparent. They should be adapted to match the comprehension level of the recipient. Consideration needs to be given to the right not to know.*

Right to self-determination

An individual's desire to actively choose the environment in which they live – their home, their community – is at the core of independent living solutions, and many of the applications that are being developed as part of ubiquitous computing (and assistive technologies) are intended to support the decision by an older person to make that choice, providing them with the tools necessary to be safe, healthy and socially connected. However, as ubiquitous computing solutions evolve and are dispersed into the environment, many individual daily decisions will no longer be necessary, raising concerns such as the following:

- If one chooses to deploy certain ubiquitous computing technologies into the environment, is one essentially allowing the technology to make decisions in one's stead? Some have suggested that subduing individual decision-making to the autonomous actions of a computer is "technology

[36] High-Level workshop, Slovenian EU Presidency & European Commission, Bled, 12 May 2008.

paternalism" allowing the computer (or, by inference, the engineer who designed the computer) to make decisions based upon rules that others have deemed to be in one's best interests.[37]

- In addition to the risk that the user will sublimate their own decisions to that of a computer, it is also highly possible that the mere availability of technological solutions will encourage reliance upon their use, potentially masking real user needs. A potential outgrowth of the increase in technology-based solutions to key concerns associated with the elderly such as falls prevention, wandering, cognitive decline, etc., is the replacement of focused needs assessment with a quick technical solution. For example, the availability of monitoring solutions to track individuals prone to wandering may cause caregivers not to thoroughly examine for the root cause of wandering, and instead only deal with the symptom.

- If opt-out options are built into all such systems, will the system itself become less effective, negatively impacting goals to protect the health and safety of the individual?

Right to privacy

The European citizen's right to privacy was behind the Data Protection Directive[38], which obliged Member States to protect "the fundamental rights and freedoms of natural persons, and in particular their right to privacy with respect to the processing of personal data", ensuring specific legal remedies to the individual. The Charter of Fundamental Rights of the European Union (2000/C 364/01) established privacy as a fundamental right of each citizen. Many of the EC-funded projects in the area of independent living for senior citizens and ambient technologies include a specific focus on the issue of privacy and, in particular, on protecting any personally identifiable information.[39]

However, as we enter new technological territories, defining what are considered personal data becomes far more difficult. Are one's movements within one's own home personal data? Are one's movements in and around the community not? Is every object associated with a person, if fitted with a location-aware sensor or RFID tag, somehow part of one's domain of personally identifiable information? From a legal perspective, even an IP address can be explicitly associated with an individual, and deemed to identify a person especially as connected to actions taken over the Internet by an individual.[40] If this is the case, how should systems using such information be designed to create appropriate levels of anonymity in order to shield the user from unnecessary exposure?

Most privacy protections that have been devised to date are focused on providing protections that assume that the relationship for personal data tends to be a straight line connection between the individual and some

[37] Spiekermann, Sarah, and Frank Pallas, "Technology Paternalism - Wider Implications of Ubiquitous Computing", *Poiesis & Praxis: International Journal of Ethics of Science and Technology Assessment*, Vol. 4, 2005.

[38] Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data, Official Journal of the European Communities of 23 November 1995, No L. 281, p. 31 et seq.

[39] For example, the HERMES project, (Cognitive Care and Guidance for Active Aging), includes a data protection plan as a deliverable, and the SOPRANO project (Smart Environments for Older Europeans), also funded under FP7, included amongst its key ethical principles that "Participants will be treated with respect at all times and their anonymity will be protected."

[40] White, A., "IP Addresses Are Personal Data, E.U. Regulator Says", Associated Press, 22 January 2008, http://www.washingtonpost.com/wp-dyn/content/article/2008/01/21/AR2008012101340.html

organisation (government, service provider, supplier, etc.), and that the organisation is responsible for adhering to the requirements of these protections. However, many of the applications envisioned for senior citizens suffering from health and mobility problems are likely to include a web of intimate connections (family, friends, health professionals, neighbours) with whom the individual may wish to share details about their health conditions and daily activities, but that sharing may change over time as relationships themselves change and shift.

Social and e-Inclusion and accessibility

There have long been concerns that for as much as technology can serve people in innumerable ways, it may also tend to have an isolating effect, either by excluding some users through a lack of appropriate response to their needs, or at another extreme through the creation of a technological safe haven that eliminates the need for any human contact whatsoever[41]. These concerns are amongst those which are being examined on a broad basis under the e-Inclusion programme of the European Commission. Some of the difficult issues that are being explored now are the sometimes conflicting priorities for technology and inclusion in ensuring that senior citizens can effectively utilise technology so they may fully participate in society, while also ensuring that they are allowed to exercise a right to opt-out.

Beyond this, much of the current focus of technology development in the area of ubiquitous computing is on overcoming disabilities and preventing medical or physical harms. There is concern, however, that technology needs to be viewed as empowering users, rather than merely safeguarding them from harm. Thus, to provide an inclusive approach, the solutions need to examine what users can do and desire to do, rather than focusing merely upon limitations. Beyond this, as technologies are being developed and deployed, the aspect of needs must be fully understood – that is, it is critical to clearly determine whose needs are being met by the solution. Are the needs being met those of an elderly person, or those of the caregiver, masquerading as a solution for the benefit of the elder? This same concern was echoed at the Bled Ethics and e-Inclusion Workshop, and it was particularly noted that there is a conflict (which remains unresolved) in this area, requiring further examination and debate:

> *Needs change with increasing age, possibly coupled with failing health and mobility. There is a potential conflict not only between needs and wishes but also between the recipient's and carer's perception of these.*[42]

As with any new/emerging technologies, those examined here continue to face high barriers to broad adoption, including issues of reliability/consistency in performance, integration/interoperability, broad market availability, lack of commitment by industry to invest in solutions for a market segment with unknown dimensions, and high costs for those solutions which have been developed to date.

