Ambient assisted living systems for older people with Alzheimer's

A thesis submitted to Cardiff University in the candidature for the degree of the Doctor of Philosophy

By

Riyad Al-Shaqi

Cardiff School of Engineering,
Cardiff University
United Kingdom

May 2016

ABSTRACT

The older people population in the world is increasing as a result of advances in technology, public health, nutrition and medicine. People aged sixty or over were more than 11.5% of the global population in 2012. By 2050, this percentage is expected to be doubled to two billion and around thirty-three countries will have more than ten million people aged sixty or more each. With increasing population age around the word, medical and everyday support for the older people, especially those who live with Alzheimer's who can't be trusted for consistence interaction with their environment, attract the attention of scientists and health care providers. Existing provisions are often deemed inadequate; e.g.; current UK housing services for the older people are inadequate for an aging population both in terms of quality and quantity. Many older people prefer to spend their remaining life in their home environment; over 40% of the older people have concerns about having to move into a care home when they become old and nearly 70% of them worry about losing their independence or becoming dependent on others. There is, therefore, a growing interest in the design and implementation of smart and intelligent Ambient Assisted Living (AAL) systems that can provide everyday support to enable the older people to live independently in their homes. Moreover, such systems will reduce the cost of health care that governments have to tackle in providing assistance for this category of citizens. It also relieves relatives from continuous and often tedious supervision of these people around the clock, so that their life and commitments are not severely affected. Hence, recognition, categorization, and decision-making for such peoples' everyday life activities is very important to the design of proper and effective intelligent support systems that are able to provide the necessary help for them in the right manner and time. Consequently, the collection of monitoring data for such people around the clock to record their vital signs, environmental conditions, health condition, and activities is the entry level to design such systems. This study aims to capture everyday activities using ambient sensory

information and proposes an intelligent decision support system for older people living with Alzheimer's through conducting field study research in the Kingdom of Saudi Arabia within their homes and health care centres. The study considers the older people, who live with Alzheimer's in Kingdom of Saudi Arabia. Since Alzheimer's is a special form of dementia that can be supported in early stages with the ambient assistive systems. Further, the results of the field study can also be generalized to societies, which are interested in the mental and cognitive behaviour of older people. This generalization is related to the existence of common similarities in their daily life. Moreover, the approach is a generalized approach. Hence it can also be utilized on a new society which is conducting the same field study. This study initially presents a real-life observation process to identify the most common activities for these patients' group. Then, a survey analysis is carried out to identify the daily life activities based on the observation. The survey analysis is accomplished using a U-test (Mann-Whitney). According to the analysis, it has been found that these people have fourteen common activities. However, three of these activities such as sleeping, walking (standing) and sitting cover about 72% of overall activities. Therefore, this study focuses on the recognition of these three common activities to demonstrate the effectiveness of the research. The activity recognition is carried out using a common image processing technique, called Phase-Correlation and Log-Polar (PCLP) transformation. According to results, the techniques predicted human activities of about 43.7%. However, this ratio is low to utilise for further analysis. Therefore, an Artificial Neural Network (ANN)-based PCLP model is developed to increase the accuracy of activity recognition. The enhanced PCLP transformation method can predict nearly 80% of the evaluated activities. Moreover, this study also presents a decision support system for Alzheimer's people, which will provide these people with a safe environment. The decision support system utilises an extended sensory-based system, including a vision sensor, vital signs sensor and environmental sensor with expert rules. The proposed system was implemented on an older people patient with 87.2% accuracy.

ACKNOWLEDGEMENTS

First, I thank my allah, that helped me for this work, also I take this opportunity to express my great debt of gratitude to my supervisors Dr Monjur Mourshed and Professor Yacine Rezgui, for their excellent guidance, support and invaluable patience throughout this work. My deep thanks to Dr Mohammed Alshehri from department of geriatrics and family medicine and community for three years provided great support and technical assistance.

I would like to thank the Armed Forces Hospital in Riyadh Saudi Arabia, Prince Sultan city for old people for giving me an opportunity in pursuing a PhD study. My thanks also to the research office staff of the Cardiff University School of Engineering.

I would also like to thank the technical staff of the Cardiff University School of Engineering, particularly to Dr Baris Yuce, and Professor Omar Kasule from King Fahd Medical City in Riyadh.

Finally I would like to extend my thanks to my family, especially my wife and my parents, for their support and encouragement.

DECLARATION

This work has not previously been accepted in substance for any degree and is not concurrently submitted in candidature for any degree.

Signed …………………………… (Riyad Al-Shaqi) Date………….……………….

STATEMENT 1

This thesis is being submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy (PhD).

Signed …………………………… (Riyad Al-Shaqi) Date………….……………….

STATEMENT 2

This thesis is the result of my own independent work/investigation, except where otherwise stated. Other sources are acknowledged by explicit references.

Signed …………………………… (Riyad Al-Shaqi) Date………….……………….

STATEMENT 3

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organizations.

Signed …………………………… (Riyad Al-Shaqi) Date………….……………….

LIST OF PUBLICATIONS

The author is currently publishing the following journal publications:

- Al-Shaqi R., Mourshed M., Rezgui, Y. 2015, ‘Progress in ambient assisted systems for independent living by the older people’. accpeted for publication in journal of medical systems.
- Al-Shaqi R., Mourshed M., Rezgui, Y. 2015, ‘Towards independent living of people living with older people with Alzheimer’s: Behavioural Patterns’. (Submitted).

Conference poster:

- Al-Shaqi R., Mourshed M., Rezgui, Y. 2015, ‘Towards independent living of Alzheimer’s people in Saudi Arabia: Patterns of Daily Living and Features of Smart Homes’. The 8th Saudi Student Conference in UK, Queen Elizabeth II Centre, Westminster, London. http://uksacb.org/ssc8/ocs/index.php/8th/SSC/

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AALS Ambient Assisted Living Systems

3D Three-Dimensional

AAL Ambient Assisted Living

AD Older people with Alzheimer's

ADL Activity of Daily Living

AI Artificiel Intelligence

AIT Ambient intelligence technologies

ANN Artificial Neural Network

CAR Circadian Activity Rhythm

CRF Conditional Random Field

DFSA Deterministic Finite-State Automata

DLF Disabled Living Foundation

EEG Electroencephalogram

EMG Electromyography

EPR Erroneous-Plan Recognition

EU European Union

GERHOME Gerontological Smart Home Environment

GFR Ground Reaction Forces

GPS Global Positioning System

HMM Hidden Markov Model

HVAC Heating, Ventilation and Air Conditioning

ICC Information Collection Centre

ICT Information and Communication Technologies

KSA Kingdom of Saudi Arabia

MIT Massachusetts Institute of Technology

NFC Near Field Communication

OECD Organisation for Economic Co-Operation and Development

PASW Statistics Predictive Analysis Software (Former SPSS name)

PCs Picture Communication Symbols

PDAs Personal Digital Assistant

PS Physical space

QOL Quality of life

RFID Radio-Frequency Identification

ROI Region of Interest

SADA Saudi Association of older people with Alzheimer’s

SoC System on Chip

TAFETA Technology Assisted Friendly Environment for The Third Age

TV Television

UK United Kingdom

UN United Nations

UN DESA United Nations Department of Economic and Social Affairs

VS Virtual Space

WHO World Health Organization

WSN Wireless Sensor Networks

LIST OF SYMBOLS

Chapter 3.	
n	The sample size.
N	The total size.

Chapter 5.	
$I(x, y)$	The image intensity value on point (x, y).
$F(u,v)$	The Fourier transformation of the image $I(x, y)$.
$F^{*}(u,v)$	The complex conjugate of the $F(u,v)$.
$(\Delta x, \Delta y)$	The amount of the translation on *(x, y) directions*.
ρ	The radial distance of the position (x, y) in polar domain.
θ	The position angle of the (x, y) according to the reference plane in polar domain.
α	The rotation angle according to the original image.
λ	The scaling factor for the given image.
$M(u,v)$	The magnitude of the $F(u,v)$ in Fourier domain.

Chapter 1: Introduction

This chapter presents a comprehensive overview of the study aim, objectives, and contributions, as well as a brief discussion of the thesis structure, including the aim of each chapter. Information Technology (IT) applications in home assisted living have been used extensively for occupational monitoring and tedious task support. While many techniques are reported for the older people, significant gaps exist for the support of dementia people. The role of integrated sensor network and image processing techniques in activity recognition is introduced as a novel method for designing Ambient Assisted Living (AAL) systems.

1.1 Motivation

Older people are the group of citizens who are ages 60 and over. Care services for the older people cost billions of dollars worldwide, primarily due to being heavily dependent on human supervision and the lack of technology to support them to live independently (Barton 2009). As illustrated in Figure 1.1, discrepancies exist in expenditure for older people care services worldwide. This is could be related to a lack in wealth, modern technology applications in health care services or lack of correct information in developing countries.

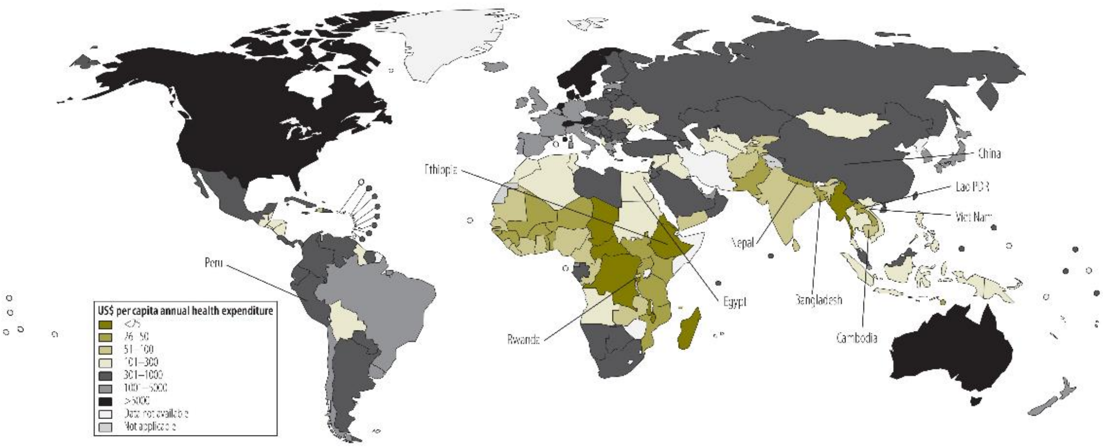

Figure 1.1: Total health expenditure per capita worldwide, 2012.
(Adapted from World Health Organisation (2014) http//gmapservero.who.int).

