Nocturnal Sensing and Intervention for Assisted Living of People with Dementia

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1. Introduction

Research on Ambient Assistive Living (AAL) technologies is capturing significant attention from the scientific community and attracting investment from relevant areas of public services like the healthcare sector and government.

Much of that research has been focused on the idea of the Smart Home as an extension of the social and health care services that can supplement the attention given by healthcare professionals, family, and friends. Smart Homes systems are based on the deployment of technology within a house to increase safety and health by deploying sensors and actuators which allow the system to detect when help is required and provide some assistance.

‘Sensors’ allow us to measure some aspect of reality. There are a variety of sensors to be considered like those that detect levels of specific substance, movement, pressure, biometric information, etc. A Smart Home system can detect that help is required because there is an explicit request on behalf of an occupant or because the information gathered from the sensors suggests that. The system may then decide to act on this using ‘actuators’, i.e., devices that act upon the environment. Examples of actuators can be speakers, monitors, printed diagnosis by a machine or an SMS delivered or a voice call to a carer.

Most of the contributions reported in the technical literature focus on the most active period of the day (daylight time) because that is their interest or because they assume the night time will be well covered by the same technology and the same associated procedures. Our project NOCTURNAL (Night Optimised Care Technology for UseRs Needing Assisted Lifestyles) assumes that the night period and daylight periods of the day are different enough to require separate analysis [McCullagh et al., 2009].

This chapter explains the technological infrastructure of NOCTURNAL within the context of sensing and actuation used in AAL (Section 2), highlights the peculiarities of assisting people in the hours of darkness (Section 3), reflects on the consequences to society of the AAL associated technology and explains how those elements have been taken into account to define the infrastructure that is being developed in our project (Sections 4 and 5).

2. Overview of Sensing in Healthcare

Ambient Intelligent (AmI) systems for healthcare are being developed as part of the fundamental shift from hospital-centred to home-centred models of care within the health service. This development is very timely with the need for a new healthcare system that can cope with an increasingly aging society [WHO, 2005].

Ambient Intelligence systems can be defined as "*A digital environment that proactively, but sensibly, supports people in their daily lives.*" [Augusto et al., 2007] Ambient Intelligence systems are supported by Smart Environments, physical environments enriched with sensing and actuating devices. This combination provides a platform to develop autonomous semi-intelligent behaviour exhibited by systems like smart homes [Cook et al., 2009].

A significant catalyst which has prompted AmI-supported healthcare has been the rapid development and expansion of the sensor market combined with the affordability of technology and gadgets. A full range of small, reliable and non-intrusive sensory equipment is readily available and can be easily installed into any environment. The challenge is to develop software, which utilises data from these sensory devices and actuates a help response within the sensory environment, this constitutes a specialized application of the traditional architecture of intelligent systems being developed in the last decades, see Fig 1.

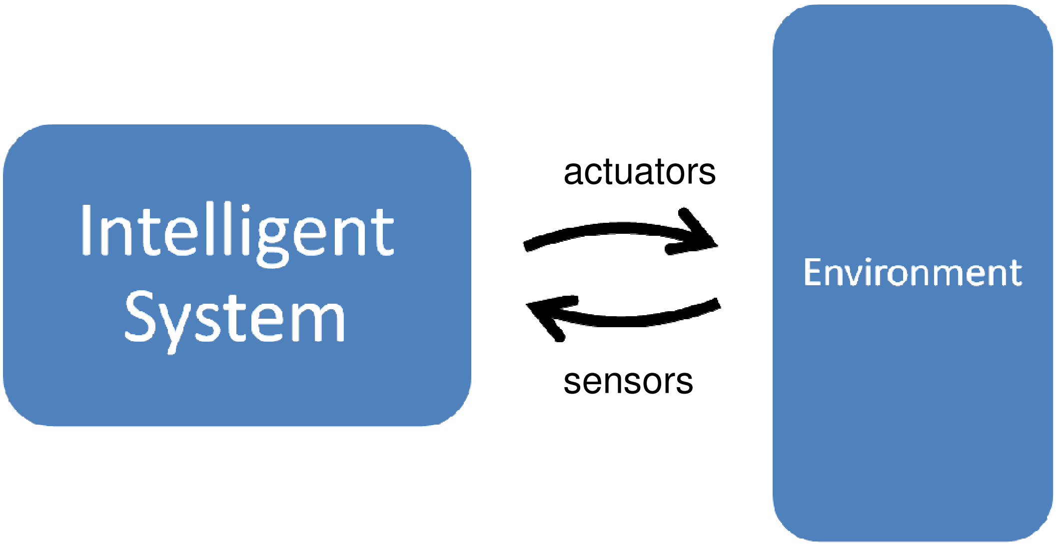

Fig. 1: Diagram to illustrate the passing of event information to the intelligent system which actuates an appropriate action back into the Environment.

In essence, an enriched environment of sensors and other electronic devices networked together, can act as a 'personal aid'. The personal aid can respond accordingly to each scenario based on either real time events alone or by analysing previous collected data sets and actuate a response which benefits the users within their environment. Increasingly, these systems are developed through Multiagent Systems (MAS), autonomous programs that perceive changes in the environment (for example, a Smart Home) and can act upon it.

There are three main types of sensors used to measure such conditions, as illustrated in Table 1. Of these types there are also many versions which use different sensing principles and/or may operate within predetermined ranges.

Table 1: Sensor types, examples, utilized for and target settings

Sensor Type	Examples	About	Used for	Special Settings
Signal Emission	Magnetic switches/exit sensors	Used on doors	Tracking movement from room to room	Size, distance range
	I-Button[ib].	Information tag	Access to computers, buildings etc	
	ultrasonic,	Echoes radio/sound waves against objects	Distance and location measurements, detecting movement	
	light dependent resistor (LDR)	Voltage driven circuit measure	Measuring light levels in an area	
	Radio Frequency Identification tags (RFID)	A traceable signal	Tracking local movement	
	Passive InfraRed sensor (PIR)	Detects movements	Detecting movement	
	Wireless sensors	Wire free, run on batteries.	Detecting movement	
	Electrical	Measure currant	Monitoring appliances	
	Global Positioning Satellite systems (GPS)	Satellite picks up location	Tracking and guidance	
Pressure	Bed Occupancy	Measures presence, movement and pressure	Analysing sleeping quality and patterns	Numerical range, Weight distribution
	Pressure mats	Mats with a pressure sensor to detect presence	Detecting movement	
	piezoresistive pressure,	Measure pressure		
	Digital air	Detect air	Detect leaking gas	

	pressure sensor, digital barometric pressure sensor	changes	etc	
	Thermostats	Measures temperature	Detecting changes in room temperature	
Motion (based on natural forces)	Mercury tilt switch	Measuring stability levels	Ensuring devices such as wheelchairs remain flat on the ground	
	Accelerometers	Measure speed and directional movement	Detecting loss/deterioration in balance and falls	