[41] On the other hand, there are a few ubiquitous technologies aimed at encouraging social engagement, enabling the elderly user to feel connected to loved ones in a non-intrusive manner. For example, the Presence Lamp, an experimental technology developed by Intel, utilises a lamp in a senior citizen's home, connected to a sensor in the sofa, or the senior's favorite chair, with a companion lamp similarly installed in the home of the senior's care-giver or family member. When the elderly person sits in the chair, the light turns on in the other location, inviting interaction.

[42] "Bled Exploration of issues and guidance" on Ethics and e-Inclusion: Contribution to the European e-Inclusion Initiative. High-Level workshop, Slovenian EU Presidency & European Commission, Bled, 12 May 2008.

Conclusions

Upon examining many of the ethical issues arising from the development of any new technology, in combination with the particular needs for protections that are relevant to the vulnerable, elderly population, we can see that more guidance is required with regard to the design of these technologies, their testing and deployment. Many of the recent projects funded by the EC under FP5, FP6 and FP7 have included some element of ethical review, and some have included ethical advisory boards. However, there appears to be inconsistencies in the ethical approach adopted by these projects (most appear to have paid little attention to ethical issues). A similar conclusion seems justified in regard to the technologies being developed directly by industry. The need for guidance is certain, and given the complexity of the research and development market around these technologies, encompassing both academic and industrial actors, effective dissemination into a broad range of research, development, distribution and support organisations is critical.

Some of the key issues that must be addressed in designing, testing, and deploying ubiquitous computing technologies in this context have been outlined in the previous section. However, all of these solutions provide for ethical ambiguity, requiring developers and users to make choices and trade-offs.

For example, if a software-based cognitive aid, meant to assist the user with visual or mnemonic reminders, is capable of detecting patterns of cognitive decline, is there an ethical imperative to alert physicians or caregivers about such declines, given that such an alert may result in an intervention that diminishes the user's independence? Through informed consent to the possibility that such declines would be alerted to caregivers, would the efficacy of the system be compromised (e.g., because the user chooses to opt-out based upon fear of losing their independence)? To address these issues, there is a need to determine ethical cost/benefit from various perspectives to reach the solutions that are optimal for the purposes of ensuring long-term, healthy, independence for the user.

In approaching these complex issues, the SENIOR Project has proposed the following[43]:

> *An approach geared towards the protection of human rights could instead match the different needs of the ageing and provide concrete guidance to evaluate technological items for the elderly. To assist decision-makers in deciding how and when a given innovation is better, it might be worthwhile considering the following principles:*

- *As technology embodies and reinforces values, evaluation requires making values explicit.*
- *As innovations can perform effectively only as part of socio-technical networks that embody multiple needs and expectations, the shielding and enabling effects of technology need to be articulated in relation to both current and potential practice.*
- *As technology, in particular assistive and health care technology, is a public-private good open to public policy interventions, reflexive science is produced within socio-political projects. Feedback should be sought when a given technology is introduced in a given context, for instance, in nursing homes.*
- *As the framing of policy is vital, civil society should be made a pivotal locus of transparent and public deliberations when the interests of senior citizens in a given place at a given time are at stake.*
- *As industry develops technology largely on the basis of its own logic, the role of the private sector within publicly funded systems, such as health care systems, needs to be made explicit.*

[43] SENIOR Project Consortium, "Ethics of e-Inclusion of older people: Discussion Paper for the Workshop on Ethics and e-Inclusion, Bled, 12 May 2008."

As this dialogue continues and evolves in looking at additional areas of technology, ethics, and e-Inclusion, the SENIOR Project will aim towards the goal of developing an effective roadmap for the development of Ethical and Inclusive ICT for the Elderly.

Annex A: Ubiquitous Computing Technologies

Key building block technologies that are contributing to the current evolution of Ubiquitous Computing, especially as they relate to the elderly, are described on the following pages.

RFID

Radio frequency identification (RFID) is one of the key technologies enabling ubiquitous computing, and is far from an emerging technology, with roots in technologies dating to WWII. However, the real emergence of RFID over the past 10-15 years has been as a result of continual enhancements enabling RFID tags (which provide unique identification information) to be produced in smaller and smaller forms, and at increasingly lower costs. These tags may be passive (i.e., they have no power source, and the data is accessed only when the tag is in proximity to a reader or antenna which acts as the power source) or active (which have their own onboard power source). Tags also vary in terms of the communication range and frequencies used for transmission of data, and in their ability to be used in various types of environmental conditions. RFID applications began to be deployed in mass market applications in the late 1990s, and as large governmental and retail distribution adopters established standards for vendors, a strong wave of adoption followed in the supply chain application. Figure 2 provides a high-level conceptual view of supply chain management application of RFID[44], showing various applications of tags (including one associated with a person, individual products, or pallets/containers of products) which are read by an interrogator (referred to as a reader, although in some cases, this may serve as a read/write device). The information collected by the reader is usually then transmitted to a local or central system as input to an application and further processing.

