Technology for Ageing in Place

Introduction

Ageing in Place, enabling older people to remain at home in their community and avoid institutional care for as long as possible, has been the dominant paradigm for successful aging over the last decade. On the face of it, ageing in place is praiseworthy as an ideal state of affairs. Putatively, it offers the best prospects for quality of life among the older population while contributing to cost reduction for institutional care and relief of the financial and resources burden upon the geriatric healthcare system. Moreover, the prospect of transposing the primary point-of-care to the older person's home offers potentially substantial social and economic benefits to stakeholders, care recipients and providers alike. Nevertheless, various operational factors oppose the effective implementation of sustainable ageing-in-place infrastructures capable of supporting independent living by older people into advanced aged. To address these limitations, technological interventions, in particular information, computing, and communications technologies (ICT), are receiving increased recognition as the lynchpin to support successful ageing in place, through mitigating many of the complex practical challenges presented by independent living in the community. This article is an informal and synoptic review of the current state-of-the-art in ageing-in-place technologies, with an outlook to future possibilities with the advent of nascent technologies in the fields of robotics, smart sensors, neural interfaces, and artificial intelligence.

Objectives and Prerequisites

To establish the role of technology for ageing in place within proper context, it is necessary first to consider the foundational objectives and prerequisites, abstracted from any particular technological approach implementation, for a secure and safe environment designed for older people living independently in the community.

Fundamentally, the purpose of ageing-in-place technology is to create an ambulatory 'safe zone' within which the older resident's functional, physical, medical, and social needs dictate the appropriate type and necessary level of intervention the system will provide.

Viability of an ageing-in-place scheme that meets the above criteria depends upon various factors that control the ability of the care system to accommodate the changing functional needs of the older person, usually in the context of declining health and increasing physical and cognitive impairment. A minimally viable system requires the deployment of basic medical and social support services for monitoring and maintenance of physical and psychological wellbeing, safety, accessibility and mobility. Equally imperative are the logistical support requirements and constraints of the care provider, whether formal or informal, that can render economically sustainable an ageing-in-place programme.

When developing technological interventions, it is essential to consider both sides of the care service model (cared-for and carer). Monitoring technologies, in particular, exemplify this challenge. For example, a scenario in which technological means are available for detecting night-wandering of a cognitively disoriented person is ineffective if no protocols for human intervention or alternative mediated response are in place (Rowe, Campbell, Lane).

Independent Living with Declining Health and Frailty

As people get older, the majority acquire multiple and chronic medical conditions. Such age-related chronic co-morbidities often are accompanied by physical and cognitive impairments that are liable to affect, with varying severity, basic and instrumental activities of daily living. Beyond a certain threshold of impairment, independent living becomes unsustainable without physical support and intervention. There also is an increased risk of social isolation and loneliness that accompanies reduced mobility.

Management and treatment of multiple co-morbidities demands efficacious solutions to maintain adherence to strict medication regimes; this is particularly true for older citizens living at home lacking direct support from family members or a 24-hour caregiver. Typically, an older person is required to take three of more different medicines several times daily in order to maintain nominal health. Many of these medicines are in tablet form and the multiplicity of prescriptions for different hours of the day presents a formidable memory burden and inconvenience for the self-medicating patient. Frequently the result is non-adherence to the medication regime with the potential consequences of declining health, function, and shortened lifespan. The self-medication compliance deficit among older people has spawned a plethora of medication reminder and timed dispensing systems. Many devices of this sort are designed to operate independently of the health delivery service, relying significantly upon the consistent cooperation and vigilance of the patient. More advanced compliance solutions communicate with the care system's information network and in some varieties, integrated with the personal emergency response system (PERS). This networked feature is now appearing as part of comprehensive ageing-in-place support service packages offered by commercial suppliers, especially in the USA.