In the UK for example, current housing services for the older people are insufficient in meeting the needs of the growing population of senior citizens (Metz, 2000). A number of studies have shown that the most hazardous situation for the older people is falling and this commonly occurs within their own homes (Lam et al., 2015, Pohl et al., 2015, Ramsey et al., 2015). An individual patient, who lives with older people with Alzheimer's, costs about £27,647 to the UK economy (Albeiruti and Al-Begain 2014). Furthermore, this amount increases with unexpected incidents such as falling, as one of the more common problems associated with these people and can lead to serious consequences including fracture, internal bleeding and life threatining conditions (Buchner and Larson 1987). Providing assistance to the older people who is living with cognitive impairments, such as older people with Alzheimer's to live independently can be achieved by monitoring their activities constantly inside their homes (Tunca et al., 2014). This technique can provide comprehensive support for older people living alone and emulates the service provided in care homes; where human intervention is only provided when it is needed. One of the 21st century healthcare challenges is mainly related to how health practitioners can provide sustainable care to the growing number of the older people in their homes or in assisted unsupervised living environments (Ettinger et al., 2015).

There are various challenges that older people may face in order to create an independent life, such as: spending a great deal of time alone at home, reduced mobility, reduced social integration, difficulties with basic and trivial life needs, experiencing gradual loss of memory, and finally facing increased risks related to daily activities such as cooking, bathing, etc. Moreover, providing proper entertainment to the older people may improve the quality of their lives (Mahadevan et al. 2014) as it supports calm and safe feelings. For example, multimedia-enabled entertainment tools can promote effective treatment for those with memory problems (Jain and Singh

2014), which should be taken in consideration in designing ambient assistive living systems.

An Ambient Assistive Living (AAL) system is defined as an assistive system that achieves 'intelligent environments', aiming to compensate for predominantly age-related functional limitations of different target groups through the use of information and communication means (Steinke et al., 2012). At the same time it takes a charge of control and supervision services to achieve an independent life style (Pieper et al., 2010). In other words; AAL systems can be referred to as the concept, product, and services that combine new technologies and social information in order to improve the quality of life of the occupant(s). Designing effective intelligent AAL system inside the home environment that can provide monitoring, evaluation, and support for the older people and people with mental problems, is a challenging task as their responses are not easily predictable (Pollack 2005). An effective AAL system needs to achieve the following:

- Effective monitoring system able to recognize activities.
- Monitoring of people' environmental and vital signs conditions.
- Effective precaution knowledge-based decision support system (DSS).

Although several systems have been proposed to reduce possible risk for the older people, other people with mental and cognitive problems such as older people with Alzheimer's, still missing several issues, such as the quality of the data acquisition process, the accuracy of the system, the response time, and high system cost. These issues motivate researchers to develop cost effective and smart solutions using mobile technologies (sensors, actuators and micro-controllers) including existing smart solutions, such as Artificial Intelligence (AI) approaches, to provide rapid, replicable, and acceptable reasoning process under uncertainty and complex conditions (Nilsson et al., 2014). Moreover, additional challenges arise from the integration of sensor-networks, privacy, security, human-machine interaction, mobility, cognitive impairment, feature extractions, generalisation, and prior knowledge about the subject's condition (Bleda et al., 2014). To deal with this complexity, a contextualised methodology that combines both measurements and text information should be applied in order to have a better understating of the human actions observed. To contextualize the information a knowledge-based solution is often the most appropriate one (Yuce et al. 2015).

1.2 Research aims and objectives

The aim of the project is to develop an AAL system to meet the requirements of an ageing society and to support older people including older people with Alzheimer’s to live independently in their own homes.

The study focuses on older people who are 65 or over, as this age group is of particular interest to society in Kingdom of Saudi Arabia, due to requiring special attention in terms of life support from relatives or health professionals. Moreover, some people among this group have chronic symptoms, such as Alzheimer's or have physical disabilities that require help in food preparation, washing, putting on clothes, eating, and personal hygiene. This can be achieved by monitoring their behaviours and modelling their activity patterns using distributed sensory system around various locations in their homes combined with text information and a logical decision making system. Hence, the objectives of the research are to:

1. Understand the state-of-the-art of existing Ambient Assistive Living technologies to highlight gaps and recommendations from previous researchers;
2. Investigate the daily life and activities of older people including those with Alzheimer’s in order to identify opportunities and areas where ambient assisted living systems could contribute to their Independent living life style;
3. Engage with care providers and professionals to identify the requirements for independent living home design and associated systems;

4. Cross-reference (2) and (3) to develop a conceptual framework for an efficient AAL system that is able to support the older people including those with Alzheimer’s to live independently through performing activity recognition;
5. Develop a robust method for older people activity recognition using environment distributed sensors and image processing;
6. Validate the developed framework using realistic case studies.

1.3 Hypothesis and research questions

On the basis of the objectives mentioned above, this PhD thesis seeks to test the overall hypothesis:

'The non-intrusive AAL system can be developed which is able to meet the requirements of an involving ageing society and help older people including those with Alzheimer’s to live independently in their own homes’. To meet this requirement, four major research sub-questions related to the validity of AAL arise:

Question 1 (RQ1): What help can current ambient assisted technologies and older people support projects offer in providing ideas for an efficient support system for older people including those with Alzheimer’s ?

Answering RQ1 involves performing an extensive literature review for ambient assisted living technologies and research projects related to older people support.

Question 2 (RQ2): What are the common daily activities of the older people and those with Alzheimer’s?

Answering RQ2 involves performing patient observation in care homes and in their own homes to identify common daily activities during the day that are of interest for monitoring and requirements for support.

Question 3 (RQ3): What is the professionals' perception for independent living home and associated systems requirements of the older people including those with Alzheimer's?

Answering RQ3 involves performing distribution, collection, and analysis of structured survey questionnaire among professionals and care providers to capture their opinions.

Question 4 (RQ4): What are the elements of an effective AAL system that is able to support the older people including those with Alzheimer's to live independently?

Answering RQ4 involves combining patient observation and questionnaire analysis to develop a conceptual design for AAL system blocks that could meet the identified requirements of older people including those with Alzheimer's to live independently.

Question 5 (RQ5): What is the hardware and software requirement needed to develop an effective activity recognition system using distributed sensors and image processing techniques?

Answering RQ5 involves setting the hardware structure for an effective ambient sensors network, wearable vital signs sensors, vision monitoring devices, and image processing techniques to achieve robust activity recognition.

Question 6 (RQ6): How can the developed system be validated in a laboratory environment?

Answering RQ6 involves designing testing scenarios for evaluating the capabilities and performance of the developed system in a simulated laboratory environment emulating some activities performed by an older people or healthy performer.

The hypothesis of this research assumes that monitoring, modelling, and managing older peoples' activities including those with Alzheimer's, can be achieved. Hence, their independent life style can be achieved through designing and implementing an effective AAL system. Consequently, older people who give priority to living independently in their own homes can achieve their target independence (Winkler 2007).

1.4 Research justification

Older people who would like to continue to live in their own home, even sometimes alone without continuous supervision from others, are the segment of people who will benefit from the results of this research. This research will provide them with a comprehensive and effective assistive intelligent system that will enable them to achieve this target at the same time as feeling safe and having assistance from a data-based driven intelligent monitoring system that contains their personal life style profile, as well as achieving direct assistance from other supporters and family members if the situation requires so. Moreover, the subject's relatives will be able to organise their personal life in a better way through the trust that will be built with time in such technology, allowing them not to be commited to continuous monitoring of their beloved older people.

1.5 Thesis contribution

The thesis research contribution can be summarised as follows:

- Common daily activities found were counted as fourteen activities that need to be monitored continuously by the system to achieve the required level of support.
- Development of a framework for an effective AAL system.
- Develop computer vision techniques for non-intrusive activity monitoring.
- Implement the developed system hardware and software for testing purposes.

- Validation of the developed system through designing experimental test scenarios.

1.6 Structure of the thesis

The thesis is structured to cover seven separate sequential chapters. A brief summary of the contents of these chapters is as follows:

Chapter 1- Introduction: This chapter summarises the aims and objectives of the research, hypothesis, research questions, research method, and contribution. It presents an overview of the research subject and thesis structure as well.

Chapter 2- Literature review: This chapter presents an in-depth, critical review of ambient assisted living systems. It also covers the recently reported research projects related to ambient assisted living support. Literature publication selection is based on the overall aim of the thesis as outlined to highlight the gaps and recommendations in the current ambient assisted living systems that have been designed to support older people including those with Alzheimer's people.

Chapter 3- Research methodology: This chapter demonstrate the research philosophy, the tools used in the survey, and the ethical considerations adopted to carry out this research work.

Chapter 4- Requirements for an effective AAL system: This chapter presents the observations recorded in the case study of older people including those with Alzheimer's carried out in Saudi Arabia. It includes the developed questionnaire response results from caregivers and professionals, associated with extensive analysis, to highlight the main activities required for monitoring these systems and the perception of the professionals in relation to system design.

Chapter 5- Human action recognition using intelligent image processing techniques. In this chapter, human action recognition is performed using an image processing unit. It includes phase correlation log-polar (PCLP) transformation and Artificial Neural Network (ANN)-based PCLP transformation for human action recognition using real-time visual sensory information.

Chapter 6- This chapter includes the decision support system implementation for older people with Alzheimer’s validation using extended sensors and rule-based decision making using selected possible scenarios.

Chapter 7- Conclusion: This chapter presents the discussions, conclusion, contribution of the thesis, and suggestions for possible future research that can be built on the findings of this research.

There are three appendices for references; the first appendix contains a copy of the people’ observation survey form. The second appendix contains a copy of the professionals’ opinion questionnaire with their statistics and calculation methods. The third appendix contains four ethical approval forms, from the Cardiff School of Engineering, the medical services supervisors in hospitals, King Fahd Medical City in Riyadh, and from the faculty of medicine in Riyadh, KSA.

1.7 Summary

This chapter presents a brief summary of the study motivation, aims, hypothesis, objectives, and research questions. It also presents an outline of the seven chapters that construct the thesis dissertation.