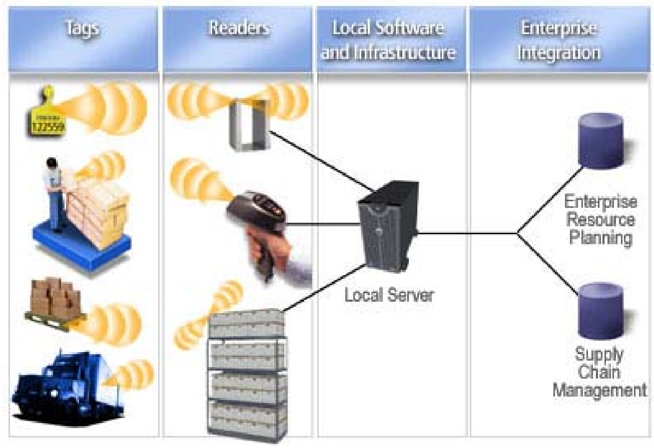

Figure 2: How RFID Works

Although RFID technology is commonly seen in its similarities to the bar code identification system, it is a more advanced system. Unlike bar codes, some RFID tags can be read in bulk, do not require direct line of sight for scanning, and can uniquely identify objects within a multitude of identical items.[45]

RFID technology has a wide range of applications, with the broadest current use in tracking goods in supply chains and in tracking assets within a facility. Some other notable applications include:

- Tracking animals by injecting a chip under the skin. An animal identification system then aims to protect livestock and poultry from disease outbreaks by allowing animal health officials to know which animals are involved in an outbreak and where they are located.[46]

[44] Illustration source: http://www1.webmethods.com/images/solutions/webMethods_RFID_121703.jpg
[45] "RFID Technology- Fact Sheet", *Office of the Privacy Commissioner of Canada*, 23 February 2006. http://www.privcom.gc.ca/fs-fi/02_05_d_28_e.asp

- Use of RFID in transportation and travel has become commonplace, providing for storage of identification information in travel documents and transportation payment systems such as the London Underground's Oyster card, Moscow Metro[47], EZ Pass[48], and other toll collection systems.

- RFID is commonly used in wander management applications in care homes where there is a concern for residents suffering from dementia. Wander management applications have also moved past the controlled environment of the senior citizens' residence, and in some cases to law enforcement, as in the case of Project Lifesaver launched by the Sarasota, Florida, Police Department.[49]

- Research is also being done in the use of RFID skin patches, which would allow for post-surgery monitoring by both physicians and patients.[50]

- With far less market uptake to date, VeriChip[51] has developed an FDA-approved RFID tag (about the size of a grain of rice) which is meant to be injected under the skin, and which is intended to act as identification should an individual be brought into a medical facility where they are unable to communicate effectively.

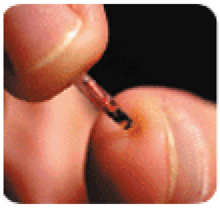

Figure 3: Human Implantable RFID Tag

- RFID is emerging as an option for tagging frequently lost objects, providing cognitive support to the elderly in the early stages of dementia.

Figure 4: SESAMONET Navigation path around Lake Maggiore

There are many new applications using RFID emerging from the global research community, both academic and industrial, based upon a response to new markets and availability of research funding. As an example, the SESAMONET (Secure and Safe Mobility Network) project, co-funded by the EC, prototyped a path for safe navigation for the visually impaired, through the combination of RFID tags embedded in the ground, along with a smart walking stick, phone and headset, providing recorded messages about location. Interestingly, while the costs of RFID tags are decreasing, this project kept costs at a minimum by using recycled chips which had previously been used for tracking cattle.[52]

As more and more objects (and locations) are "tagged" and are given unique numbers and identifiers, it is possible to quickly see a connection between all these objects and how they might each become nodes in the "Internet of Things". Complemented by other types of tagging mechanisms (graphical tags, SMS tags, etc.), RFID-tagged objects may be joined in a wireless and self-configuring network to support new and evolving applications impacting daily life. Supporting the emergence of RFID and other tagging mechanisms as unique identifiers of objects (and in some cases, people or animals) is the IPv6, with vastly larger

46 "National Animal Identification System", *United States Department of Agriculture*, 8 July 2008. http://animalid.aphis.usda.gov/nais/index.shtml
47 "RFID FAQ", *RFID Technology*, 2008. http://www.rfidabc.com/rfid_FAQ_2.htm
48 A toll collection system common along the East Coast of the US.
49 "Sarasota Police Department and Project Lifesaver", http://www.sarasotagov.com/InsideCityGovernment/Content/Police/Lifesaver.htm
50 "RFID Skin Patches For Medical Applications", *Wireless Healthcare*, 17 May 2007 http://www.wirelesshealthcare.co.uk/wh/news/wk20-07-0006.htm
51 http://www.verichipcorp.com/content/company/rfidtags#implantable; Verichip is also currently exploring implantable glucose sensor technology to aid in the management of diabetes.
52 "SESAMONET- improved mobility of the visually impaired", *European Commission Joint Research Centre*, 19 October 2007. http://ec.europa.eu/dgs/jrc/index.cfm?id=4210&lang=en

addressing capability (addresses under IPv6 are 128 bits in length as compared to 32 bits under IPv4) [53]., which provides for approximately 5×10^{28} (roughly 2^{95}) addresses for each of the 6.5 billion (6.5×10^{9}) people alive today.[54]

However, this quickly expanding network of objects presents new security challenges (and related, but separate, privacy issues) as noted by the Committee on Networked Systems of Embedded Computers of the Computer Science and Telecommunications Board:

> *The networking of embedded devices will greatly increase the number of possible points of failure, making security analysis even more difficult. Defining and then protecting system boundaries where physical boundaries are likely to be nonexistent and where nodes can automatically move in and out of the system will be a serious challenge. Further, managing the scale and complexity of EmNets while at the same time handling the security challenges of mobile code and the vulnerability to denial-of-service attacks will require significant attention from the research community.*

Sensors

Sensors are becoming smaller and cheaper to produce, with limited power consumption, enabling them to be used in a broad range of scenarios, including movement (monitoring when an object is moved, or measuring vibrations), light (measuring varying colour and intensity of light, which could include determining whether indoors, outdoors, or change in time based upon a change in location of light source), proximity (which could monitor the presence of activity nearby, trigger applications that would otherwise be dormant), audio (level, pitch, etc.), temperature of an object, or of the ambient environment, force (which may be used to determine weight of an object, for example, as a vessel is being filled), humidity, acceleration, magnetism.