Falls Intervention

An effective ageing-in-place scheme must include adequate protocols to address the risk of falls and their prevention. Diverse technical solutions have been proposed and several developed to address the question of falls prevention among the older population. These range from appropriate design of the built and home environment and 'smart' orthotics that provide biofeedback or adaptive mechanical compensation to promote improved balance or alter the centre of gravity of a patient. However, notwithstanding a much improved and detailed understanding of the complex environmental, physiological and biomechanical processes involved, very few (if any) of these 'active' solutions have yet been demonstrated to be efficacious in statistically reducing the risk of falling.

Self-Neglect

Remote monitoring and detection for self-neglect is gaining increased attention in the research community (Bakkes, Morsch, & Kröse, 2011). Deployment of validated systems to monitor and respond to self-neglect, however, is minimal; several small or medium sized pilot installations have or currently are being evaluated in the USA, Europe, and Austral-Asia.

A key challenge to reliable detection of self neglect, in particular, is rooted in the diverse yet inter-related modalities in which the neglect process can occur, for example, malnutrition, personal care and hygiene, and self medication compliance. A holistic (multimodal) self-neglect monitoring protocol therefore is required in

order to provide effective monitoring and intervention protocols. Such protocols necessarily would include regular medical examinations (potentially implemented via a telemedicine service platform) and non-intrusive monitoring (as far as possible) of location, behaviour, and activities of daily living.

Smart Home Technologies

The socio-economic viability and sustainability of regional and national aging in place and assisted living care schemes (as an alternative to sheltered accommodation) is predicated upon appropriate and adequate information processing and communications infrastructures to support networking and embedded systems (Bronswijk, Kearns, Normie, 2007). Decentralization of healthcare provision is resulting in the migration from secondary and tertiary care frameworks towards enabled primary and community delivered care (Augusto, 2007). In the case of the older population, the shift is from in-patient and institutional care to assisted care for ageing in place. This is greatly facilitated by advances in information and communication technologies (ICT), exemplified by ubiquitous intelligent sensor networks that are dynamically responsive to a wide range of measured environmental, physiological, and affective parameters. Incorporation of these features into the domestic living environment is essentially what constitutes the concept of 'Smart Home'.

The "Smart" or "Intelligent" home environment has been extensively promoted in "techno" circles as the ultimate solution for the older person living independently and has been accompanied by more than its fair share of hype. The putative goal of the smart home in the ageing-in-place context is to enable older citizens to age in place with autonomy, security, dignity, and reasonable quality of life, whereby the subject's medical status and welfare is constantly, yet unobtrusively, monitored and functional assistance for home management and personal motility provided as needed. Conceptually, the smart home is required to monitor and evaluate the physiological, cognitive, and emotional status of the subject, and respond accordingly. In functional terms, a smart home is equipped to deliver advanced technology-based services to its users via a variety of installed devices and systems, usually networked via an executive control hub (a decision-support computer server that may be located in the home, or communicate remotely from a commercial service provider's premises).

Potential benefits include: enhanced safety and security (for example, by behaviour and activity monitoring and provision of emergency assistance when an imminent harmful situation is determined), environmental control responsive to the user's medical status, control of lighting and home appliances to provide networked assistive technology support for basic and instrumental activities of daily living (ADL/IADL). Notable recent implementations of smart homes systems include creation of semi-autonomous supervised environments for people with mild cognitive impairment.

The degree of success of smart home applications ultimately relies upon the extent to which their design and implementation follows a model that empowers elders, making them active participants in the healthcare process and in the monitoring of their condition rather than passive recipients of care services. (Demiris, 2008).

The essential elements comprising a smart home environment are: Sensors, Communications, Actuators, and User interfaces. Sensors, systems and applications are coordinated and supported and by server-based computer software applications known as 'middleware'.

User control of an integrated smart home system is accomplished through a variety of interfaces, including existing home appliances already familiar to older adults, such as the telephone, television, and music entertainment centre. But increasingly, a new class of experimental user interfaces are being introduced that employ voice and gesture recognition, and also remotely sensed physiological signals such as body temperature, pulse, and even patterns on brain electrical activity (see below in "Future Directions").