Chapter 2: Literature review

This chapter discusses the societal challenges related to ageing population, the need for independent living by the older people, and reviews the state of the art on current AAL technologies that is oriented to provide assistance for older people. It provides older people demographic distribution around the world with an emphasis on the forecasted increase in their number as well as the cost of care support provided to them. It also provides a general background on the behavioural characteristics of older people including those with Alzheimer's in different stages. The chapter also provides details regarding the older people daily activities challenges that need to be addressed to implement efficient and effective support for this category of citizens.

2.1 Introduction

One of the challenges of an increasingly ageing population in many countries is the effective delivery of healthcare services, which is often complicated by the decline in their neurological conditions. Personal care of the older people is of great concern to their relatives, especially if they are living alone in their homes, where the possibility for unforeseen circumstances is high. The alternative to living in their own homes is simply moving them to nursing or care homes, where the cost is often high, which increases further if specialised care is provided at their place of residence. Enabling technologies for independent living by the older people; such as the Ambient Assistive Living systems (AALs) are considered as an alternative to enhance assistance provided to them in a cost-effective manner. In light of significant advances in tele-communication, computing, sensor miniaturisation and the ubiquity of mobile devices, end-to-end and autonomous intelligent ambient assisted living has now become a possible reality. The promise of such systems is the continuous and real-time monitoring of the environment and occupant behaviour using an event-driven intelligent system, thereby providing a facility for monitoring, assessment, and triggering proper assistance when needed. As a growing area of research, it is essential to investigate the approaches adopted in developing AAL systems in the literature to identify current practices and directions for future research and improvement. This chapter is, therefore, aimed at a comprehensive and critical review of the frameworks and sensors systems used in various ambient assisted living applications, focusing on objectives and relationships with a care and clinical perspective. In general, most frameworks focused on activity monitoring for assessing immediate risks, while the opportunities for integrating environmental factors for analysis and decision-making, in particular for the long term care, were often overlooked. Socio-cultural aspects such as divergence among groups, acceptability and usability of AAL systems were also overlooked. Also, there is a distinct lack of strong supporting clinical evidence in most currently implemented assisted living technologies. Moreover, the potential for wearable devices and sensors, as well as distributed storage and online access (e.g., cloud) are yet to be fully explored in this application domain.

2.1.1 Ageing population and demographic distribution

The older people population in the world is increasing as a result of advances in technology, public health, nutrition, and medicine (Beard et al., 2012, Aytac et al., 1999). Rising life expectancy and declining birth rates will continue to influence this significant shift in demographics around the world, although at a different pace (UN, 2013). People aged sixty or over were more than 11.5% of the world population in 2012. By 2050, this percentage is expected to be doubled, recording two billion, where thirty-three countries will have more than ten million people aged sixty or over each (Haub, 2012). The Organisation for Economic Co-operation and Development (OECD) forecasted that during the first half of the 21st century, its member countries would experience a significant increase in their older people population, as well as a steep reduction in their working-force population (OECD, 2005). For example, the percentage of the population aged 65 or over in the UK increased to 16% by 2009 and 40% of the country's population will be aged fifty or over by 2026 (Winkler et al., 2007).

Figure 2.1 illustrates the number of people aged 65 years or over, per hundred children under 15 years, in different regions in the world between 1950 and 2050. The ageing population in America and Europe is steeper compared to Africa. In Asia, the Chinese population is aging rapidly, due to the one child policy that the government enforces and the country's low mortality rate (Zhang and Goza, 2006). In the Middle East, the percentage of older people to young people is generally low compared to western countries. However, this moderate percentage of the aged population will increase throughout the region, with steep increase in countries with declining fertility and extensive development. By 2050, around 22% of the forecasted 1.1 billion people in the Middle East are expected to be of sixty years or over (UN DESA, 2012).

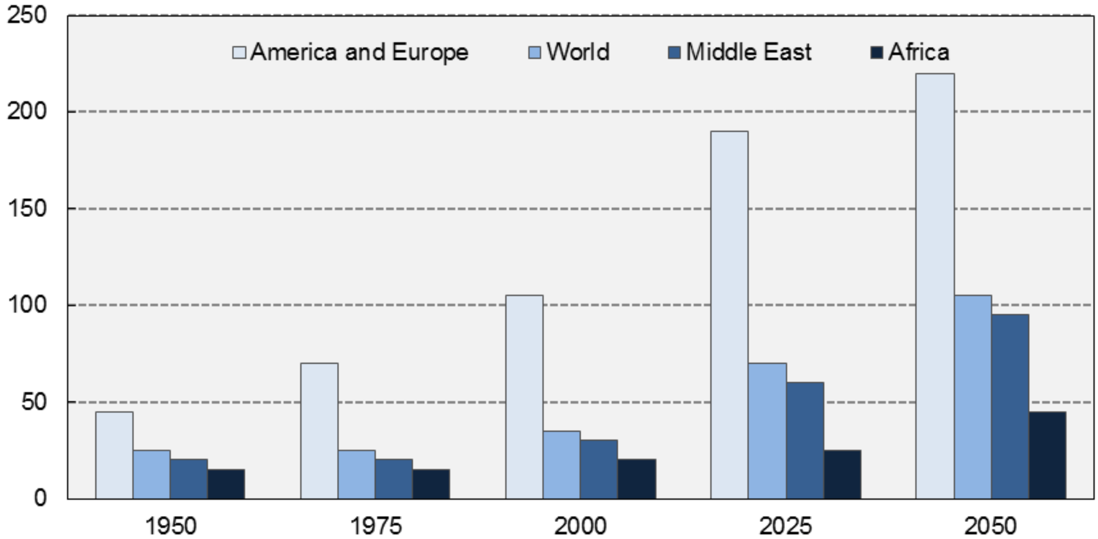

Figure 2.1: Number of people aged 65 years or over.
Per hundred children under 15 years. Source: (UN, 2012).

2.1.2 Alzheimer's characteristics

Dementia is a group of symptoms that affect mental tasks such as reasoning and memory performance. It is generally caused by various types of aging conditions, the most common of which is Alzheimer's. Alzheimer's is common among older people (Román, 2002). It is known as a neurological brain functions disorder that affects primarily older people in different ways (Vas and Rajikumar, 2001). It is not defined as a normal part of aging, although it could be the most common form of illness that affects this group of people and it gets worse over time (Mace and Rabins, 2011). Although symptoms can vary widely from patient to patient, the main problems the majority of people notice are in the form of forgetfulness, confusion, being lost in familiar places, misplacing things, or trouble with speech that may affect their proper performance at home or work. Some of symptoms of older people with Alzheimer's include confusion, short-term memory loss, problems with spatial orientation, personality drifting, and mood swings. In general, these symptoms are mild, and may not be noticeable to the persons themselves as well as to their relatives. Alzheimer's generally leads to cognitive impairment, communication problems, erratic behaviour, and loss of control over memory functions (Dupont, 2012).

2.1.3 Older people with Alzheimer's demographic distribution

Alzheimer's is related in general to age and is rising exponentially with it. Worldwide, the number of people ages 65 and over will jump from 169 million (14.2% of the current world population) to 287 million (equivalent to 24.7% of the forecasted world population) by the year 2050. Conservative estimates indicate that the number of people living with dementia problems in developed countries will increase to around 36.7 million in the year 2050, as a result of the modern life effect on older peoples' health. In the UK currently more than 800,000 older people living with Alzheimer's, while each individual care costs around £27,647 annually (Nourhashemi et al., 2001). Moreover, estimates indicate that the annual cost of caring for people with dementia in the UK will rise to nearly £50 billion over the next 30 years (Wancata et al., 2003, Health, 2009). In the Middle East, Alzheimer's people's number will increase over the next five decades, as a result of the increase in older people aged 65 and over (Katzman and Fox, 1999). In Saudi Arabia, there are around 50,000 older people living with Alzheimer's according to the Saudi Association of Alzheimer's statistics (Al-

Muhanna et al., 2011). This number is rapidly increasing, while their dependency on caregivers builds up with time, raising a lot of concerns in relation to the cost of care, diagnosis, treatment, and the impact within the country's conservative society culture (SADA, 2013).

2.1.4 Alzheimer's stages

According to the Alzheimer's Association report published in the year 2012, there are seven known clinical stages of older people with Alzheimer's. However, these stages often overlap and not every person experiences all of them (Association, 2012). The first stage is a normal stage, or a mentally healthy person. The second stage is known as normal aged forgetfulness, where persons over the age of 65 experience cognitive and/or functional difficulties. The third stage is known as mild-cognitive impairment, where the person experiences compromised capacity to perform functions, especially those related to work. The fourth stage is known as mild- Alzheimer's, where a decreased ability in complex daily life activities, such as preparing meals, becomes noticeable. The fifth stage is known as moderate Alzheimer's, where a decreased ability in proper self-clothing becomes noticeable. The sixth stage is known as excessive Alzheimer's, in which the ability to perform basic every day activities is compromised. The seventh stage is known as severe Alzheimer's, at which the patient requires continuous assistance with basic survival needs. Figure 2.2 demonstrates the characteristics of each of these stages.