Because sensors are becoming significantly smaller, it is possible to utilise them in novel ways, enabling the objects into which they are placed to become "smart". As examples:

Figure 5: Sensors embedded in Textiles

- Sensors are increasingly being embedded into ***textiles***, enabling clothing to measure an individual's physical condition, whether for medical applications, entertainment or for monitoring sports-performance.[55]

Figure 6: iShoe Prototype

- Sensors may be used within carpet materials, embedded in canes or in the insole of shoes to measure and recognise an individual's gait. Current research is aiming to identify

[53] In a summary of its policy regarding support for the deployment of IPv6, the Commission expressed the view that IPv6 is "an essential technology for implementing ambient intelligence" http://ec.europa.eu/information_society/policy/ipv6/index_en.htm

[54] "Committee on Networked Systems of Embedded Computers of the Computer Science and Telecommunications Board", *Embedded, Everywhere*, National Academic Press, Washington, DC 2001.

[55] Illustration in Figure 5 from Liu, Jian, Lockhart, E. Thurmon, Mark Jones and Tom Martin, "Local Dynamic Stability Assessment of Motion Impaired Elderly Using Electronic Textile Pants", *IEEE Transactions on Automation Science and Engineering*, [forthcoming].

changes in an individual's gait as a proactive predictor of weakness or loss of balance that may lead to falls.[56]

- Vibration sensors are embedded into the environment, able to distinguish between a dropped object and a person falling on the floor.[57] This, in combination with flooring materials (and underlay) designed to make falls less harmful, can be designed into new houses or retrofitted into existing homes.[58]
- Sensors are also being embedded into other types of materials, including paint, although specific application to the needs of the elderly is as yet unidentified.[59]

The development of smaller sensors and wireless sensing networks that enable their effective use for more applications has been significant – most notably, the Smart Dust project sponsored by the US Defense Advanced Research Projects Agency (DARPA)[60], and carried out at the University of California in Berkeley. The project resulted in the development of the TinyOS open source operating system as well as highly miniaturised "motes" which are part of the sensor network, providing sensor input as well as storage and other functions.[61]

Figure 7: Spec pictured next to a ballpoint pen

However, beyond their miniaturization, sensors are becoming more powerful in being able to respond with some level of intelligence to changes monitored in the environment. The International Telecommunication Union's Strategy and Policy Unit observes that:

> *Greater artificial intelligence and increased independence from human intervention are the key attributes of the sensor. The development of smart dust implies that sensors are getting smaller, but the creation of a network of sensors means that they are also getting smarter. The next stage for the sensor is the webbed sensor network. A web of sensors can enhance the ability of sensors to act independently, and can lead the way in enhanced web networking to create a sensitive and responsive Internet of Things.*[62]

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[56] Significant research efforts are focused on this issue, due to the high incidence of falling injuries as both a cause of death or non-fatal injuries resulting in hospital admission for trauma amongst older adults. According to the US Center for Disease Control (CDC), more than one third of adults 65 and older fall each year in the United States (CDC 2006). http://www.cdc.gov/ncipc/factsheets/adultfalls.htm. The illustration shown above is a prototype of the iShoe being developed by researchers at MIT. Refer to http://web.mit.edu/newsoffice/2008/i-shoe-0716.html

[57] Alwan, M., P.J. Rajendran, S. Kell, et al., "A Smart and Passive Floor-Vibration Based Fall Detector for Elderly", *Information and Communication Technologies Medical Automation Research Center (MARC)*, Department of Pathology, University of Virginia, 24-28 April 2006.

[58] Most attention to the issue of flooring materials is centered upon elder care and hospital environments, where large numbers of individuals may be affected, either in terms of preventing falls or reducing levels of injury such as hip fractures. Examples of such studies: "Can flooring and underlay materials reduce the number of hip fractures in the elderly?" Minns, Nabhani, Bamford, Rich and Donald IP, Pitt K, Armstrong E et al. "Preventing falls on an elderly care rehabilitation ward", Clin Rehabil 2000;14:178-185.

[59] Several paint-embedded sensor projects are ongoing, primarily focused upon enabling paint to actively monitor for cracks which might allow water to seep under the surface of the paint, providing intelligence as to when surfaces may need re-painting in order to avoid oxidation of or damage to underlying surfaces, or even changing the colour of the paint. Information about projects in this area of research may be found at the following URLs:

1. http://www.tudelft.nl/live/pagina.jsp?id=e04f0e09-703f-46a7-a94b-b87cc5a49b2a&lang=en
2. http://www.idtechex.com/printedelectronicsworld/articles/smart_paint_warns_motorists_of_ice_00000974.asp
3. http://www.njit.edu/president/annualreport/2003/security/watts.php

[60] The vision for the original funding of the "Smart Dust" project by DARPA was to provide a way to sense battlefield conditions, where thousands of sensors might be scattered over an area by plane or helicopter to obtain information about vehicle movement in remote locations or environmental data.

[61] Image Source: http://computer.howstuffworks.com/mote5.htm

[62] "ITU Internet Reports: The Internet of Things," *International Telecommunication Union*, November 2005.