Numerous sensors exist to aid the delicate issue of tracking. These include RFID, GPS, ultrasonic, PIR's and Pressure mats. RFID tags have been commonplace in research projects for tracking participants [Altus et al., 2000; Arcelus et al., 2007; Miura et al., 2008]. The tags work by transmitting a unique identification on a radio frequency which is picked up by strategically positioned readers. Within healthcare active RFID tags which contain a battery and transmit signals autonomously predominate to ensure continuous 24hour monitoring. The use of RFID tags has been mainly limited to the hospital and nursing home environments. A more advanced version of tracking location is by GPS. GPS satellites broadcast signals from space that GPS receivers use to provide a latitudinal, longitudinal, and altitudinal coordinates. By the process of triangulation, the location of any person carrying a GPS device can be pin-pointed. This type of tracking has been used for people who suffer from mental illnesses such as amnesia or dementia but have the physical ability to lead an active life in the community [Shoval et al., 2008]. This form of tracking is reliant on the client being in possession of a GPS receiver. This can come in the form of a hand held device or a chip attached to a piece of clothing [Lin et al., 2006]. PIR sensors form the basis for most home based tracking systems. PIR's work by detecting the movement of heated objects (in most cases people) in a non-obstructed field of vision. Originally they were commonly used for intruder alarms and for outdoor security lights but have now been integrated into the healthcare system as a method of detecting movement activities and wellbeing for vulnerable elderly in hospitals [Noury et al., 2008] or living at home [Lee et al., 2007].

Motion detection is a distinct area within tracking. The purpose of motion detection is not always to determine where people are going but more so physical attributes such as presence. Motion detectors include some of the previously mentioned sensors as well as pressure sensors, light sensors, accelerometers, cameras and mercury tilt switches. Pressure mats have found application in beds to monitor presence [Chong and Kumar, 2003] and on floors to monitor movement activities of wandering or balance [Srinivasan et al., 2005]. Most bed sensors comprise a pressure strip that monitors pressure and provides a Boolean response i.e. in/out of bed. Floor mats can contain many different pressure points each measuring differences of force exerted. The output can be interpreted as a simple presence or provide more information, such as direction, walking patterns or size of pressure area to notify stability or if someone has fallen [Redfern et al., 1997]. An accelerometer is an electromechanical device that measures acceleration forces, useful for detecting instances of trips, falls or sudden jerk actions. Accelerometers have been used to monitor people with the propensity to fall although other healthcare options include measurement of heart activity [Haskell et al., 1993] and epileptic seizures [Tormans et al., 2007]. Cameras and microphones have been used in more controlled experimentation, mainly due to the ethical issues surrounding imagery devices. Visual representation from cameras can take different modalities. Cameras facilitate tracking using heat sensing or by area defined tracking [Zhou and Hu, 2004], and hence provide more function than PIR's. A Mercury Tilt Switch is a switch which allows or interrupts the flow of electric current in an electrical circuit. It is dependent on the switch's physical position or alignment relative to earth's gravity, or other inertia. Tilt switches has been used to retrieve information such as posture i.e. how long a person spends upright, sitting or lying down [Digorry et al., 1994, Lewis et al., 2001] or monitoring mobility devices such as wheelchairs to detect incidents where the mobility device was at an unnatural position indicating the likelihood of an accident or that help may be required [Galligan et al., 2003].

RFID tags have not been limited to the field of tracking; they can also be used as a method for identification. Nurses using a personal digital assistant (PDA) equipped with a portable RFID reader could check patient identification (ID) emitted from the RFID against a database before administering any medications [Bacheldor, 2007]. Another identification tag is the I-button. It is used as an ID tag, almost like a key card for people to use to access computers, lifts, buildings etc. The information contained in the button would actuate an appropriate response from an associated device after being scanned. Even though it is relatively small like a pendant, it can prove troublesome as it needs to be carried around and short range detection means the I-button must be placed close to its associated sensor [Davidson et al., 2003].

Other types of sensors are used to monitor physical situations such as heart conditions. Photodetectors are sensors of light energy. Light Dependent Resistors (LDR) work using a resister which changes in resistance according to light intensity. Within healthcare they have been used to measure heart activity by receiving light emitted radiation from a diode clipped onto an ear lobe. The LED converts blood vessel pressure into an electronic signal [Livreri et al., 2008]. Smart garments have been created with the capability to monitor vital signs and human posture by using electro active polymer actuators [De Rossi et al., 2003]. Indeed the development of actuating fabrics for detecting vital signs and motion has been previously investigated [Carpi et al., 2001; De Rossi et al., 2002; Mazzoldi et al., 2002]

Wireless sensors provide greater mobility and range. They are cheaper to install with no need to hardwire and as a consequence reduces danger of trips and falls [Goldberg and Wickramasinghe, 2003]. An added advantage is the ability to attach more devices to current setups without the need to physically disturb an environment [Wickramasinghe and Mishra, 2004].

As previously stated sensors combine together to form a network with multiple readings forming the basis for actuating an appropriate response. There are many examples of multi-functional sensor inputs, which combine well together to create a smart environment, such as Vigil [Holmes et al., 2007] which proves the ability and employability of such systems.

[Chen et al., 2006] highlighted the need for a comprehensive approach to the programming and managing sensor and actuator applications. [Hill et al., 2000] proposed the need for an overall system architecture and a methodology for systematic advance.

3. Peculiarities of Nocturnal Sensing and Interventions

There is a significant body of research that has described the needs of people with dementia and has produced solutions to address those needs using information and communication technologies (ICT). Key examples of such research include the ENABLE and COGKNOW projects. In the ENABLE (Enabling Technologies for People with Dementia) project, the effect of assistive devices to support memory, to provide pleasure and comfort, and to facilitate communication (calendar, medicine reminder, lamp, locator, gas cooker monitor and picture phone) among people with dementia with regard to their quality of life, and the burden on their carers was assessed [Adlam et al., 2003]. In the more recent COGKNOW work, the aim was to develop a system to support people with dementia in different aspects of their daily life including remembering, maintaining social contacts, performing daily life activities and feeling safe [Davies et al., 2009]. Each of these projects focused on the needs of people with dementia, but primarily during the hours of daytime. This is a natural area of need for people with dementia with an emphasis on supporting people as they interact and are most active in daily life.