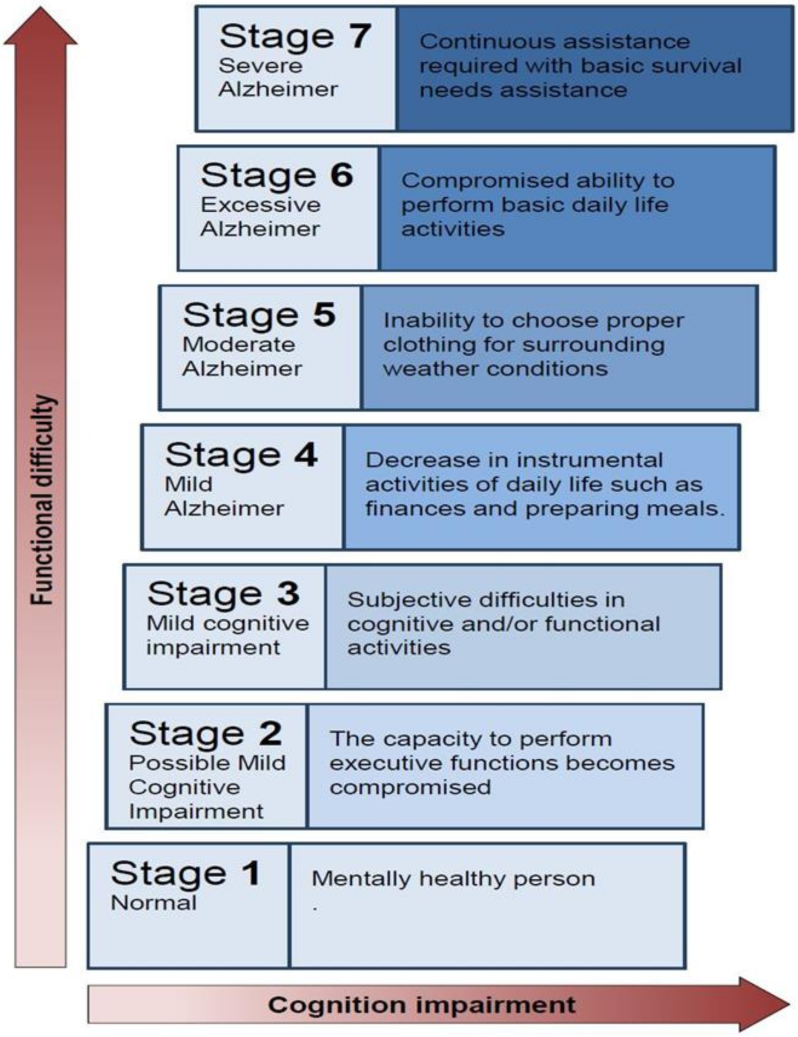

Figure 2.2: Relation between functional disability and cognition impairment.

2.2 Independent living of the older people

Nearly 40% of the world's older people population lives independently (UN, 2012). The majority of them are women, while studies indicate that many older people want to live in their home environment (Dwyer et al., 2000, Mba, 2013). Moreover, studies have shown that most of older people living with neurological problems give priority to living independently in their homes, although they are dependent on others for the management of their daily life (Chan et al., 2009). Over 40% of people have concerns about having to move into a care home when they become old and nearly 70% of people worry more about losing their independence or becoming dependent on others than on dying, according to the survey conducted by the Disabled Living Foundation (DLF) in 2009 (DLF UK, 2009). The differences in the percentage of older people living independently among developed and developing countries are significant, where older people who live independently represent around 75% in developed countries (UN, 2012). It is important to note that living alone or just with a spouse in developed countries may be regarded as economic independence, while in developing countries it maybe an indication of vulnerability (WHO, 2011), where the social norm expects the older people offspring to look after their parents in old-age. Therefore, home is a crucial focal point for ensuring independent, healthy, and socially inclusive living, where it should be designed and equipped with the right infrastructure to support and host a variety of services that older people may require to meet their needs (Shikder et al., 2010). Moreover, easy access to the social environment (healthcare facilities, care support, supermarkets, cultural centres, opportunities to socialise, etc.) whether from homes, or integrated into homes through adapted digital technologies, is important to offset potential challenges such as isolation, loneliness, and associated physical and mental declines (Alm et al., 2009, Tamura et al., 2004).

2.2.1 Level of support required for dementia people

An increased ageing population brings a number of challenges for society (UN DESA, 2012, Kwan, 2012). Prolonged ageing may increase neurological conditions, such as cognitive decline, chronic conditions, constrained physical activity, hearing and vision problems (Shikder et al., 2012, WHO, 2006). To support older people's stay in their own homes while keeping their quality of life, various assisted living technologies have shown positive effects for older peoples' daily life support (Bharucha et al., 2009). However, several limitations on the practical implementation of these assisted living technologies have been identified. This is due to the importance of providing satisfactory clinical evidence for improvement as a result of introducing these technologies, as well as the level of end- users' acceptance of them. (Blaschke et al., 2009, Demiris and Hensel, 2008, or and Karsh, 2009). To address these problems, it is essential to share the knowledge about current achievement in assisted living technologies by both developers and healthcare professionals.

2.2.2 Ambient assisted living systems (AAL)

One of the key healthcare challenges is related to the provision of sustainable care to the growing number of older people in their own homes or in an assisted living environment. The promise of such applications is the continuous real-time monitoring of the environment and occupant behaviour using an event-driven intelligent system, thereby providing a facility for monitoring, assessment, and triggering of required assistance when needed. These enabling technologies, along with preventative measures for healthy and active ageing, are generally considered as the way forward from the perspectives of health and social care. The rationale is that healthy and active ageing can support independence that enables the older people to live well even with long-term health conditions (Oliver et al., 2014).

Significant advances in telecommunication, computing and sensors miniaturisation, as well as the ubiquity of mobile and connected devices, are influencing the development of AAL systems. Despite their recent progress and demonstration of positive effects on older people's daily living, several limitations of the research and practice of ambient assisted systems have been identified (Bharucha et al., 2009). It is important to consider when dealing with AAL technology the development of satisfactory clinical evidence, for real improvement in quality of life that can be achieved by introducing this technology (Demiris and Hensel, 2008). Other challenges relate to the definition of the level of end-users' acceptance of the technology, usability, implementation, privacy, and ethical concerns (Or and Karsh, 2009). Most importantly, the needs and demands of older people as technology users are not specifically addressed where many projects are designed based on the researchers' assumptions (Or and Karsh, 2009, Chan et al., 2008). In addition, health and care workers responsible for the older people are not always well informed about the impact of the implemented AAL systems in the aspects that affect their work practices (Blaschke et al., 2009).

2.3 Activity of daily living (ADL)

A persons' ability to perform activities of daily living (ADLs) is used by health care professionals as a measure of their functional and health status, especially for older people. ADLs are defined as the usual routine things that a person may do during everyday life such as eating, bathing, dressing, grooming, working, homemaking, cooking, and leisure activities. ADLs can be divided into two main parts, basic ADLs and Instrumental ADLs.

Basic ADLs are things that most people do once they get up in the morning and get ready to go out of the house. They constitute self-care tasks including:

- Functional mobility activity for moving from one place to another, which is measured as the ability to walk and get around independently, get in and out of a chair, and get in and out of a bed.
- Bathing, showering, dressing, and self-feeding
- Personal toilet hygiene and grooming.

Instrumental ADLs are not necessarily for fundamental everyday living, but they allow a person to live independently in a community. They constitute using equipment tasks including:

- Housework, cooking, and preparing meals.
- Taking medication on time.
- Shopping and managing money.
- Using telephones and transportation systems.

2.3.1 Challenges of activities required for monitoring

Phua et al. (2009) illustrated studied memory and problem-solving abilities to produce what then they called Erroneous-Plan Recognition (EPR), aiming to identify imperfections or faults in specific plans implementation by memory deficiency' people. Several challenges faced the researchers that are related to the correct definition of a plan within daily living activities, the choice of the activities to be monitored, the type of sensors required to recognize these activities, and the activities recognition technique to be used. In this study, they used independent sequential error detection layers to identify specific errors in the plan implementation. Their obtained results indicated that error data can be separated effectively. This study gave examples of how the suggested EPR system can work well with Deterministic Finite-State Automata (DFSA) technique for identifying error probabilities.

2.3.2 Vital signs monitoring requirements

Wireless body attached sensor devices and smart phones were utilised to monitor the health condition of older people in a recent study by (Bose, 2013). These body attached devices offered remote sensing for the older people, notably of vital signs for health condition assessment anytime and anywhere. Moreover, it supported creating a customised solution for each subject according to their individual health condition requirements. If the system detects an emergency situation or deteriorating conditions, the smart phone will alert pre-assigned supervisors or the older people person's family or neighbours through text messages or by making a phone call with a predefined condition description voice message. In some cases, it even alerts the ambulance service with a detailed report of the subject's condition and location. Moreover, the system features some unique functions to support the older people person's daily life basic requirements, such as regular medication reminder, medical guidance, etc. However, Bose highlighted in his work that there is still need for innovation in the

Wireless Sensor Networks (WSN) field to enable such technologies to reach a reliable application in this domain.

The work illustrated by (Arai, 2014) was concerned with vital signs monitoring such as blood pressure, body temperature, pulse rate, bless, location/attitude, and consciousness using wearable distributed sensor network for the purpose of rescue of older people who will be in urgent need of support in evacuation from a disaster location. Experimental results show that all of the vital signs, as well as location and attitude identification of the older people person, were correctly monitored with the proposed sensor networks. Moreover, it was clear that there is no specific correlation between pulse rate and the subject's age. There is no specific calorie consumption that can be linked to age. The EEG signal can be linked to eyes movement to predict psychological state, and there is clear difference between a healthy person and a patient with dementia. Finally, it was found that there are links between blood pressure and physical/psychological stress condition (Arai, 2014).

2.3.3 Safety measures and interactions requirements

Lauriks et al. (2007) provided detailed analysis of the state-of-the-art in information and communication technologies (ICT) that can be applied in supplying the unmet needs of older people. They categorised these needs as a tailored information system, customised support, social interaction, health condition monitoring, and observed safety requirement. ICT solutions targeting memory problems demonstrate that people with memory problems are able to use simple electronic equipment with enough confidence. Instrumental ICT-based systems targeting social activities could be simply implemented via the use of mobile phones or entertainment robotic platforms. GPS-based tracking devices proved their ability to enhance feelings of safety. However, more studies regarding these ICT solutions in simulated daily life situations are required before going to commercial implementation for older peoples' daily life support. The final step after sensor data fusion is in adding the activity recognition algorithms used to characterise the activities performed by the older people.

2.3.4 Activity recognition requirements

Normally, AAL systems technology that is able to support older peoples' life should have the ability to:

- Monitor their activities in the environment to guarantee their safety.
- Perceive their physiological status to maintain their health and wellness.
- Alert caregivers and family members if the older person is in difficulties or exhibiting significant distress.
- Facilitate in house rehabilitation of the older people using automatic audio and visual prompts.
- Automate certain tasks that the older people are unable to execute alone.

From previous discussion, it is clear that human activities will show some patterns, rhythms, and trends, but these are not as regular as machines. Some irregular activities could be part of routine activities. One of the major challenges to detect incidences by an automated monitoring system, such as a fall or wandering, is to distinguish true incidences from non-incidence activities. This is why sensors augmentation can help for classification of data by adding more information to sensors measurements that may help for this classification.