Surveillance technologies

Although not truly ubiquitous, many surveillance technologies that have been developed or are being researched for security applications have become more prevalent for in-home monitoring applications, and bear mentioning here. Traditionally, such technologies tend to be highly privacy-invasive, but newer technologies are evolving to provide options that are far less so. As applications for the elderly, particularly with families living far apart, such monitoring systems are becoming more prevalent. Examples of some applications include not only video monitoring systems (which might be coupled with intelligent video content analysis), but those which produce anonymised images of individuals.[63] Motion detection schemes monitor daily behaviour and movements, and send out alerts to care-givers if there are significant departures from an established norm. More hidden sensors connected to household appliances (coffee or tea maker, television, etc.) record patterns of behaviour in their use and alert for exceptions.[64]

Other Technologies

A broad range of other technologies are closely related to and intertwined with those described briefly here. To be addressed separately[65], they include:

- Intelligent user interfaces
- Assistive technologies
- Robotics
- Adaptive software

[63] "Elder-Centered Recognition Technology for the Assessment of Physical Function", *Active Elders*, 9 November 2007. http://eldertech.missouri.edu/hccelder.htm.
[64] S. Helal, W. Mann. H. El-Zabadani, et al., "The Gator Tech Smart House: A Programmable Pervasive Space", University of Florida, March 2005. http://ocw.kfupm.edu.sa/user062/COE40001/smarthomepaper.pdf
[65] A total of five preliminary technology-focused papers will be developed as deliverables of SENIOR, including *Ubiquitous Computing*, *Ubiquitous Communication*, *Intelligent User Interfaces*, *Assistive Technologies and Robotics*, and *Adaptive Software*.

Annex B: Markets and Ubiquitous Computing for the Elderly

The development of ubiquitous computing technologies is largely driven by business and consumer markets, more so than from the perspective of directly serving the needs of the elderly, with most large industrial players focusing upon development that increases business efficiency and enhances business collaboration, wireless communication and social networking. For example, RFID's advancement over the past 10 years has been driven more by supply chain requirements than any other application or market segment. The move to IPv6 has been driven by the imminent exhaustion of IP addresses under IPv4, and surveillance and monitoring technologies by the global expansion of the security industry.

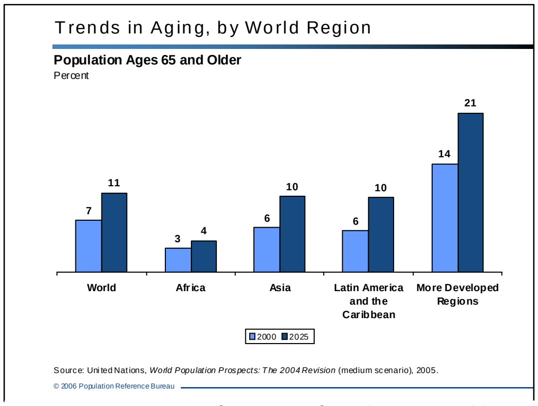

Figure 8: Projections for percent of population 65 or older by region, 2000 vs. 2025

Nonetheless, given the availability of these technologies, these building blocks are beginning to become available for development and testing of solutions for a broad range of markets, and a vast number of universities in Asia, Europe, and North America have dedicated resources to their study (see Annex D for a representative list of university programmes and Annex E for a similar list of industry-sponsored centres). With the rapid graying of developed regions of the world, as shown in Figure 8[66], following decades of falling birth rates, researchers and industrial actors see opportunities to turn these technologies into useful and profitable solutions and capture a rapidly emerging market.

Note of caution: Regarding all of the aforementioned building block technologies, while much progress has been made in advancing them through miniaturisation, reduction of power requirements, and reliability, the real-world application to addressing user needs in practical terms has not been widely tested, and much work remains to be done. Many of the products that have been developed have been piloted with small populations, and tend to serve more as a demonstration than as a reliable trial for production-ready systems. As important as the advancement of the technologies themselves is in this area, significant innovations are still lacking in terms of applications and with that, business models that provide sufficient profit motivation for industry to invest heavily. Given that business models are highly intertwined with diverse health/medical reimbursement schemes around the globe, movement out of the laboratory and into real-world application is slow to come. Applications which have come to the fore are examined in the following sections:

Applications

New technologies are being used in new applications to enhance health and well-being, support daily activities, assure independence and strengthen social connections with family, friends and the community. Key applications that are already in some stage of production delivery are described below. The development of these applications gives some strong clues as to the focus of development in the future, as researchers look for accessible solutions to the needs of senior citizens, including:

[66] Population Reference Bureau. http://www.prb.org/Publications.aspx

- Independent daily life: domotics and cognitive aids
- Health and well-being: telemedicine, falls prevention, medication compliance
- Safety: in-home monitoring
- Social connections: communications.[67]

Domotics[68] and cognitive aids. Domotics is not a new field, and has often been deemed a luxury appointment for a newly constructed home, using an embedded network of controllers, sensors and actuators to help control the environment (heating, air conditioning, lighting), entertainment systems and physical security. However, costs are continuing to decrease, and wireless technologies are making it easier and more cost-effective to retrofit such systems into existing, older homes. In addition, projects such as Amigo[69], Easy Line+[70], i2home[71], MPower[72], Netcarity[73], Persona[74] and Soprano[75] are helping to make the systems more accessible to senior citizens by more directly addressing their needs and the cognitive challenges that may occur in later life, with subtle systems of reminders about time of day, people and conversations.

Health Care. Applications providing support for remote health and wellness monitoring through telemedicine have become more commonplace over the past few years. While the uptake of such systems may still present challenges (reimbursement schemes in some countries has limited broad adoption), their benefit to senior citizens who may have difficulty in leaving their home for a visit to a physician and to those in remote locations is clear. Sensors are becoming more unobtrusive, with devices resembling more traditional home appliance such as a scale and, as previously mentioned, some sensors are embedded into articles of clothing. Beyond the broad reach of telemedicine, researchers are taking new approaches (e.g., through sensors embedded in rugs, canes and shoes, accelerometers and vibration sensors) to address the specific high-risk health issue of falls. In addition, recognising that medication compliance is critical to those individuals with one or more chronic conditions, reminder systems range from simple, alarm-based systems to more fully integrated systems that measure specific doses and report non-compliance to remote monitoring systems. A few examples of health care focused projects (several of the projects mentioned under Domotics also include health care elements) include CHRONIUS[76] and HEBE[77].