It can be argued that the needs of people with dementia at night time have not received a similar degree of research effort in terms of ICT research involving telecare and telehealth services. Certainly their needs can be very different from daytime needs but they are equally if not more important [Carswell et al., 2009].

Firstly, the environment at night is very different. The person with dementia will be more likely to be in an environment where disorientation is more likely and natural due to low light conditions. Secondly, the person with dementia is more likely to be confused and disorientated as they awaken, either naturally as they awake from sleep as we all do, or if they are exhibiting ‘sundowning’, where the behaviour of people with dementia changes as the evening and night falls [Scarmeas et al., 2007]. Older people generally experience changes in their sleeping behaviours. This includes going to sleep early but awaking earlier as well, having more fragmented sleep patterns, suffering from insomnia, and from sleep apnoea, which is “increasingly seen among older people and is significantly associated with cardio- and cerebrovascular disease as well as cognitive impairment” [Wolkove et al., 2007]. People with dementia may also be likely to ‘wander’ often causing distress to themselves and their carers when they ‘elope’ from their room and building, sometimes requiring the intervention of the emergency services to locate them [Hermans et al., 2007]. Thirdly, the person with dementia is more likely to be alone, or not have as immediate access to carers as during the daytime. This can cause any stress and anxiety experienced by the person with dementia as they awake in the dark to be significant and to increase unchecked and more rapidly than would otherwise be the case if a care was with them.

These three issues of environment, the situation of the person with dementia and the access to caregivers set the background for enumeration of the needs of people with dementia and their carers during the night hours. The use and role of sensors and actuators in supporting people with dementia and their carers during the night hours is markedly different from during daylight hours. This is because of a number of inter-related reasons.

There are fewer activities of living experienced during night time, and most of the activity is in the bedroom and bathroom therefore the complexity of the system to recognise the basic behaviours from data should not be increased. However there may be a paucity of data as activities at night time may be sparse, and the underlying purpose of the acts that generate the sensor data may be difficult to infer.

There is an important role in supporting the carer of a person with dementia during night time. This can be by providing an intervention that alleviates the burden of care on the carers enabling them to achieve un-interrupted sleep, for example [McKibben et al., 2005], or by assisting the carer in supporting the person with dementia by automating some tasks.

The person with dementia may have a much more pronounced and immediate need for help and support as they awake in an unknown, dark environment. While not an emergency, the sensors and actuators must be capable of creating an intervention that moderates the anxiety of the person with dementia rapidly.

Therefore, at night time the sensors conduct their activities as they would during day but less data would be available for comprehension compared to day time sensing. During night time the actuators have a different role to fulfil from day time in managing the lighting for the person with dementia in particular to provide illumination and lighted guidance to the bathroom and back. In addition to light, sound can play a more important role during night time than day time. In particular, the use of music as a therapeutic intervention has been shown to reduce anxiety of people with dementia [Aldridge, 2000]. Light and music together can provide powerful intervention capability, and it has been shown that there is significant reduction in restlessness immediately after people with dementia in care homes experienced multi-sensory environments through the use of lighting, tactile surfaces, meditative music and the odour of essential oils [Robinson et al., 2006]. Better lighting can also play an important role in reducing the risk of falls, in particular when people with dementia seek to go to the bathroom and back. Night time falls may be reduced by proper lighting, reducing nocturia, avoiding bedtime sedatives, and use of a bedside commode (if walking to the bathroom is unsafe) [Moylan and Binder 2007]. The Joseph Rowntree Foundation report [Kerr et al., 2008] made recommendations for home management of older people. These recommendations were to ensure that, where appropriate, relevant technology should be used, for example, guidance around noise, light, safety, silent call system, as well as to ensure that systems are in place for night staff to have all the equipment technology and facilities required to provide good night time care.

In summary, important requirements for nocturnal care of people with dementia are: (a) more specialised algorithms to infer behaviour from sparse data, (b) specially designed interventions, perhaps including music and video, that provide therapeutic support to people to reduce anxiety and (c) sophisticated guidance, perhaps through the use of lightning.

The NOCTURNAL decision making process is summarized in Figure 2. The system understands the environment through a variety of sensors. This data can be partially processed and acted upon locally through a local Decision Support System (DSS). The information is passed through the web to the NOCTURNAL server which stores the information in a Database. More complex Intelligent Data Analysis can be conducted there (possibly contacting the general server) and the result of that analysis can trigger actions of the system contacting healthcare professionals, carers and the house occupants (including PwDs). See more details in [Zheng et al., 2009].