2.4 Activity recognition

Current AAL systems generally aim to provide user specific support within the home environment, such as automated operation of heating, ventilation, air conditioning system (HVAC), lights, alarms for medicine, etc. (Hoof et al., 2010). Some systems perform specific tasks that require interaction with outside agents or systems; e.g. paying bills, ordering groceries, etc. (Broek et al., 2010). In some cases, AAL systems provide support for tedious work, such as home robots that provide assistance for moving objects or presenting food (Urdiales et al., 2013). For older people with cognitive impairment, the support should be responsive; i.e., the subject's daily activities should be monitored to first identify his/her daily activities, and then provide the current task relevant support. Eunju et al., (2010) studied the principles of activity recognition and demonstrated that it can be expanded to achieve increased societal benefits, especially in human-centric applications such as older people care. Their study focused on recognizing simple human activities, while recognising complex human activities is still a challenge and an active area of research. The nature of the problem; i.e., understanding human activities, require an understanding of the subject's activity profiles. Of various techniques, the first one they tested for activity recognition was based on an initial personalised model where, a conceptual activity phase should exist as the first step to build a pervasive identification system (Chen and Nugent, 2009). The second technique they tested was focused on utilising probability algorithms to generate a model for activity recognition (Wu and Huang, 1999), where the most common methods used for this purpose are the Conditional Random Field (CRF), and the Hidden Markov Model (HMM). Le et al., (2008) illustrated a method that enables activity recognition of an older people person who lives alone. They studied the case of a subject living in a house, equipped with non-invasive presence sensors; to detect and assess their loss of autonomy by studying the degree of activities performed. In their work they first detected the subject's mobility states sequence in different locations around the space. Then, from such states, they extracted descriptive rules to select activities that most influenced the subject's autonomy. Medjahed et al., (2009) illustrated an activity recognition system using fuzzy logic in home environments with the help of a set of physiological sensors, such as cardiac frequency, posture, fall detection, sound, infrared, and state-change sensors. They validated their approach on a real environment and used this activity identification approach to build a model for anxiety, with increasing or decreasing confidence according to the state of each sensor used. They successfully embedded the characteristics of the data provided from different sensors using fuzzy logic which allowed recognition of daily living activities for generic healthcare applications.

The work reported by Helmi and AlModarresi (2009) is a fuzzy system for pattern recognition that was utilised for activity modelling using tri-axial accelerometers. The accelerometers were utilised to detect and classify human motion into four categories: moving forward, upstairs, downstairs, and jumping movements. Their identification system depended on three different features: standard deviation, peak amplitude, and correlation between different axes which used as inputs to a fuzzy identification system. Fuzzy rules and input/output membership functions were defined from the experimental measurements. Their results supported the claim that a fuzzy inference system (FIS) outperforms other types of classifiers (Helmi and AlModarresi, 2009).

Papamatthaiakis et al., (2010) used data mining techniques to build a smart system that is able to recognize human activities. They studied everyday indoor activities of a monitored subject. Their experimental results showed that for some activities, the recognition accuracy outperforms other methods relying on data mining classifiers. They claim that this method is accurate enough for dynamic environments.

Zhu and Sheng (2011) illustrate a method for indoor activity identification that links the subject’s motion and position data. They attached an inertia sensor that detects the orientation in three dimensions to the subject’s right thigh for motion data collection, and used an optical position system to get the subject’s location data. The optical positioning system can be replaced by any other location detection system. This combination maintained high identification accuracy while being less invasive. They utilised two neural networks to identify basic activities. Firstly, Viterbi algorithm for finding the most likely sequence of hidden states was employed to recognize the activities from motion data only, forming a coarse classification stage. Second, Bayes’ theorem was applied to update the recognised activities from motion data in the first stage. They built a mock apartment to conduct their experiments. The obtained results proved that this method is effective and produces acceptable results for activity recognition.

2.5 Activity recognition using image processing

In recent decades, human activity recognition has become a highly important task due to the applications in smart buildings, intelligent hospitals, traffic and road safety surveillance and for military matters (Khan and Sohn, 2011). Activity recognition also becomes very important for managing and controlling the safety of older people and people including those with Alzheimer's, as they may possibly have abnormal actions. The human activity recognition systems allow authorities to have a precaution system to provide for any unexpected actions.

Although since 1990 several approaches have been proposed, there are still missing points in direct application of these approaches which motivate researchers to develop better solutions for human activity recognitions, such as having lower cost, better data acquisition, integrated, and replicable solutions (Lara and Labrador, 2013). Furthermore, the accuracy of the human activity recognition process is entirely dependent on the complexity of these activities.

In the literature, several human activity recognition methodologies were utilised for different purposes. Most of these methods are based on feature extraction in the region of interest (ROI) in the image (Suman and Pamela, 2015; Zhang and Sawcuk, 2012; Foroughi et. al. 2008 and Gui et al. 1994). Human activity recognition techniques can be categorised into two main groups in the area of the machine vision as active vision-based and passive vision-based techniques concentrating on the data acquisition process (Xu et al., 2013). Active vision techniques utilise the active sensors such as ultrasound, radar, laser and infrared to determine human activity with both 2D and 3D environment. Passive vision techniques, on the other hand, utilise passive sensors, which do not transmit the energy to environment, to capture 3D information about the human action and utilise a feature extraction method to determine human actions.

Moreover, human activity recognition can also be classified into two groups according to the complexity of the activities because according to the complexity of the activities as direct event based direct recognition for simple activities, and sub-event based indirect recognition for complex activities in the form of a set of sub-simpler activities (Aggarwal and Ryoo, 2011).

Several image processing techniques, such as segmentation-based approaches (Dudzinski et al, 2013), Discrete Fourier Transform (Kumari and Mitra, 2011), statistical approaches such as cross-correlation (Efros et al. 2003), and phase correlation are used for this purpose (Ogale et al. 2007). Although several techniques utilised such as machine vision, and intelligent system-based approaches such as Artificial Neural Networks (ANN) (Khazaei, 2013; Luo et al, 2013), these are very popular due to their simplicity and robustness for complex problems such as human actions recognition.

2.5.1 Active vision-based human activity recognition

In the literature, active sensor-based image recognition is widely utilised to track human action to determine the action type using active sensors such as Kinect (Locko, 2011). The activity recognition is based on video surveillance and human tracking in the images. Thus, the human action recognition is determined based on the analysis of the motion tracking of human actions through the scene (Kautz, 1987). These types of human action recognition technique utilise feature extraction method on the multiple ROIs in each set of image sequence, while features in each image can be extracted, which could be shapes, positions, colours, and relationships between objects and humans. The process steps are defined as illustrated in Figure 2.3.

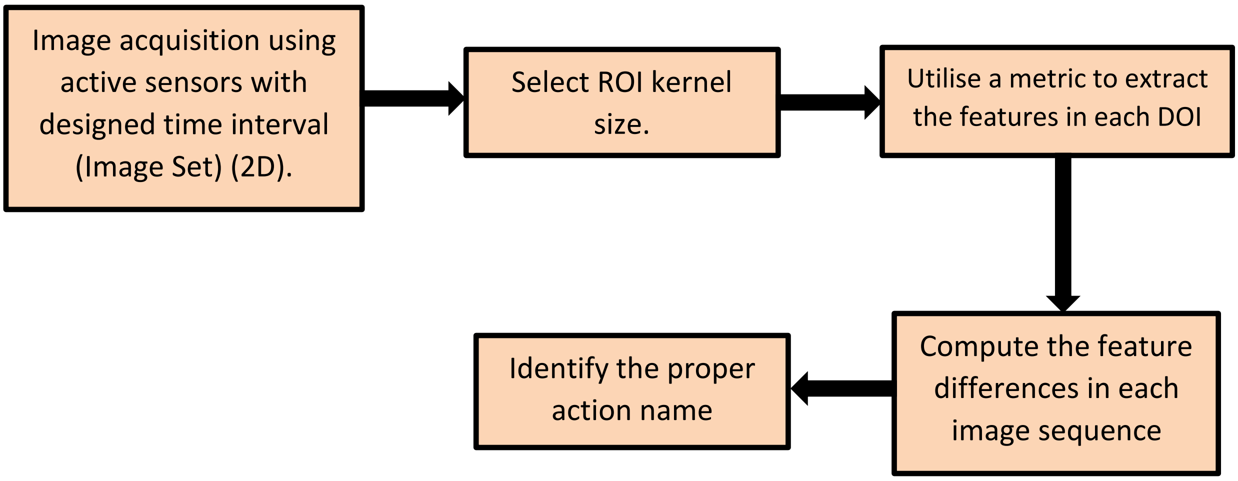

Figure 2.3: The human action recognition process. Using active vision-based system.

2.5.2 Passive vision-based human activity recognition

Passive vision-based systems are highly accurate. Utilising CCD cameras, El-Hakim et al., (1996) suggested that these types of systems performed very well, with fully-defined features such as edges. Thus it is very popular for 3D object tracking with a single sensor. Kahn et al., (1996) proposed a passive vision-based solution to recognize human actions using 3D image information. Azarbayejani and Pentland, (1996) proposed a real time stereo-based triangulated solution using passive vision to track humans with 3D information. Passive vision-based solution is highly effective in extracting the features for human action recognition. The general model of the passive vision-based approach is shown in Figure 2.4. There are some major drawbacks for passive vision-based solutions that affect its application in human activity recognition such as high cost, low resolution, and limited range (Gavrilla, 1999).

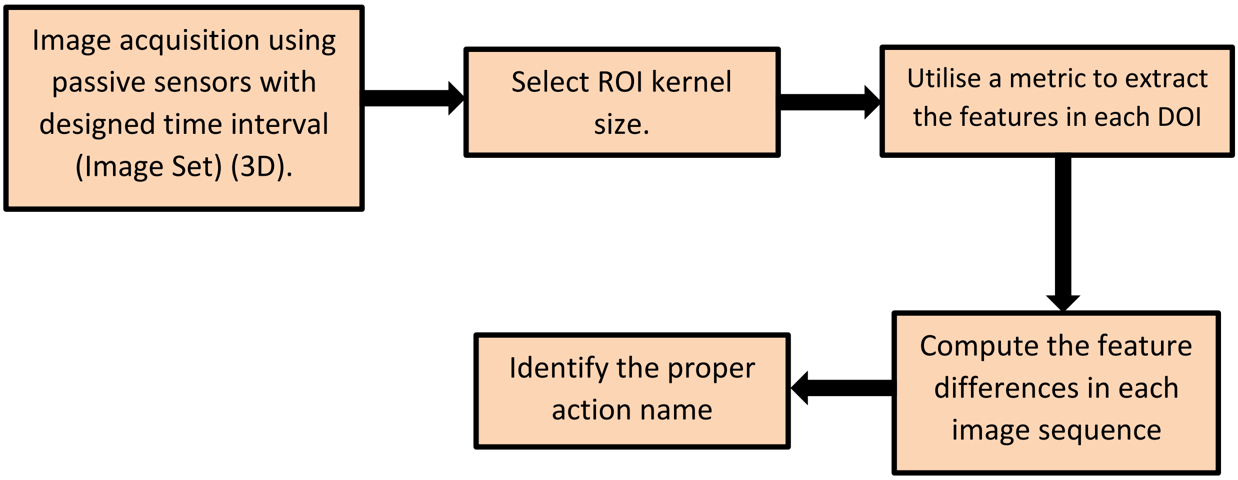

Figure 2.4: The human action recognition process. Using passive vision based approach.