Monitoring. Researchers are developing increasingly more unobtrusive monitoring systems. Until recently, active monitoring of an individual within the home environment was either extremely limited (e.g., with personal emergency response systems that required the user to actively initiate a call for help by pressing a button) or invasive (i.e., through surveillance cameras). The focus of research and development for monitoring

[67] Communications technologies will be examined by SENIOR in the Ubiquitous Communications Workshop and related paper.
[68] Image Source: http://www.thisoldhouse.com/toh/article/0,,1214514,00.html
[69] www.amigo-project.org
[70] http://www.arenque-ks.com/easynet/index.html
[71] www.i2home.org
[72] http://www.sintef.no/Projectweb/MPOWER/Home
[73] http://www.netcarity.org/
[74] http://www.aal-persona.org/
[75] http://www.soprano-ip.org/
[76] http://www.chronious.eu/
[77] A completed FP6 project on monitoring falls by using accelerometers and location sensing technologies. Project fact sheet available on CORDIS.

systems is now on behavioural monitoring, enabling systems to track the daily movements of individuals through motion sensors and sensors embedded in electrical outlets that can monitor the use of specific home appliances (television, coffee maker, etc.). These monitors and sensors are coupled with software that evaluates and compares behaviours with typical behaviours, and issues alerts to care-givers based upon level of adherence to those typical patterns. In addition to commercially available monitoring applications, other recent research projects of interest include EMERGE[78] and UbiSense[79].

Appendix A lists examples of other applications that are either available today or in advanced stages of research.

Growth Drivers

> **Population ageing** may be seen as a human success story—the triumph of public health, medical advancements, and economic development over diseases and injuries that had limited human life expectancy for millennia.
>
> K. Kinsella and D. Phillips, "The Challenge of Global Aging", Population Bulletin 60, no. 1, 2005.

Global ageing & governmental support. Much has been written about the implications of the ageing of the world's population, and how that impacts the citizens of both developed and lesser-developed nations. However, some consequences of these demographic trends are providing impetus for technology development and acceptance.

With the significant shift in population in the past decade, and the continued growth in the number of senior citizens over the next 40 years, these issues have become a priority for the United Nations[80] and the World Health Organization[81] even as the specific needs of senior citizens have shifted dramatically. The Second UN World Assembly on Ageing, held in 2002, resulted in the Madrid International Plan of Action on Ageing, which focused on economic development, advancing health in old age and development of enabling and supportive environments. Taking this Plan of Action and key initiatives of the European Commission into account, significant focus has been placed upon addressing the multitude of issues that support the needs of the ageing population of Europe.[82] With an increasingly high percentage of the population aged over 65 years, Europe has ample motivation to address the special needs of senior citizens aggressively.[83]

This work has progressed on numerous fronts, from enhancing the ability of older adults to remain in the workforce for longer periods, to health-enhancing and assistive technologies, to solutions enabling individuals to live independently, safely, and to optimise their ability to participate in society, with a particular focus on enabling older citizens to take advantage of the wealth of resources available as part of the Information Society. With new technologies and supportive programmes being developed for senior citizens there has resulted better differentiation between younger senior citizens (65-79) and older senior citizens (80+). For the former, there is more focus on "active ageing" as they transition from a daily working routine into a new role in the community and family. For the latter, the focus is more on managing chronic health issues and ensuring an ability to continue to perform activities of daily living (ADLs) with or without care-giver support.

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78 "Our Drive- Our Motivation", *EMERGE*, 7 March 2008. http://www.emerge-project.eu/index.html

79 Research project run by Imperial College London using cameras to monitor a person's activity level, gait and falls.

80 http://www.un.org/ageing/

81 "Ageing", World Health Organization, 2008. http://www.who.int/topics/ageing/en/

82 The numerous policy documents, programmes that are an outgrowth of those policies, and specific projects funded under those programmes are discussed in detail in SENIOR Project Deliverable D1.1, "Environmental Scanning Report."

83 Population Reference Bureau, http://www.prb.org/Publications.aspx

Mobility and families at a distance. Another social change that directly affects the need for technological solutions for both groups is that of geographic mobility, which has been increasing for several decades and which, within the EU, has become even more prevalent with the accession new Member States over the past decade. This mobility often introduces significant physical distances between parents and their adult children, which was less common in previous generations. Migration from lesser-developed regions to those boasting better labour markets can produce particularly significant challenges as adult children are the most common choice as care-giver to a senior citizen.[84]

> *"Insofar as demographic and cultural changes in family structures predict a lower likelihood of support from children to elderly parents, this applies to practical support, and derives mainly from increased geographical separation distances and from the growing trend for parents to take new partners. Social support is unlikely to be affected by these changes if parents and children maintain good relationships."*[85]

The need to address this issue of *practical support* is helping to drive technology development, providing solution for senior citizens that their children may not otherwise be able to provide.

Technologies in search of an application? As researchers endeavour to break through new barriers in scale and performance, much of their work continues to focus upon technology itself, rather than practical applications. For example, of the 22 papers selected from the UbiComp 2005 Conference and featured in the published proceedings, only a few focused on practical real-world applications ("Analysis of Chewing Sounds for Dietary Monitoring" and "Abaris: Evaluating Automated Capture Applied to Structured Autism Interventions"). Many studies focused upon location awareness as well as developing a granular understanding, sometimes through ethnographic studies, of how people will ultimately interact with such applications, to communicate, to work or to play.