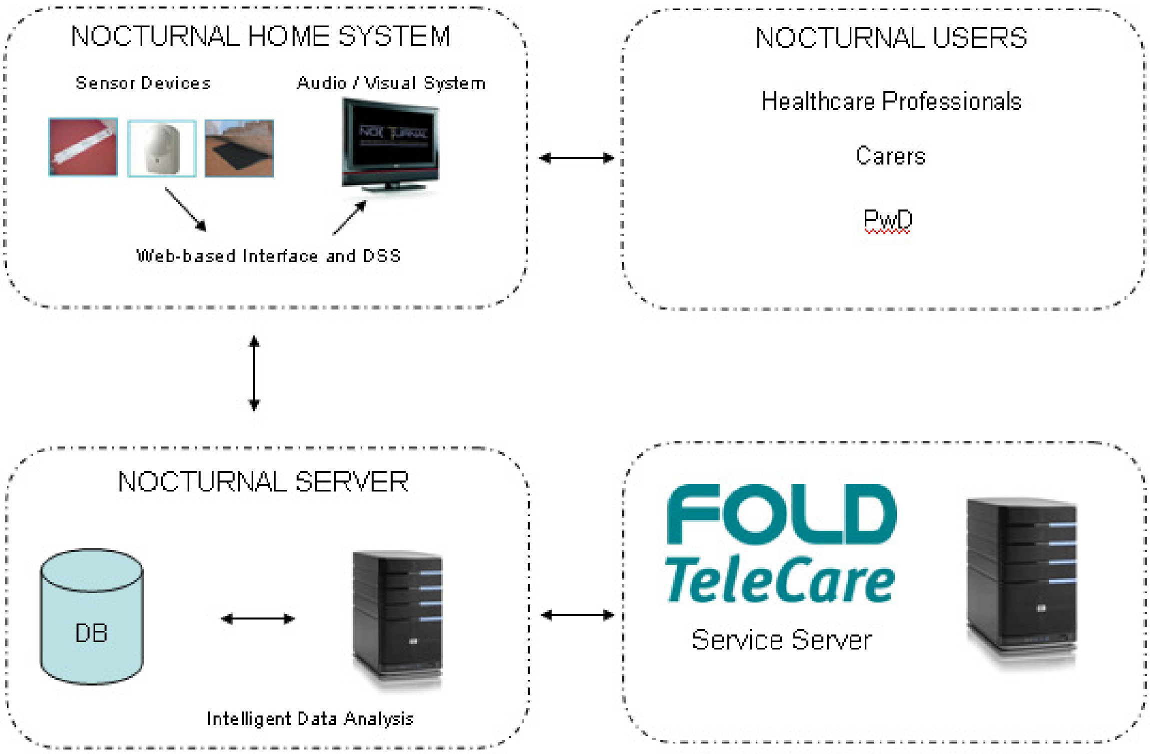

Fig. 2 Gathering of data and operational flow in NOCTURNAL.

4. NOCTURNAL Sensing/Intervention Platform

NOCTURNAL is currently set up to monitor every room within the person with dementia's home. At present the sensor range consists of PIR's, pressure strips, door contact and voltage monitors. The range of sensors is provided by Tunstall[1]. Tracking the client within their home is one of the most important goals of the project. Receiving data from any of the sensory equipment helps to pin point the location of a client which in turn will enable the system to serve the client better.

One PIR (Fig. 3A) is located in each room. The PIR's are located in a corner of each room where visibility restricted. This is to ensure that each PIR will not detect the client's movements in any other room. Pressure strips (Fig. 3B) are used as a bed sensor. There are two strips per bed. Each strip is approximately 1m long by 5cm wide. The strips are placed at different intervals and overlap in the middle (Fig. 3C). Door contact sensors (Fig. 3D) are used in a number of ways. The majority of door contact sensors are located in the kitchen area. At present door contacts are set to measure the opening and closing of the fridge, food cupboard and front and back doors. Voltage sensors (Fig. 3E) are connected to plug-in appliance and are used to measure usage frequency. As they are an adaptor they are easily installed. The adapter is pushed into the plug socket and the appliance is plugged into the adaptor. Appliances currently being monitored are a kettle and microwave. All sensory equipment is attached to a ROM box (Fig. 3F) which collects the data in CSV format where it is sent off to a secure server. Whenever an emergency is triggered, the

[1] http//www.tunstall.co.uk

ROM box puts out or receives a call from the healthcare team at Fold Telecare, who provide current home healthcare to elderly people in Northern Ireland.

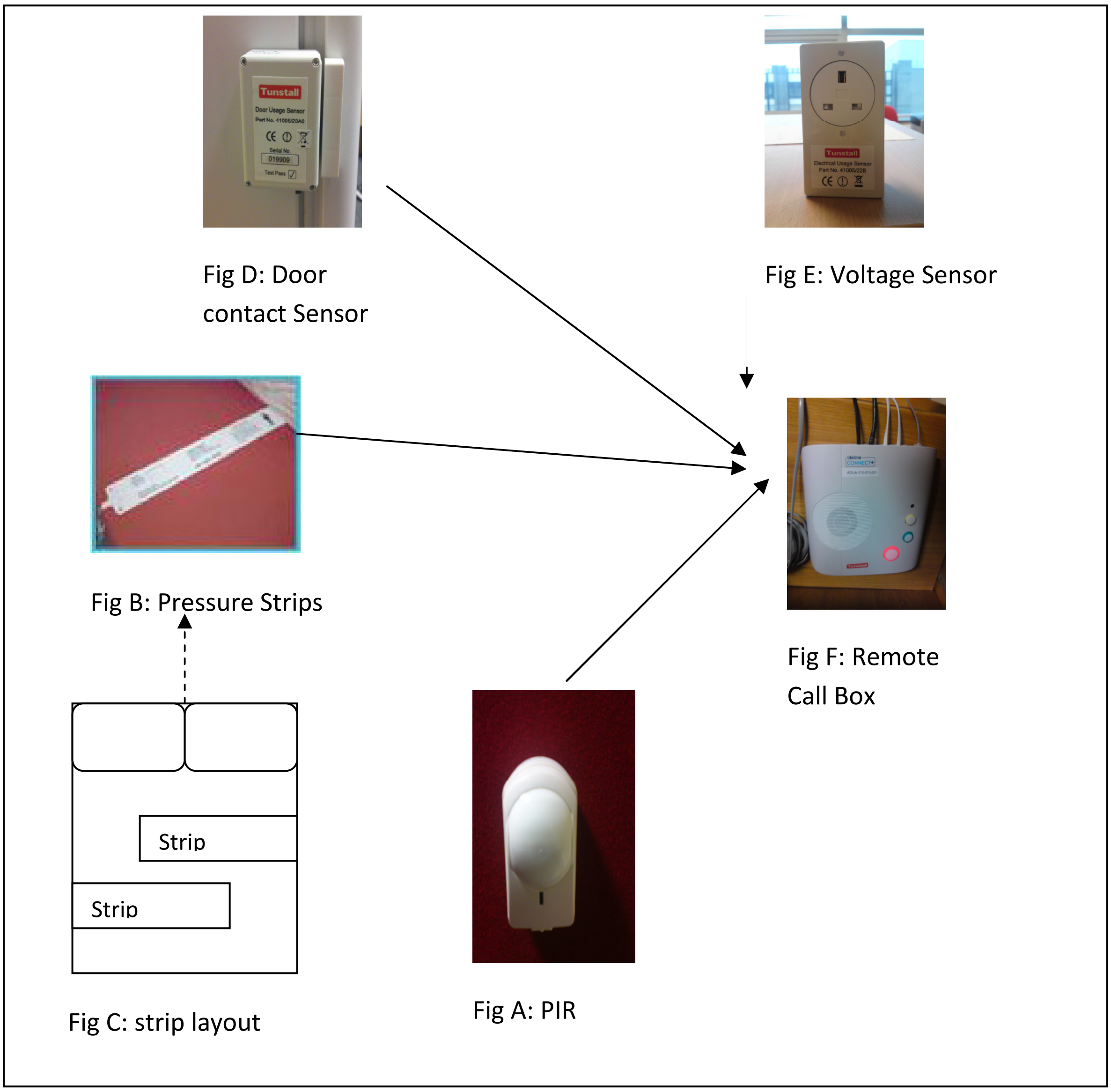

Fig 3. Data collection to support algorithms providing intelligence throughout the home.