To concretise the smart home concept and indeed the preceding discussion on health maintenance, consider the following scenario. Miriam, a widow in her mid-eighties, still lives in the house where she raised her family. Miriam takes daily medication for osteoporosis, diabetes, and atherosclerosis. The latter condition is responsible for a noticeable decline in Miriam's cognitive function and she is increasingly forgetful and disorientated. Miriam's children live overseas and she refuses to enter institutional care or sheltered accommodation. With the help of local authority grants, Miriam's house has undergone some structural modifications to help maintain her independence, including a stair lift and grab bars in the bathroom. Last year Miriam subscribed to a community alarm service and she wears an emergency

response button on the wrist (when she remembers to put it on). Six month ago, Miriam volunteered as a subject for a smart home project run by the local university. Several items of technology were recently installed in the house. These include microphone and vibration sensor fall detection sensors embedded in the floor of the bedroom, kitchen and bathroom. Miriam also now has an upgraded to the community alarm, which is connected to the fall detection system just described. In the bedroom, pressure sensors have been inserted under the mattress; these automatically cause night lights distributed between the bedroom and bathroom to illuminate, when Miriam get out of bed during the night. As with the fall detection system and community alarm, information from the bed sensors are wirelessly routed to the TV set-top box, which in turn is connected via ADSL to a 24-hour call centre. Wall-mounted television flat panel screens in the bedroom and kitchen also are routed wirelessly to the set-top box.

In the kitchen, the refrigerator door has been fitted with a sensor which logs when and how frequently the door is opened. The cold water faucet also has a sensor monitoring the volume of water used. If the faucet is not opened at least twice in a 12-hour period, an automatic alert is flagged at the call centre.

Retrofitting Technology

A significant impediment to provisioning technology for ageing-in-place facilities is that older people's homes often are structurally unsuitable or unprepared for the straightforward installation of smart-home systems and devices. Adaptation can be a complex and costly affair, frequently requiring structural modifications to accommodate sensors and actuators. New building regulations for accessibility and ICT infrastructure do not address the problem when buildings, often as old as the resident, are considered. This situation is problematic to greater or lesser degree according to country and region, and national or municipal building regulations (Johansson, Josephsson and Lilja, 2009). Another contributing cofactor is the lack of mature technical standards both for harmonised interfaces and interoperability of devices and products from disparate manufacturers. Various industry-led initiatives are in the progress to redress this, including KNX (a pan-European collaborative standard for home and building control[1].

Usability and Acceptability

It has been established through numerous studies (e.g., Gentry 2009 and Kaye et al., 2011), that technology for ageing in place requires at least the following three attributes from the perspective of the user, as prerequisites for usability and acceptability:

- Unobtrusiveness
- Familiarity
- Choice - optional override and control by the user

The attribute of 'unobtrusiveness' is typified in systems that are not visually or otherwise apparent during the everyday activities of the subject. Examples are miniature sensors embedded in the home building structure, furniture, utilities, kitchen appliances, telephone apparatus, entertainment systems, and even clothing. A wirelessly networked array comprising environmentally embedded sensors can provide a comprehensive health and welfare monitoring capability for the older resident without he or she having to be constantly aware of its existence.

Familiarity of surroundings is particularly important in the context of the older person ageing in place with cognitive decline. Unfamiliar features impinging within the home environment are liable to elicit confusion and anxiety from a subject with mild cognitive impairment (MCI) or early stage dementia. Therefore, familiar objects may be co-opted into a technologically enabled living environment for ageing in place, which might include a standard telephone handset incorporating internal modifications for enhanced functionality, such as being intelligently networked into a personal emergency response system (PERS). The telephones (typically placed in the bedroom, living room, and possibly bathroom), can be configured as the platform for a host of situation monitoring systems, communicating information (appropriately filtered and formatted) to the remote call centre or caregiver's terminal device (e.g. PDA or iPhone). Television receivers, with the addition of a modified set-top cable/satellite decoder, incorporating a steerable videocam module, can provide interactive communication capabilities, such as videoconferencing with caregivers and family members. Functional usability factors, however, are insufficient to ascertain the feasibility or appropriateness of an ageing-in-place programme. The cultural backdrop is equally important when determining whether a technology-led strategy will be accepted and used effectively by the older beneficiary (Lindly, Harper, and Salen 2008).