Inhibitors

Market barriers. One of the key inhibitors to development of ubiquitous computing solutions explicitly targeted at the needs of senior citizens is economic. As industrial planners look at R&D costs vs. potential revenues, the outlook continues to be challenging. Globally, there are stark differences amongst reimbursement schemes for medical or assistive devices, and in many cases, such technologies might be considered luxury goods, leaving a limited market into which a manufacturer might sell. In its Communication on Ageing well in the Information Society, the European Commission states that:

> *Although the older population has a large buying power and ageing is becoming a global phenomenon, the market of ICT for ageing well in the information society is still on its nascent phase and does not yet fully ensure the availability and take-up of the necessary ICT enabled solutions. The reasons include low awareness of the opportunities and user needs and insufficient sharing of experiences, fragmentation of reimbursement and certification schemes, lack of interoperability, and high costs of development and validation.*[86]

[84] "Selected Caregiver Statistics", Family Caregiver Alliance, 2008, http://www.caregiver.org/caregiver/jsp/content_node.jsp?nodeid=439.
[85] Stuifbergen, M.C., J.J.M. Van Delden and P.A. Dykstra, "The implications of today's family structures for support giving to older parents", *Ageing and Society*, Vol. 28, 2008, pp. 413-434.
[86] Published Brussels, 14 June 2007.

The primary market barriers identified in a 2005 report presented at the 2005 White House Conference on Aging included issues such as inadequate privacy legislation, fragmented regulatory schemes and reimbursement schemes that have not kept up with the emergence of new technologies (e.g., Medicare insurance, which covers medical costs for senior citizens in the US, has not typically reimbursed for medical care that does not include a face-to-face encounter with a health care provider, limiting the emergence of telemedicine options).[87]

Privacy concerns. Consumers tend to view many new technologies with some initial scepticism because they are unfamiliar. Even though personal computers and the Internet have become commonplace in urban, suburban and rural communities, in wealthy, middle-income and to a lesser degree in lower-income homes, privacy concerns continue to be high. A SeniorWatch Survey conducted in 2007 found that 16.7 per cent of elderly respondents who were interested in using the Internet more did not do so because of their concerns about security or privacy (with levels of concern varying by country from 38.9 per cent in Germany to 7.1 per cent in France).[88]

[87] "Technology and Innovation in an Emerging Senior/Boomer Marketplace", prepared for discussion at the 2005 White House Conference on Aging by the Office of Technology Policy of the Commerce Department's Technology Administration, 11 December 2005.

[88] SeniorWatch 2: Assessment of the Senior Market for ICT, Progress and Developments, Final Study Report, April 2008. Beyond these elderly-specific data, a recent survey in the US showed an increase in concerns about privacy due to increasing levels of identity theft (which had been steadily decreasing since 2001). According to the survey by the University of Southern California's Center for the Digital Future, 61 per cent of adult Americans are concerned about privacy. Jesdanun, Anick. "Online Privacy Concerns Increase", LiveScience, 16 Jan 2008. http://www.livescience.com/technology/080116-ap-online-privacy.html

Annex C: Ubiquitous Computing Technology Examples

Following are a few additional examples, beyond those included in the body of the paper, illustrating different types of technologies being employed to enhance independent living for the elderly through ubiquitous computing.

Product/Description	Vendor	URL
QuietCare: Motion-based in-home monitoring	QuietCare	http://www.quietcare.com/
iShoe: Gait/balance monitoring	MIT, NASA	http:// web.mit.edu/newsoffice/2008/i-shoe-0716.html
Pill Pets: Play-based pill reminder	MIT AgeLab	http://web.mit.edu/agelab/projects_wellness.shtml
Smart Photo Frames: Photo frame that provides graphical information about well-being of elderly relative	Intel	http://www.intel.com/research/prohealth
CardioPocket: A wallet, which also serves as a 1-lead (rhythm strip) ECG transmitter for diagnosing heart rhythm disturbances.	SHL Telemedicine Ltd.	http://www.shl-telemedicine.com
Textro-Sensors: Physiological monitoring system for heart rate/respiration measurement.	Textronics Inc.	http://www.textronicsinc.com
Dementia Care: Nightlight and Bed Occupancy Sensors	Bath Institute of Medical Engineering	http://www.bath.ac.uk/bime/projects
FallSaver: Fall management program which utilizes a wireless position monitor inside a patch worn on the thigh, detecting motion change in a patient's leg before they become upright and in a full weight bearing position.	Your Choice Living	http://www.ycliving.com