The aim of the completed network will be to have a sensor enriched environment which will aid the client by introducing ambient control mechanisms throughout the house. Whatever the client decides to do at night they will be aided in a number of ways. The new system will build upon the current setup and provide additional features. Figure 4 illustrates the overall NOCTURNAL architectural. The same types of sensors will continue to be used in the future developments; the intuitive use of these sensor readings will carry greater functional outcomes.

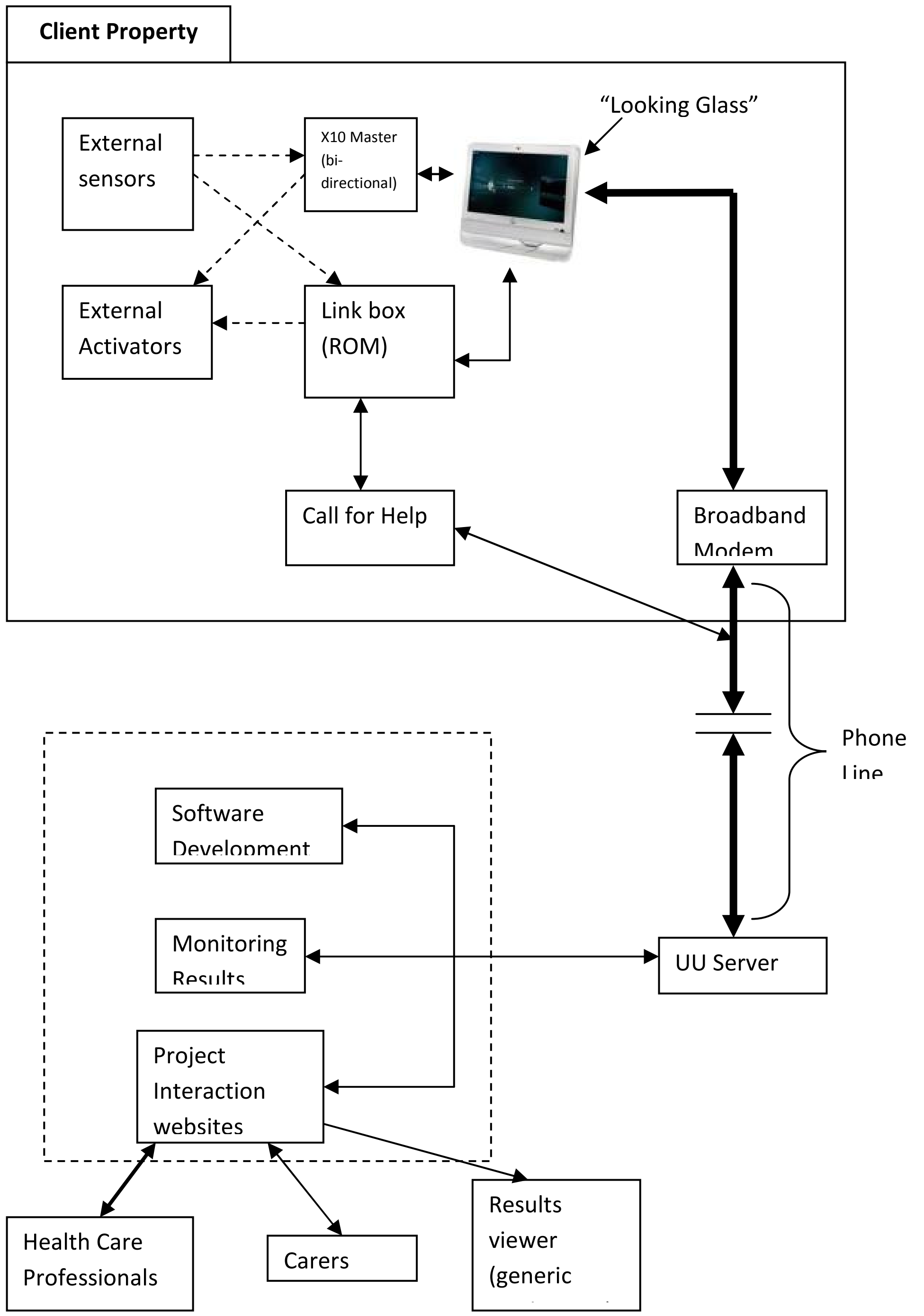

Fig 4: Complete Nocturnal Architecture

Some of the additional features will focus around providing greater guidance. Smart sensing will help automatically control the lights in a number of beneficial ways subject to conditions. Firstly it will ensure any areas the client wanders into lights up. Not only will the new room light up but it will also maintain a lit pathway back to the safety of where the client ought to be. More complicated lighting guidance algorithms will be developed to also encourage clients to follow a logical path when needed, for example lighting the way to the bathroom to ensure the client receives less intent to wander off to another location instead.

A primary goal of NOCTURNAL will be to encourage good sleeping habits. One of the AmI features NOCTURNAL will aim to assist with is encouraging the client to experience a regular day/night pattern. A combination of bed and PIR sensors will detect wrestles sleep and Nocturnal will actuate combative measures such as raising light levels and/or playing low level music. Studies have shown varying degrees of success when applying these techniques [Sixsmith and Gibson, 2007; Ziv et al., 2007]. The intelligent reading of each situation combined with personal client knowledge will help actuate the correct solution for each individual, enabling them to return to sleep.

An important, multi functional feature for each dwelling will include an audio visual unit. This unit will form a type of Avatar with extra input received from the array of sensors located throughout the house. On the back end, the audio visual unit will be able to collect all the in-house sensor information and form a Decision Support Structure (DSS) using IA's to actuate the appropriate response. All the information collected can be exported to a main database which collects all the Nocturnal home data sets for Knowledge Management (KM), development of future global services and tailored services for individual clients which can be sent back into the local audio visual units in each home. One of the functions the unit aims to address is the encouragement of better cognitive ability. The unit will display pictures and play music for reminiscence therapy, which has also been proven to alleviate anger, confusion and tension [Wang, 2007; Woods et al., 2005]. Wireless speakers linked to the audio visual unit will be spread throughout the house to help facilitate better communication with the client. This will enable audio help in the form of guidance, help support and comfort, especially for those living at home alone. Examples include, verbal prompting when needed in the form of helpful hints when something is wrong like leaving the fridge door open, task completion e.g. washing hands after toileting, and recognition of scenarios e.g. It's 3am in the morning, the client needs to realise the time and that they should be trying to sleep.