2.5.3 Direct human activity recognition

Direct recognition-based techniques are one of the popular human action recognition technique types used to identify simple human activities such as gestures and actions related with sequential forms. This group of techniques are based on the time and space relationship sequential image recognition process (Aggarwal and Ryoo, 2011).

2.5.4 Indirect human activity recognition

Sub-event-based indirect human action recognition techniques are hierarchical techniques for complex human actions recognition (Aggarwal and Ryoo, 2011). These groups of techniques utilise statistical, synthetic, and description-based methodologies to extract sub-activities in each image scene. The accuracy of the process is highly related to the complexity of the actions (Kruger et al., 2007).

2.6 Sensor systems for activity recognition

An activity monitoring system typically consists of two sub-systems: (a) a *sensor system* that is able to detect what happens in the environment, and (b) an *intelligent model* that is able to recognise activities from sensor information. The aim of ambient intelligence is to enrich the surroundings with modern sensor devices interconnected by a communication network to form an electronic servant, which senses changes in the surroundings, then reasons the causes of these changes, and selects the appropriate actions necessary to benefit users of the environment.

Chen et al., (2012) conducted a comprehensive survey examining the development in sensor-based activity identification systems. They presented a review of the major characteristics of video-based and sensor-based activity identification systems to highlight the strengths and weaknesses of these techniques and to compare between data and vision driven activity recognition techniques. They categorised the assisted living technologies into two main groups based on the sensing method:

- Direct sensing Muñoz et al., (2011) and;
- Indirect sensing Virone et al, (2008).

Direct sensing involves tracking the parameters that are related to the subject himself, whereas indirect sensing focuses on identifying the environmental condition and spatial features. Both direct and indirect systems are employed in research and practice for capturing human behaviour. Direct sensing includes sound capture, video camera, and motion sensors as well as wearable body sensors. Raw data/signals from these sensors are transferred to the database. Sensed data are typically annotated and often combined with each other to identify human behaviour in the later stage of analysis, where Health-related AAL systems can be divided into six main categories:

- **Physiological Assessment:** these include pulse rate, respiration, temperature, blood pressure, sugar level, bowel, and bladder outputs, etc.
- **Functional Assessment**: these include general activity level measurements, motion, gait identification, and meal intake, etc.
- **Safety Monitoring:** these are related to the analysis of data that detect environmental hazards such as gas leakage. Safety assistance includes functions such as automatic operation of bathroom/corridor lights, reducing trips, and falls.

- **Security Monitoring:** these are related to measurements that detect human threats such as intruder alarm systems and responses to identified threats.
- **Social interaction:** these are related to systems that contain video-based communication to support mediated connection with family and virtual participation in activities etc.
- **Cognitive monitoring systems:** these are related to cognitive assistance technologies, including those of automatic reminders and other cognitive aids such as automated medication, key locators, etc. They also include verbal task instruction technologies for appliance operation and sensor assistance technologies that help users with deficits such as sight, hearing, and touch (Demiris and Hensel, 2008).

Distributed computing enables wider deployment of technology in everyday life. Smart sensors, devices, and actuators have become more affordable, powerful, and easy to install. Rapid developments in embedded systems and in particular the System on Chip (SoC) low power computing architecture such as ARM enabled the embedding of intelligence in everyday devices and equipment (Furber, 2000). As a result, people can now be observed and assisted in their own home instead of mobilising them to hospitals, resulting in economical and secure care supervision (Dengler et al., 2007). Moreover, features rich smart phones can have bi-directional communication with cloud infrastructure to offload compute-heavy tasks, offering opportunities for rich functionalities. They can be used to attract elders' attentions to certain actions, requirements, or guidance, while going through their daily life activities, as well as communicate certain information to supporters and family members in critical situations. Consequently, these technologies can reduce healthcare costs significantly as well as the physical burden on health care supporters and family members (Fahim et al., 2012).

The challenges of the AAL systems effect on users were investigated by Allameh and his colleagues, where they identified that a user's acceptance of personal space modifications depends on user's needs and lifestyle preferences. Their work classified the developments in AAL systems into three parts: ambient intelligent space (AmI-S), physical space (PS), and virtual space (VS), that can be integrated together to support independent life. Moreover, their model allows for changes in lifestyles due to changes in user's activity pattern. Currently, there is an interest in more detailed investigations on the linkage between AAL systems and user's lifestyles (Allameh et al., 2011).

A typical AAL system is illustrated in Figure 2.5 where the user's behaviour is monitored through a distributed home sensory system, which links caregiver and friends/family to the older people home through an assurance system. In some applications, relatives and emergency services are also linked to the system for instant alerting in specific situations. Table 2.1 provides a list of commonly used sensors in an AAL system, along with their usage, signal type, installation difficulty, generated noise, and cost. Sensors that generate binary signals are typically easier to install and require less calibration than those with continuous signal output.

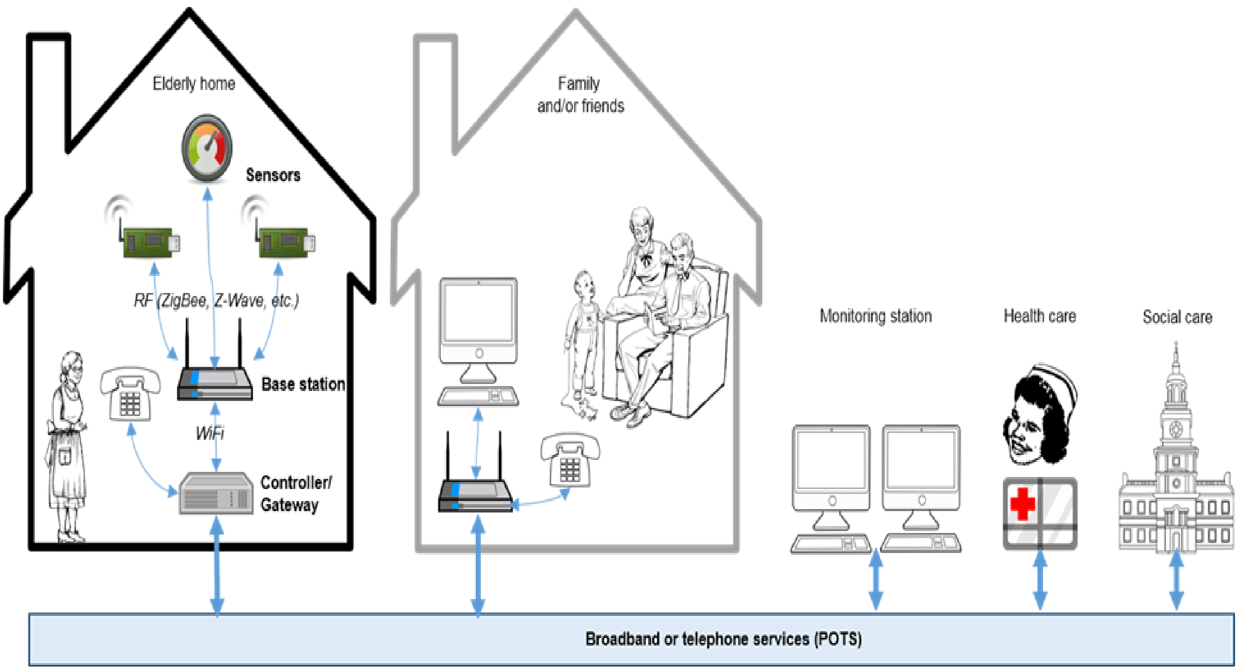

Figure 2.5: **Architecture of an Ambient Assisted Living system.**

Table 2.1: **AAL system sensors characteristics and cost.**

Sensor	Usage	Signal type	Reference	Device Cost* (US$)	Installation	Comment	Noise
Magnetic switch	Detect the opening of doors, windows, cabinets, etc.	Binary	(Virone et al., 2008)	5.00±0.75	Easy	High operational reliability. Maintenance free.	No
Temperature sensor	Detect ambient or water temperature	Continuous	Rowe et al. (2007) Virone et al. (2008)	9.00±2.00	Moderately difficult	Normal operational reliability. May need frequent calibration.	No
Photo sensor	Detect luminance level	Continuous	(Rowe et al. 2007, Muñoz et al. 2011)	5.00±1.25	Moderately difficult	Location and orientation dependent	No
Pressure pad	Measure applied pressure at surfaces	Continuous	(Virone et al. 2008, Muñoz et al. 2011)	25.00±5.00	Difficult	Need frequent calibration.	Almost no noise
Water flow sensor	Measure flow in taps and showers	Continuous	(Gaddam et al., 2010)	24.00±3.00	Easy	Need frequent maintenance.	No
Infrared motion sensor	Detect motion or movement	Binary	(Rowe et al. 2007, Virone et al. 2008, Muñoz et al. 2011)	35.00±2.00	Moderately difficult	Normal operational reliability. May need frequent calibration.	No
Home electric appliances	Send signals when user turns equipment on/off	Binary	(Rowe et al., 2007)	30.00±5.00	Easy	Need frequent maintenance.	Almost no noise
Power/current sensor	Send numeric numbers according to electricity usage	Continuous	(ONS, 2008)	120.00±3.00	Difficult	Needs professional installation and maintenance.	No
Force sensor	Detect movement and falls	Continuous	(Kidd et al., 1999)	33.00±5.00	Difficult	Need high adjustment	Yes
Smoke/heat sensor	Detect smoke or fire	Binary	(Mitseva et al., 2009)	18.00±6.00	Easy	Needs proper installation.	Yes
Biosensor	Monitoring human vital-signs	Continuous	(Lie et al. 2009, Ichapurapu et al. 2009)	180.00±5.00	Difficult	Need professional adjustment	No

Note:
*Indicative cost data, as of January 2015 – collected by the authors from various US suppliers. Cost varies according to measurement accuracy, technology, device packaging and number of units.