Ethical Considerations

As technological costs fall, and assistive technology becomes more affordable and easier to use, we are likely to witness an increased range of available products and services, and larger numbers of older people utilizing them. However, smart home technologies for ageing in place may also result in increased or exacerbated social isolation.

Yet, the development of an ethical framework within which to evaluate the appropriateness of ageing-in-place technologies is proceeding somewhat behind the newly introduced. This is partly owing to the accelerating rate of progress in technological innovation and shorter lead-time between proof of concept and commercial availability. But, it is also due to the often unanticipated nature of ground-breaking, so-called 'disruptive' technological advances, which emerge to shatter previous paradigms about the social role and scope of technology. The measure of success of ageing-in-place applications ultimately will rely on the extent to which their design and implementation follows a model that empowers elders, making them active participants in the healthcare process and in the monitoring of their condition rather than passive recipients of care services. (Demiris, 2008; Mordini, 2010).

Future Directions

A plethora of smart home and ageing-in-place support applications, currently in development at university, government, and industrial research centres around the globe, is rapidly advancing the field through the sustained market introduction of more powerful, more versatile, more intelligent, and more affordable ageing-in-place technological interventions. Leading the field are multidisciplinary research consortia formed under the aegis of the European Commission. Key shared-cost research initiatives are being carried within the EC's Seventh Framework Programme (FP7) on the themes of "Ageing Well in the Information Society", "e-Inclusion"[2], and "e-Accessibility"[3]. Another EC supported initiative is "Ambient Assisted Living" joint programme (AAL)[4]. Many of the projects in these programmes concern the creation of intelligently responsive living environments, embedded with activity and health-monitoring sensors, and voice and video mediated guidance systems for the older resident (Wadhwa & Wright, 2010). Several of the projects are investigating the role of autonomous homecare robots. Results from several of FP7 (and earlier FP6) projects already have been validated in pilot installations and are expected to reach the market during the present decade.

Personal Hygiene

Several groups, working independently, have created prototype restrooms and toilets equipped with an array of biosensors designed to measure parameters such as urine and stool production and biochemical composition, and frequency of evacuation. Various metabolic and health status factors that may be diagnosed and monitored in this manner include nephritic, hepatic, and endocrine function; in particular, indications of dehydration, malnutrition, diabetes, and haemorrhage can be detected (Coughlin, 2010). Other interesting developments in hygiene management provide gentle guidance (through artificial intelligence scene pattern recognition and synthesised voice interaction) to cognitively impaired elders while washing hands (von Bertoldi et al, 2008).

Home Service Robots

In a smart home ageing-in-place environment, mobile or stationary robotic systems are envisaged to operate autonomously, when required, but will be federated to a distributed intelligent smart home network; in other words, exchanging information with other ageing-in-place systems, whether fixed sensor nodes or various communication and actuation systems (e.g., security, heating, ventilation, entertainment). In such an arrangement, the robot responds contextually to the status of the older resident interacting with his or her environment.

Owing to the mobile attributes of most service robots, they possess more degrees of freedom for performing adaptive tasks for caregiver functions. However, the possibility for malfunction and potential danger to the human subject also is present. Consequently, the design of home service robotic systems requires considerable vigilance in respect of fail-safe and security features; this requirement is especially pertinent with respect to old and frail human subjects (Franchimon & Brink, 2009).

Robots with affective-response capability have recently entered the market. Japan pioneered this field a decade ago through the development of robotic pets and further research in this direction has taken place in Europe (Heerink, et al., 2010). More recently, companies

such as Alderbaran Robotics (France), have introduced human-form "android" robots such as 'Nao', that are responsive to voice, eye-gaze, and gesticulation (Heinrich & Wermter, 2011). Currently, several national and international ageing-n-place technology collaborative projects involving robots of this type are in progress. Examples are FLORENCE (Multi Purpose Mobile Robot for Ambient Assisted Living)[5]; KSERA (Knowledgeable Service Robots for Aging)[6]; and SRS (Multi-Role Shadow Robotic System for Independent Living)[7].