Whilst the system will react with real time solutions based on real time sensor input and short term recorded pattern deviations, a tailored healthcare plan from professionals can be developed as a consequence of the sensory information gathered over much longer periods. This data will allow the healthcare professional to analyse information gathered with regards to the client's habits/rituals over varying timescales. From this they will be able to provide structured therapy sessions throughout the day, which can be brought to the client through the NOCTURNAL visual display unit and also inform intelligent agents with information which would enable them to provide better responses to the real time sensory data they receive within the clients home.

5. Addressing user acceptance

NOCTURNAL provides assistive technology, which aims at improving the quality of life of people with dementia, whilst at the same time preserving privacy. NOCTURNAL could pose a threat to personal dignity as data on activities of daily living, e.g. duration of sleeping, wandering and toileting activities are sensed and evaluated with respect to what is 'normal'. An 'abnormal' activity will require the system to respond by alerting a carer, or possibly by the direct use of technology (lighting or audio prompt). Many see this as a 'Big Brother' or 'The Truman Show'[2] approach to healthcare. However change is inexorable. A September 2006 report to the Information Commissioner [Wood, 2006] provides the following commentary: "We live in a surveillance society. It is pointless to talk about surveillance society in the future tense. In all the rich countries of the world everyday life is suffused with surveillance encounters, not merely from dawn to dusk but 24/7."

NOCTURNAL addresses concerns by adhering to best practice ethics guidelines [Kluge, 2003], in the gathering of information from people and about people in order to identify which is the best way to provide assistance. As personal data will be collected, the assisted person and their carer will be informed and their consent sought. The assisted person will be able to have their information removed at any time, in accordance with Data Protection Act. Persistent data stored on computer systems will be anonymous and encrypted, protecting the personal data.

[2] The Truman show is a 1998 movie where the house and living environment monitors the occupant's every move and broadcasts to a receptive audience for entertainment purposes.

When asked about 'quality of life', older peoples' first preference is for "comfortable and secure homes" [Clark and Crissel, 2006]. Whilst accepting the potential for intrusion, the ethical dilemma is to weigh up the pros and cons of such an intervention.

A report from the Alzheimer's Society[3] states: "Keeping people with Dementia at home for longer, is normally the preferred mode for the person with dementia and their carer. Poor hospital care also had a negative impact on the people's dementia and physical health. The majority of people with dementia leave hospital worse than when they arrive with a third having to enter a care home as they are unable to return home."

Thus from a physical health perspective, people with dementia are better at home.
The NHS Confederation estimated that the cost of helping older people to cope with daily routines of living in their own homes is expected to treble to about £30 million by 2026. The current health and social care system will not be able to sustain this burden and there is political pressure to provide social insurance to fund elderly care. However, care also costs less at home.

The South Eastern Trust (Northern Ireland Health and Social Care) estimates that he cost of a week's nursing home care is £526 in 2009/10 and residential home is £418, whereas for a complex domiciliary care package of personal care tasks the costs fall

[3] www.alzheimers.org.uk/site/scripts/news_article.php?newsID=579 (accessed in November, 2009).

well below £300. The Trust will spend at least £60M on institutional care in 09/10 and thus there is a focus to contain such expenditure. Financial viability of care is recognised as an imperative across the world; indeed, the European Union (2001) stated that care for the elderly was dependent upon "…guaranteeing accessibility, quality and financial viability."

"At least £80 million a year and probably hundreds of millions could be saved if people with dementia are enabled to leave hospital one week earlier. Hospitals must commit to reducing the length of stay if we are to stop people with dementia deteriorating in hospital and lessen the chance of people being discharged to a care home" Alzheimer's Society.

Thus from a societal perspective, people with dementia are better at home. Society needs technology. Telemedicine solutions such as NOCTURNAL, can assist the person with dementia and their carer to sustain home based care, for as long as possible.

However there is also a danger that by increasing the amount of technology that we could contribute to social isolation; by reducing the need for interaction with carer, and health care professionals.

For example, NOCTURNAL assistive technology and telecare can:

- orientate the person that it is day time or night time
- switch on the lights automatically if the person gets up at night time
- alert a carer or monitoring centre that the person needs assistance.

This can potentially free carers to spend time with the person and it may enable a carer to get a good night rest, knowing that if the person gets up at night they will be alerted. Here technology obviously benefits the individual.

However the dangers as expressed by “atDementia”[4] are: “If assistive technology does not meet the individual needs and preferences of the person it may be ineffective or may even cause additional confusion or distress. For example, assistive technology and telecare may not be the answer if:

- the person switches off or unplugs the equipment
- the person is confused or distressed by any alarm sounds or recorded messages
- there are insufficient carers or care workers to respond to an alert.

Assistive technology on its own cannot provide human contact and personal care. Many older people experience loneliness and social isolation. Ideally technology should be provided as an addition to contact and care, not as a replacement.

All technology has the potential to work for good or bad, and as such we should not be surprised that assistive technology obeys the well-known ‘law of unintended consequences’ [Merton, 1936]. This can be ameliorated by involving users (people with dementia, carers and healthcare professionals) in the design process which is an approach in keeping with the TRAIL lab [Galbraith et al., 2008].

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[4] http://www.atdementia.org.uk Information on Assistive Technology for people with dementia, accessed in November 2009.

“TRAIL is focused on supporting this diverse set of stakeholders as we develop new technologies, research perspectives, processes and integrated service solutions that deliver real value to our users, the ageing people in the North of Ireland and further afield across Europe” [TRAIL 2009].

This approach has been adopted by NOCTURNAL to support user acceptance.

6. Conclusions

Recent developments in the assistive technology industry have made available a variety of technology which can be used to deploy a diversity of new applications closely related to people’s daily lives. Policy makers in the healthcare system have been also gradually moving the focus of healthcare from the traditional hospital focus to the home. At the same time, our society have become accepting of technology (mobile phones, GPS technology in the car, computers and Internet at home) that can be used to assist our daily lives. This confluence of factors has paved the way for the use of technology that can provide assistance at home to increase independence. This is particularly meaningful for older people, especially if they are affected by conditions like Alzheimer’s Disease.