Annex D: University Ubiquitous Computing Programmes

Programme Name/University	Country	URL
Aachen University Media Computing Group	DE	http://hci.rwth-aachen.de/tiki-index.php
CHAI Computer Human Adapted Interaction Research Group	AU	http://chai.it.usyd.edu.au
Coventry University Cogent Computing Applied Research Centre	UK	http://www.cogentcomputing.org/
Federal University of Campina Grande Embedded Systems and Pervasive Computing Lab	BR	http://embedded.ufcg.edu.br
Federal University of São Carlos Ubiquitous Computing Group	BR	http://gcu.dc.ufscar.br
Fraunhofer IPSI Institute AMBIENTE Lab in Human-Computer Interaction	DE	http://www.ipsi.fraunhofer.de/ambiente/english/index.html
Georgia Tech's College of Computing	US	http://www.cc.gatech.edu
Helsinki Institute for Information Technology Future Mobile and Ubiquitous Computing Research	FI	http://www.hiit.fi/fuego
Humboldt-Universitaet zu Berlin Interdisciplinary Center on Ubiquitous Information	DE	http://www.ubiq.hu-berlin.de
King's College London Centre for Telecommunications Research	UK	http://www.kcl.ac.uk/schools/pse/diveng/research/ctr
Lancaster University Computing Department	UK	http://www.comp.lancs.ac.uk/
Linköpings Universitet MDA, Department of Computer Science	SE	http://www.ida.liu.se/~mda
MIT's Things That Think consortium	US	http://ttt.media.mit.edu
Royal Institute of Technology Human-Computer Interaction Group	SE	http://hci.csc.kth.se
Tampere University of Technology Personal Electronics Group	FI	http://www.ele.tut.fi/en/research-en/personalelectronics
Trinity College Dublin Distributed Systems Group	IE	http://www.dsg.cs.tcd.ie
Ubiquitous Computing at Queen Mary	UK	http://www.elec.qmul.ac.uk/antennas/ubicomp.html
University of Aarhus Centre for Pervasive Computing	DK	http://www.pervasive.dk
University of Alicante IUII (University Institute for Computing Research)	ES	http://www.iuii.ua.es
University of Bath Mobile and Pervasive Computing	UK	http://www.cs.bath.ac.uk/pervasive/
University of Birmingham Pervasive Computing Research	UK	http://www.eee.bham.ac.uk/pcg
University of Bristol's Mobile and Wearable Computing Group	UK	http://www.cs.bris.ac.uk/Research/MobileWearable
University of Castilla Modelling Ambient Intelligence	ES	http://mami.uclm.es
University of Deusto MoreLab (Mobility Research Lab)	ES	http://www.morelab.deusto.es
University of Essex Intelligent Inhabited Environments Group	UK	http://iieg.essex.ac.uk
University of Fribourg Pervasive and Artificial Intelligence research group	CH	http://diuf.unifr.ch/pai/wiki/doku.php
University of Linz Institute for Pervasive Computing	AT	http://www.pervasive.jku.at

Programme Name/University	Country	URL
University of Madeira Department of Mathematics and Engineering	PT	http://dme.uma.pt/pt/index.html
University of Munich Embedded Interaction Research Group	DE	http://www.hcilab.org
University of Oulu Intelligent Systems Group	FI	http://www.ee.oulu.fi/research/isg
University of Oulu MediaTeam Oulu Research Group	FI	http://www.mediateam.oulu.fi
University of South Australia e-World Lab	AU	http://e-world.unisa.edu.au
University of Southampton Intelligence, Agents, Multimedia Group	UK	http://www.iam.ecs.soton.ac.uk
University of Stockholm Fuse Group	SE	http://www.dsv.su.se/fuse
University of Sussex research groups in informatics	UK	http://www.sussex.ac.uk/informatics/1-4.html
University of Technology Mobile Ubiquitous Services & Technologies Group	AU	http://www-staff.it.uts.edu.au/~peterl/mobilelab
Viktoria Institute Future Applications Lab	SE	http://futureapplicationslab.blogspot.com
Vrije University Security in Ubiquitous Computing	NL	http://www.few.vu.nl/~melanie/ubisec

Annex E: Industry-Based Ubiquitous Computing Programmes

Company	Country	URL
Alcatel-Lucent Ambient Services Group	FR	http://www.alcatel-lucent.com/wps/portal/!ut/p/kcxml/04_Sj9SPykssy0xPLMnMz0vM0Y_QjzKLd4x3NgvTL8h2VAQAqFj86w!!
CREATE-NET Pervasive Computing and Communications Group	IT	http://www.create-net.org/pervasive/
IBM Almaden Research Center	US	http://www.almaden.ibm.com/almaden/welcome.html
IBM India Research Laboratory	IN	http://www.research.ibm.com/irl/
IBM Ubiquitous Computing Lab	JP	http://www-903.ibm.com/kr/ucl/
Intel Research	US	http://www.intel.com/research/ubiquitous_computing.htm
Microsoft Research Asia Lab	CN	http://research.microsoft.com/aboutmsr/labs/asia/default.aspx
Motorola Pervasive Platforms and Architectures Lab	US	http://www.motorola.com/content.jsp?globalObjectId=6679-9298-9304
NRC Palo Alto Lab	US	http://research.nokia.com/research/labs/nrc_palo_alto_laboratory
NRC Pervasive Communication laboratory	CH	http://research.nokia.com/research/labs/nrc_pervasive_communication_laboratory
NRC Smart Spaces laboratory	FI	http://research.nokia.com/research/labs/nrc_smart_spaces_laboratory
Palo Alto Research Center, Inc. (PARC)	US	http://www.parc.com
Phillips Research	NL	http://www.research.philips.com/index.html
Ubiquitous ID Center	JP	http://www.uidcenter.org

Annex F: Elder Technology Programmes

Following is a brief listing of ageing research centres (associated with either universities or hospitals). This list is provided only as a representative illustration, where a specific centre has devoted work on technologies for senior citizens. Most universities organise their work in this area under broader engineering or health care programmes.

Programme Name/University	Country	URL
Bath Institute of Medical Engineering	UK	http://www.bath.ac.uk/bime
Curtin University of Technology Centre for Research on Ageing	AU	http://cra.curtin.edu.au
Indiana University Center on Aging and Aged	US	http://www.indiana.edu/~caa/
Lancaster University Institute for Health Research	UK	http://www.lancs.ac.uk/fass/ihr
MIT AgeLab	US	http://web.mit.edu/agelab
Quality of Life Technology Center (Carnegie Mellon/University of Pittsburgh)	US	http://www.qolt.org/
University College Dublin Centre for Technology Research for Independent Living	IE	http://www.trilcentre.org
University of North Carolina Institute on Aging	US	http://www.aging.unc.edu/index.html
University of Virginia Medical Automation Research Center	US	http://marc.med.virginia.edu