Emotional Engineering

Notwithstanding endogenous medical causes, social isolation experienced by many older people living alone is likely to be a contributing factor to depression, anxiety, and other possible symptoms of clinical psychosis.

Well-being monitoring systems are responsive to the emotional (affective) state of the subject by detecting signs of depression or agitation through, for example, pattern recognition algorithms for gestures, facial expression, and movement activity (Such et al., 2006). Affective systems currently being researched employ a variety of interventions, that by various stimulatory means attempt to ameliorate episodic depression and anxiety. These include the modulation of temperature, humidity, ambient lighting, and the production of soothing music or recorded sounds, and even pleasant aromas. The affective system also, where appropriate, can automatically establish an audio or video link with a family member of caregiver. Additional modalities include the use of functional materials (which modify their properties according to environmental or system predicated conditions), for example to modify the visual scheme and ambience of the subject's surroundings, including the colour of wall coverings and the displayed images on "smart" picture frames.

Neural Interfaces

The last several years have witnessed the emergence of new modality for assistive technology, such as non-invasive brain-computer interfaces (BCI), as a novel means for people with severe motor or communication disability to interact with their surroundings and other people. BCI technology is based primarily on the detection and processing of tiny voltages generated in the cortex and measured by electrodes placed on the scalp. The technique, known as electroencephalography (EEG), for many decades was used routinely for clinical diagnostics and neurological research; it is only since 2006 that the technology began to move out of the clinical laboratory into consumer applications. Consumer level brain-computer interfaces are starting to be introduced into home-based rehabilitation support with remote point of care. To be sure, BCI technology for practical applications on a wide scale still is in its infancy, but recently the domain has received a boost through the market introduction of low-cost consumer equipment aimed at the computer games and entertainment sector. Several companies have created special research editions of their products, which are now being harnessed for use in disability and rehabilitation applications. The capabilities of these devices are being investigated for several practical applications, including operation of virtual keyboards for text communication and the control of smart home appliances, such as TV, lights, and even powered wheelchairs. The European Commission, through its "Seventh Framework Programme" has directed substantial funds to support collaborative research by international consortia developing applications for older citizens, using BCI controlled environments. Such projects include the control and reduction of neurological tremor, such as in Parkinson's and MS sufferers (Grimaldi & Manto) and a means for emotional expression, social interaction, and environmental control for victims of cerebral trauma and stroke (Navarro et al).

Conclusions

The goal of technological intervention for ageing in place is to empower older citizens to live and socially engage with a maximum degree of autonomy, safety, security, and dignity. Technology potentially can facilitate this objective by furnishing the means and infrastructure to monitor the older citizen's medical status and welfare, while appropriately and flexibly responding to situations requiring human assistance and support. Technology also can assist in activities of daily living through automation of household functions and accessibility of the living environment for improved mobility throughout the home.

Drawing together the main threads concerning proposals for implementing technology for ageing in place, several key issues are apparent. First, technology has the potential as a powerful solution for successful independent living. Second, the ethical implications and

protocols are not yet adequately clarified; in particular, there is risk of overreliance on technology to supplant appropriate human intervention, thereby exasperating a condition of social isolation by the technology beneficiary. Third, looking to the future, technological advances are proceeding at an exponential rate, with new 'disruptive' technologies being introduced in rapid succession. Consequently, it is increasingly difficult to establish firm baselines upon which to benchmark the social and functional value of new ageing-in-place support technology-based systems and services. Nevertheless, few probably would disagree that the role of technology for successful ageing in place is paramount and merits high priority on the research agenda.

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NOTES

[1] http://www.knk.org
[2] http://ec.europa.eu/information_society/activities/einclusion
[3] http://www.eaccessibility.org
[4] http://www.aal-europe.eu
[5] http://www.florence-project.eu
[6] http://ksera.ieis.tue.nl
[7] http://srs-project.eu

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