This article reports on a system, NOCTURNAL, which is developing an innovative market solution to provide assistance during the hours of darkness to such segment of the population. A key part of the system relates to the accurate sensing and ‘understanding’ of activities developed by the people our system assists during the night. The sensing component is mostly based on off-the-shelf solutions. The ‘understanding’ component is crucial to beneficial use, and linked to concepts of data analysis, data visualization mining and AmI. One other important element of the system is the guidance offered by the system in the way of warnings and alarms to the call centre but also in the form of reassurance and help through multimodal interaction (audio-visual reminders, advice, orientation, etc.) that helps the house occupant to stay safe at home.

In developing the system, it has been necessary to weigh up the benefits and potential intrusion of such technology and always to ensure that the technology strives to act in support of user (person with dementia and carer) needs.

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References

Adlam, T., Faulkner, R., Orpwood, R., Jones, K., Macijauskiene, J., Budraitiene, A., (2004) The installation and support of internationally distributed equipment for people with dementia. *IEEE Transactions on Information Technology in Biomedicine* 8(3): 253-257.

Aldridge, D., 2000. *Music Therapy in Dementia Care*, Jessica Kingsley Publishers.

Altus, D.E., Mathews, R.M., Xaverius, P.K., Engelman, K.K., Nolan, B.A.D. (2000) Evaluating an electronic monitoring system for people who wander, *American Journal of Alzheimer's Disease and Other Dementias* 15(2), pp.121.

Arcelus,A.,Jones, M.H.,Goubran R.,Knoefel, F. (2007) Integration of smart home technologies in a health monitoring system for the elderly, *Proceedings of the 21st International Conference on Advanced Networking and Applications Workshops/Symposia* 2, pp.820–825.

Augusto, J. C. and McCullagh, P.J., (2007) Ambient Intelligence: Concepts and Applications. Invited Paper by the International *Journal on Computer Science and Information Systems*, volume 4, Number 1, pp. 1-28.

Bacheldor, B (2007). "RFID-enabled Handheld Helps Nurses Verify Meds." *RFID Journal*.

Carpi, F., Lorussi, F., Mazzoldi, A., Pioggia, G., Scilingo, E.P., De Rossi, D. (2001). *Electroactive polymer based skin and muscles for man machine interfaces*, MRS Fall Meeting. Boston.

Carswell, W., McCullagh, P.J., Augusto, J.C., Martin, S., Mulvenna, M.D., Zheng, H., Wang, H.Y., Wallace, J.G., McSorley K., Taylor B., Jeffers, W.P. (2009) A review of the role of assistive technology for people with dementia in the hours of darkness, *Technology and Healthcare,* V17, N4.

Chong, C., Kumar, S.P. (2003). *Sensor Networks: Evolution, Opportunities, and Challenges*, Proc. IEEE, vol. 91, no. 8, pp. 1247-1256.

Clark, H. and Crissel, J. (2006) *Addressing what older people want?* Policy context, Evidence submitted to the Older People's Inquiry into 'That Bit of Help', Edited by Norma Raynes, Heather Clark and Jennifer Beecham, Joseph Rowntree Foundation, www.jrf.org.uk

Cook, D.J., Augusto, J.C., Jakkula, V.R. (2009). Ambient intelligence: Technologies, applications, and opportunities, *Journal of Pervasive and Mobile Computing*, Volume 5, pp. 277-298.

Davies, R.J., Nugent, C.D., Donnelly, M., Hettinga, M., Meiland, F., Moelaert, F., Mulvenna, M.D., Bengtsson, J.E., Craig, D., Droes, R.-M. (2009) A User-Driven Approach to Develop a Cognitive Prosthetic to Address Unmet Needs of People with Mild Dementia, *Journal of Pervasive and Mobile Computing*, 5(3) pp. 253-267,

Davidson, A.J., Aujard, F., London, B., Menaker, M., Block, G.D. (2003). Thermochron iButtons: an inexpensive method for long-term recording of core body temperature in untethered animals, *Journal of Biological Rhythms* 18 (5), pp. 430–432.

De Rossi, D., Carpi, F., Lorussi, F., Mazzoldi, A., Scilingo, E.P., Tognetti, A. (2002). *Electroactive fabric for distributed, conformable and interactive systems*, IEEE SENSORS 2002 Conference (Hyatt Orlando, Kissimmee, Florida, 11-14 June 2002), pp. 5.1-6

De Rossi, D., Carpi, F., Lorussi, F., Mazzoldi, A., Paradiso, R., Scilingo, E.P., Tognetti, A. (2003). "Electroactive fabrics and wearable biomonitoring devices," *AUTEX Research Jounal*, V3, N4, pp. 180–185.

Digorry, P., Gorman, M., Helme, R. (1994). An automatic device to measure time spent upright, *Clinical Rehabilitation*, 8 pp.353–357.

Galbraith, B., Mulvenna, M.D., Martin, S., McGloin, E., Living Labs: Helping to Meet the Needs of Ageing People? In: Mann, W.C., Aging, Disability and Independence - Selected Papers from the 4th International Conference on Aging, Disability and Independence (2008), IOS Press, Assistive Technology Research Series, Vol. 22, pp. 105-118, ISBN 978-1-58603-902-8.

Galligan, C., G. Morose, J. Giordani, (2003) *An Investigation of Alternatives to Mercury Containing Products*, Lowell Center for Sustainable Development. Lowell, MA.

Goldberg, S. and Wickramasinghe, N. (2003) *21st century healthcare – the wireless panacea.* The 36th HICSS, January 6–9, Big Island, Hawaii.

Haskell, W. L., M. C. Yee, A. Evans, and P. J. Irby. (1993). Simultaneous measurement of heart rate and body motion to quantitate physical activity. Medicine and Science in Sports and Exercise, 25: pp.109–115

Hermans D.G., Htay U.H., McShane R. (2007). "Non-pharmacological interventions for wandering of people with dementia in the domestic setting". Cochrane Database *System Review* (1): CD005994

Holmes, D. Teresi, J.A., Ramirez, M., Ellis, J., Eimicke, J., Kong, J., Orzechowska L., Silver S. (2007) An evaluation of a monitoring system intervention: falls, injuries, and affect in nursing homes, *Clinical Nursing Research* 16, pp.317–335.

Kerr, D., Wilkinson H., Cunningham, C., (2008) *Supporting older people in care homes at night*, Joseph Rowntree Foundation

Kluge, E-H. (2003) *A handbook of Ethics for Health Informatics Professionals*, British Computer Society Health Informatics Committee. Endorsed by International Medical Informatics Association.

Lee, S.W., *et al.*, “A Healthcare System for Elders Living Alone Using Low-Power Wireless Sensors,” in *Proc. of Fourth Int. Conference on Information Technology and Applications*, Harbin, China, January, 2007.