2.6.1 Application of probability theory

Datasets in databases must be statistically analysed by probability theory and regression analysis to show some trends within the datasets. To eliminate noise from the raw data and to detect patterns, probability distribution and cluster analysis must be employed in which annotated information is the key for efficient data cleaning. The analysis method must be modified depending on the type of data such as binary or continuous. Based on the patterns of the data, behavioural models/algorithms could be constructed which can be used in machine learning or fuzzy decision making systems. Once the behavioural mode is established, new input data will be compared with the model/algorithm inside the computer and will be evaluated as “normal or abnormal”, which will represent the activity of the occupant of the environment. In some cases, identifying unusual data consists of the identification of irregular patterns and rhythms of behaviour through pattern mining, using templates of behaviour based on current/last day activities and circadian activity rhythm (CAR) (Virone et al., 2008, Junker et al., 2008). Hence, it is essential to recognise activities from various sets of sensors into usable information, where AAL simulators need realistic sensory data.

The study presented by Chikhaoui et al., (2012) illustrated an autonomous system for activity identification in a controlled environment, linking the activities and extracted patterns from sensor data. They used pattern mining techniques linked with probability theory to discover and recognize activities. In their work, they presented activity recognition systems as an optimisation problem in which activities are modelled as probability distributions over sequential patterns. The experimental results were extracted from real sensor data placed in an AAL environment. Their results demonstrated the effectiveness of the suggested system for activity identification.

2.6.2 Application of wearable systems

Helal et al. (2012) illustrated an automatic situation generation methodology to create an effective sensor system to monitor activities. Their system constitutes of a 3D graphical user interface to achieve virtual spatial projection from simulated sensors network in a virtual reality environment. This system gives users simulation data to contribute to activity recognition directly linked to a certain environment. Their work showed how a 3D simulator named Persim, can be used for activities identification purposes in a virtual reality domain to fuse the datasets needed for real-time activity recognition application. Their system is structured based on a computer interface used for generating data regarding activities carried-out by a virtual character in a virtual space using Persim 3D's intuitive graphical user interface (Helal et al., 2011).

On the study of Laraet et al., (2012) a system called Centinela was illustrated. This system combines the subject's body acceleration measurements with his vital signs to produce highly accurate activity identification system. The system targeted five main activities, walking, sitting, running, descending, and ascending stairs. Their proposed design consists of a portable detecting device and a mobile phone. After testing three different time window sizes and eight different classifiers, results showed that the Centinela platform can achieve around 95% accuracy, which outperforms other techniques when tested under the same conditions. Moreover, the results indicated that vital signs measurements are important in differentiating between different types of activities. These findings strengthen the claim that vital signs mixed with motion information form an effective method to recognise human activities in general better than depending on motion data only. The position of the sensors were an important point in the study, where scientists identified that locating the motion sensor at the chest of the older people person eliminates conflicts that may come if attached to the wrist (Tzu-Ping et al., 2009). In addition to activity recognition, the system presented a real-time vital signs monitoring interface, adding easy health conditions monitoring to the activity recognition target.

Krishnan and Cook (2012) developed a wireless and nonintrusive sensor system that is able to capture the necessary activity information from the sequence of sensor system measurements. In this study they proposed and evaluated a sliding time window approach to identify activities in a flowing fashion. To differentiate between different activities, they incorporated the so-called time decay correlation weighting of sensor measurements within a time window. They concluded from their experiment that combining joint information of weighted current sensor measurements and previous contextual information produces the best performing streaming activity identification system.

Chernbumroong et al., (2013) addressed the issue of developing an activity identification system for assisted living technology application from the point of view of user acceptance, personal privacy, and system cost. The main aim of this research study was to design an activity identification system for recognition of nine different daily life activities of an older people subject taking into account these aspects. The study proposed an activity recognition system for an older people person using low-cost wrist worn sensor devices. Their experimental findings showed that their system can achieve classification accuracy that exceeds 90%. They performed further statistical tests to support this claim, where they proved that by combining measurement data from an accelerometer with the temperature sensor reading, activity classification accuracy can be significantly improved.

2.6.3 Data augmentation

Augmentation and annotation of data is necessary for effective data analysis and the elimination of irregularity and errors for improved accuracy in a sensor network. There are several categories of data that can be augmented, where temporal (e.g., date and time) and spatial (e.g., location) are the major categories of augmentation of the raw data (Blaya et al., 2009; Franco et al., 2010; Virone, 2009). Other contextual information such as messages and space design could be added (Rowe et al., 2007). The addition of more specific information on raw data is suggested as a key to increase accuracy of activity recognition (Van Kasteren 2010). Other approaches include the development of ontology to include more detailed categorised information with a view to explain sensor events and the context of the occupants (Muñoz et al., 2011).

2.7 Data communication

Signals from monitoring devices and sensors are illustrated as either binary values (ON or OFF) or continuous values (e.g., 21ºC in environmental temperature) to the activity monitoring system. There are several ways to transfer signals to the database. Once devices are activated, the signal would be transferred to local data storage such as a personal computer through wired or wireless communication. Signals (raw data) might be annotated with information such as time of activation and location of monitoring devices. Systems based on structured communication cabling between devices, sensors, and computers are important for reliable system performance. Generally, system integration with basic home services still can be fully achieved by structured cabling. However, wireless systems could provide easier alternative communication means. Moreover, modern buildings have extremely poor radio transmission as many wireless devices may already be operating in the environment (Linskell, 2011).

The study of Jara et al. (2013), clarified that AAL systems technology developers are interested in the real-time wireless transmission of human vital signs for the purpose of personalised healthcare applications for older people. Currently, personalised healthcare is limited by the subject’s vital signs availability, which is continuously changing. Hence, continuous monitoring of the subject’s vital signs is important in terms of certain health condition assessment. Such continuous vital signs monitoring requires the integration of wireless communication capabilities and embedded processing systems into light weight, wearable, portable, and reliable monitoring devices that can be attached easily to the subject. Moreover, an interactive user interface system is also needed that is easy enough to be used by both the subject and the supporter. In their work, they proposed a Near Field Communication (NFC) protocol as the medium for personalised healthcare. NFC is a technology that can be easily integrated in smart phones and portable devices that possess identification capability and are able to construct communication channels among them. NFC still has its challenges regarding performance, efficiency, and reliability of data transmission, as a result of constrained resources and latency. These challenges are inherent to NFC technology as it was originally designed for simple identification purposes, not for continuous data communication and processing as is required for personalised healthcare. Their novelty is in designing a set of continuous vital signs data transmission devices communicating based on an optimised NFC system. Their system was integrated with user interface applications to provide information for caregivers and people to support monitoring and managing patient's health status using wireless communication. In their work, they also performed a technical assessment on the system latency and usability regarding the NFC communication system usage for continuous vital signs monitoring, through performing practical implementation of the system for older people and their caregivers.

In the study of Arai (2013), he demonstrated a system that is able to continuously monitor the subject's health condition. Moreover, he proposed a correction algorithm to eliminate errors in physical health monitoring introduced by wearable devices. All types of wearable sensors monitoring body temperature, pulse rate, blood pressure, number of steps, calorie consumption, accelerometer, EEG, and GPS information, are considered in this study. Monitored data were transferred from the patient's wearable devices to a patient-attached mobile device via Bluetooth. The mobile device is connected to the Internet through a wireless communication network. Hence, vital signs and psychological health data can be directly transmitted to the Information Collection

Centre (ICC) for the purpose of health condition monitoring or to provide help from designated caregivers when needed.

From previous information it can be seen that technologies have been demonstrated in many ways to form a closed system able to provide specific types of support. Within the UK, many categories of AAL systems have been developed to address specific needs or to target specific technology implementation. Figure 2.6 illustrated below, summarises most of the activities in the UK in the form of target groups, provided support, and technology utilised in the AAL systems environment (Linskell, 2011).

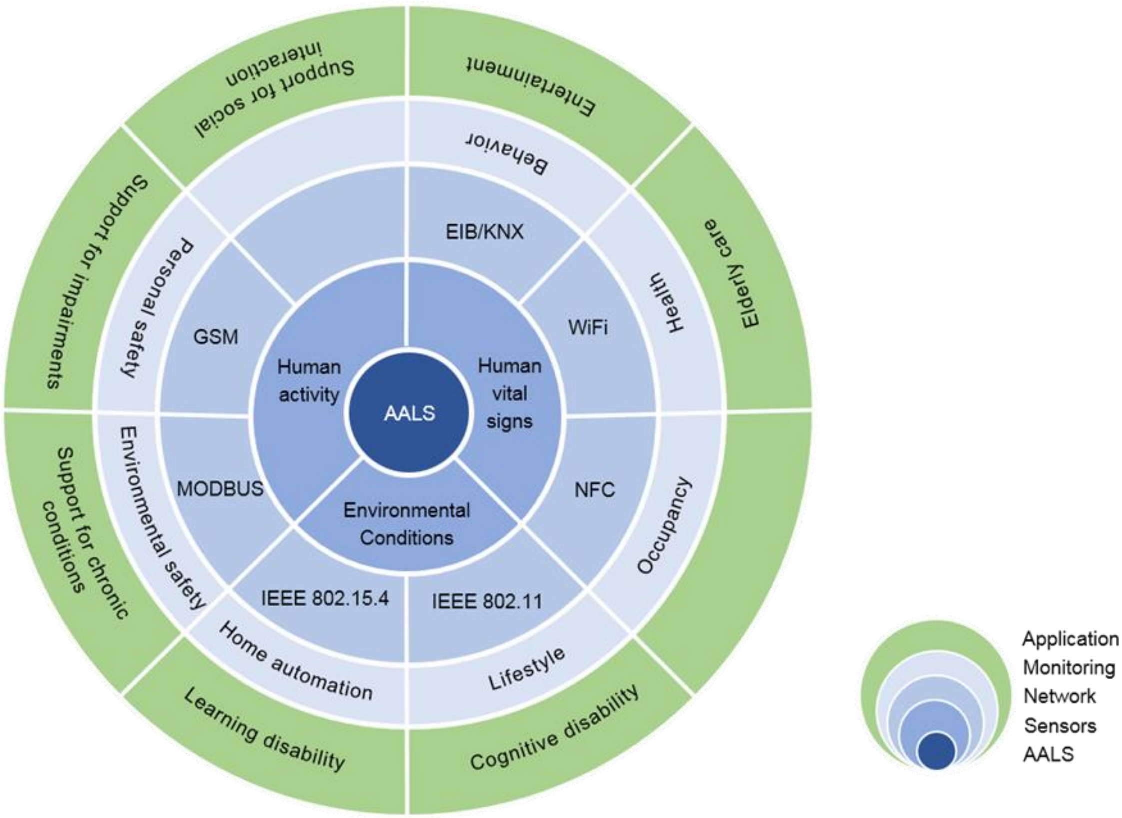

Figure 2.6: **AAL System for providing different types of support.**

2.8 Sensors fusion for activity recognition

A sensory system is the first step for assisted living technology design. The second step is related to sensors data fusion for the purpose of activity recognition. Sayuti et al. (2014) discussed the trade-offs between measurements delay and throughput in a case study utilizing the lightweight priority scheduling scheme for activity monitoring from a distributed sensors system. The findings showed that the proposed scheme presented a promising solution that supports decision making for AAL system in a real setting environment. The creation of an AAL environment not only embeds sensors to acquire information, it also processes this information and interacts with the subject for enhanced quality of life.