Lewis, M.J., Reilly, B., Houghton, L.A., Whorwell, P.J. (2001). Ambulatory abdominal inductance plethysmography: towards objective assessment of abdominal distension in irritable bowel syndrome. *Gut* 2001; 48, pp.216–20.

Lin, C.C., Chiu, M.J., Hsiao, C.C., Lee, R.G., Tsai, Y.S. (2006). Wireless health care service system for elderly with dementia. *IEEE Transactions on Information Technology in Biomedicine*;10:696–704

Livreri, P., Di Blasi, G.M., Terrazzino, G. (2008). IrDa-based Heart Frequency Monitoring for Mobiloe Healthcare Applications, Sensors and microsystems:, *Proceedings of 10th Italian Conference*, pp.105-110.

Mazzoldi, A., De Rossi, D., Lorussi, F., Scilingo, E.P., Paradiso, R., (2002). Smart textiles for wearable motion capture systems. *Autex Research Journal*, V2 N4:199-203.

McCullagh, P.J., Carswell, W., Augusto, J.C., Martin, S., Mulvenna, M.D., Zheng, H., Wang, H.Y., Wallace, J.G., McSorley, K., Taylor, B., and Jeffers, W.P. *State of the Art on Night-Time Care of People with Dementia.* Proceedings of the conference on Assisted Living 2009, published by IET, London, 24-25 of March, 2009.

McKibbin, C.L., Ancoli-Israel, S., Dimsdale, J., Archuleta, von Kanel, R., Mills P., Patterson T.L., Grant I., (2005) Sleep in spousal caregivers of people with Alzheimer's disease. *Journal of Sleep Research* 14(2):177-85.

Merton, R.K. (1936) The Unanticipated Consequences of Purposive Social Action, *American Sociological Review*, Vol. 1, No. 6., pp. 894-904.

Miura, M., Ito, S., Takatsuka R., Kunifuji, S. (2008). *Aware group home enhanced by RFID technology*, Proceedings of KES'08 5178, pp.847–854.

Moylan, K., Binder, E., (2006) Falls in Older Adults: Risk Assessment, Management and Prevention. *The American Journal of Medicine*, V120, N6, pp. 493.e1-493.e6.

Noury, N., Hadidi, T., Laila, M., Fleury, A., Villemazet, C., Rialle, V. and Franco, A. (2008). Level of activity, night and day alternation, and well being measured in a smart hospital suite, *Proc. 30th Annual Int. Conference of the IEEE-EMBS 2008*, pp. 3328–3331.

Redfern, M. S., Moore, P. L., Yarsky, C. M. (1997). The influence of flooring on standing balance among older persons, *Human Factors*, 39, pp.445 ± 455.

Robinson, L., Hutchings, D., Corner, L., Beyer, F., Dickinson, H., Vanoli, A., Finch, T., Hughes, J., Ballard, C., May, C., Bond. J., (2006) A Systematic Literature Review of the Effectiveness of Non-Pharmacological Interventions to Prevent Wandering in Dementia and Evaluation of the Ethical Implications and Acceptability of their Use, *Health Technology Assessment,* V10, N26, pp.1-124.

Scarmeas N., Brandt J., Blacker D., Albert, M., Hadjigeorgiou, G., Dubois, B., Devanand, D., Honig, L., (2007). "Disruptive behavior as a predictor in Alzheimer disease". *Archives of Neurology,* 64 (12): 1755–61.

Shoval, N., Auslander, G.K., Freytag,T., Landau, R., Oswald, F., Seidl, U., Wahl, H.,Werner, S., Heinik, J. (2008). The use of advanced tracking technologies for the analysis of mobility in Alzheimer's disease and related cognitive diseases, *BMC Geriatrics* 8, 7.

Sixsmith, A., Gibson, G. (2007) Music and the wellbeing of people with dementia, *Ageing and Society* 27, pp.127–145.

Srinivasan, P., Birchfield, D., Qian,G., Kidane,A. "Design of a pressure sensitive floor for multimodal sensing," in *Ninth International Conference on Information Visualisation*, July, pp. 41–46.

Tormans, D., Swinnen, T., Cuppens, K., Omloop, S., Geraets, B., Colleman, P., Claes, V., Ceulemans, B., Vanrumste, B. (2007) Nocturnal monitoring of pediatric patients with epilepsy based on accelerometers. Conference Proceedings of the 18th ProRISC Annual Workshop on Circuits, Systems and Signal Processing. Veldhoven, The Netherlands.

TRAIL (2009). *Technologies for Rurality, Ageing and Independent Living*, http://trail.ulster.ac.uk/, accessed Nov 2009.

Wang, J.J. (2007) Group reminiscence therapy for cognitive and affective function of demented elderly in Taiwan, *International Journal of Geriatric Psychiatry* 22(12), pp.1235–1240.

Wickramasinghe, N. and Mishra, S.K. (2004). ‘A wireless trust model for healthcare’, *International Journal of Electronic Healthcare*, Vol. 1, No. 1, pp.60–77.

WHO2005: *The world is fast ageing – have we noticed?* http://www.who.int/ageing/en Accessed November 2009.

Wolkove, N., Elkholy, O., Baltzan, M., Palayew, M., (2007) Sleep and aging: 1. Sleep disorders commonly found in older people, *CMAJ*. 176(9): 1299–1304.

Wood, D.M. (2006) *A Report on the Surveillance Society. For the Information Commissioner by the Surveillance Studies Network*, September 2006., www.ico.gov.uk, *accessed Nov 2009.*

Woods, B., Spector, A., Jones, C., Orrell M., Davies, S. (2005) Reminiscence therapy for dementia, *Cochrane Database Systematic Review* 2, CD001120.

Zheng, H., Carswell, W, Marin S., Mulvenna, M., McCullagh, P.J., Jeffers, P, Augusto, J, Wallace, J, Wang, H., Taylor, B., McSorley K. (2009) NOCTURNAL: Night Optimised Care Technology for UseRs Needing Assisted Lifestyles, *Proceedings of eChallenges e-2009 Conference*

Zhou, H.,Hu, H. (2004). *A survey—human movement tracking and stroke rehabilitation*, Tech. rep., CSM-420, Department of Computer Science, University of Essex, UK.

Ziv, N., Granot, A., Hai, S., Dassa A., Haimov, I. (2007) The effect of background stimulative music on Behavior in Alzheimer's patients, *Journal of Music Therapy* 44, pp.329–343.