There are several types of information monitoring which can be used to gather data of physical activities. In medical practice, it is common to continuously monitor people' biological status, such as heart rates and saturation level using wearable devices. Xin and Herzog (2012) in their work presented a wearable monitoring system designed to achieve continuous in-house and outdoor health monitoring to support older peoples' independence. The system acts as a health diagnosis assistant through its on-board intelligence to generate a real-time reliable health condition diagnosis. The on-board decision support system continuously learns the subject's health characteristics at certain time intervals from the attached sensor system. Hence, a dynamic decision model is continuously adapted to the subject's health profile. The system is also able to measure deviations from the normal state and categorise whether it is a definite critical situation or just a normal uncritical deviation. Pirttikangas et al. (2006) studied activity identification using wearable, small-sized sensor devices. They attached these small devices to four different locations on the subject's body. In their experiment they collected data from 13 different subjects of both sexes performing 17 daily life activities. They extracted features from heart rate and tri-axial accelerometer sensors for different sampling times. They employed the forward-backward sequential search algorithm for important feature selection from these data.

De Miguel-Bilbao et al. (2014) presented a sensory topology system that consists of action sensors and presence sensors for monitoring daily life activities, as well as the configuration of the monitored homes and users. The post processing stage for activity monitoring is independent from the home topology monitoring process. The system extracted parameters can be considered as long-term monitoring data aiming at detecting and validating daily activities, enabling early detection of physical and cognitive dysfunctions (Rashidi et al., 2011). The monitoring of household activity method can help to improve geriatric evaluation and enhance the possibility for a better remote monitoring system of older people in their homes. This knowledge can further support design and manufacture of biomedical sensors that are small, reliable, sensitive, and inexpensive (Agoulmine et al., 2011).

Shuai et al. (2010) focused on including activity duration into the learning of inhabitants' daily living activities and behaviour patterns in a smart home environment. They applied a probabilistic learning algorithm to study multi-inhabitants in the smart home environment. They predicted both inhabitants and their Activities of Daily Living (ADL) model utilising the activity duration of the people performing experiments in a smart kitchen laboratory. The experimental results for activity identification demonstrated high accuracy compared to the unreliable results that are obtained with no activity duration information in the model. Their approach also provides a great opportunity for identifying drifts in long-term activity monitoring as an early stage detection of deteriorating situation.

Language-based programming and interactive approach provide support for developers to freely express the global behaviour of a smart home application as one logical entity. The high-level language eases the implementation efforts for the application developers. By structuring the application development into different high-level models, developers can simplify the application, maintenance, and customisation due to changing user requirements or changes in the monitored living environment. In this way, people are directed to use rules for describing the required behaviour within a smart home environment. Consequently, by providing a rule-based modelling language, the gap between the user-based application development and the actual system implementation can be reduced (Bischoff et al., 2007).

Algase et al. (2003) investigated reliable measures that are suitable enough to identify wandering behaviour. Most of the studies they researched for wandering behaviour relied on the simple classification of a subject's state such as wandering or not-wandering, based upon personal caregiver judgments, which doesn't have clear consistent assessment. They found that unplanned ambulation is a key element across all methods used for wandering behaviour identification. They studied different types of sensors used to detect wandering behaviour. They found that the StepWatch device outperforms all other devices as it is always able to identify wandering behaviour correctly. The StepWatch always produced the best estimate for the subject's wandering time spent, whereas other tested devices in the study were oversensitive to normal movement and produced substantial overestimates.

2.9 Recent projects on ambient assistive living

"AAL homes" term is typically used to describe the living environment in which information and communication technologies are introduced in order to assist inhabitants' daily living activities such as moving furniture, timed medication, eating, dressing, and communicating,... etc. The early stage of implementing AAL homes projects has a focus on alarming system in emergency situations such as the incidence of fall and the system was generated primarily by users, as listed in Table 2.2. below:

Table 2.2: Application, location, and aims of recent AAL projects

Project	Origin	Application			Sensor location		Monitoring aims			Reference
		Safety	Health & wellbeing	Social Interaction	Physically fixed	Wearable	Environmental	Health	Cognitive	
AlarmNet	Virginia, USA	-	-	-	√	√	√	√	-	(Wood et al., 2008)
Assisted Cognition Environment	Washington, USA	√	√	-	√	√	√	√	√	(Qixin et al., 2006)
AWARE	Georgia, USA	√	√	-	√	√	√	√	√	(Kidd et al., 1999)
BioMOBIUS Research	Dublin, Ireland	√	√	-	√	√	√	√	-	(BioMobus, 2011)
CASAS	Washington, USA	√	√	-	√	√	√	√	√	(Rashidi, 2011, Cook et al., 2003b)
Casattenta	Bologna, Italy	√	√	√	√	√	√	√	√	(Farella et al., 2010)
CodeBlue – Wireless Sensors for Medical Care	Harvard, USA	√	√	-	√	√	√	√	-	(Wood et al., 2008)
GatorTech Smart House	Florida, USA	√	-	√	√	-	√	-	-	(Helal et al., 2005)
Georgia-Tech Aware Smart Home	Georgia, USA	√	√	√	√	√	√	√	-	(Kientz et al., 2008)
Gerontological Smart Home Environment	Paris, France	√	√	√	√	√	√	√	-	(Gerontological, 2011)
I-LivingTM	Illinois, USA	√	√	-	√	-	√	-	-	(Bal et al., 2011a)
MavHome	Texas, USA	√	√	-	√	-	√	-	-	(Cook et al., 2003b)
MIT House_n	Massachusetts, USA	√	√	-	√	-	√	-	-	(Chan et al., 2008)
ORCATECH	Oregon, USA	√	√	√	√	-	√	√	√	(Nehmer et al., 2006)
SISARL	Hsinchu, Taiwan	√	√	√	√	√	√	√	√	(Bal et al., 2011b)
Smart Medical Home	New York, USA	√	√	√	√	√	√	√	√	(Ricquebourg et al., 2006)
SOPRANO	Patras, Greece	√	√	√	√	-	√	√	√	(MÜLLER et al., 2008)
TAFETA	Ottawa, Canada	√	√	-	√	-	√	√	-	(Tafeta, 2011)
WellAWARE	Virginia, USA	√	√	√	√	-	√	√	√	(Bal et al., 2011a)
CareWatch	Scotland, UK	√	-	√	-	-	-	-	-	(Rowe et al., 2007)
TeleCARE	Scotland, UK	√	√	√	√	-	√	√	-	(Whitten et al., 1998)
CAALYX	Madrid, Spain	√	√	√	√	-	√	√	-	(Rocha et al., 2013)
Total		20	19	11	21	11	21	17	9	

It is evident from Table 2.2 that most projects (n=22) primarily aim for proper environmental and subject condition monitoring, before going into achieving any required support function. The AAL home name was derived from the main idea of home automation, which uses a distributed sensory system to collect information related to the state of the environment where humans are located inside, then in response to this information decide certain actions and activate specific actuators to operate certain home devices, perform certain functions, and interchange data with outside domains. An AAL home may be also known as a smart space, an aware-house, or one using collaborative ambient intelligence. AAL homes that have these capabilities can deliver to older people various types of home assistance, controlled medication, fall prevention, and security features, etc. Such systems generate a secure feeling for the older people inside their homes. Moreover, AAL will help relatives to observe their older people from anywhere with an internet connection (Cheek et al., 2005).

Various laboratory trials, projects, and industrial showcases concerning AAL homes are available around the world; a lot of them share many features. Looking into the objectives these projects are aiming to achieve, they use diverse technological innovation, information selection, validation method, and results confirmation.

In this respect, currently available technologies for AAL homes could be presented in three categories:

- **Social Connectedness Systems**. Those targeting facilitating social activities, social networking, and identification of social efficiencies.
- **Safety Enhancement AAL Homes**. Those targeting fall detection, personal emergency, and medication management systems.
- **Health Monitoring AAL Homes**. Those targeting managing chronic problems. It also includes active tele-health enabled remote interaction with the patient and collects continuous Health Records.

There are various projects worldwide, some of which will be briefly described in this section.

AlarmNet is a project developed in the University of Virginia aiming to provide health care monitoring for independent living, which can be considered as wireless sensor-based AAL system (ALARMNET, 2011). The system uses heterogeneous devices that contain wearable body sensors, distributed wireless sensors, user's interfaces, as well as database and decision making logic. Some of the communication and alarming devices are mobile, while others are stationary. Mobile body worn sensors provide physiological sensing for blood pressure, pulse rate, and accelerometer data. Information are collected, filtered, aggregated, and used in respect to the requirements of the home residents. The system could be adapted to the patient's medical conditions, and can be tailored to provide certain notifications to specified users or the patient themselves. Emplaced sensors devices are distributed in the environmental to collect data, such as ambient temperature, dust percentage, light intensity, and resident's local position. For example, pressure sensors can be placed on the ground to monitor their footsteps pattern to detect increased risk of fall, while a set of bed sensors can monitor breathing rate, heart rate, and levels of movement during sleeping. AlarmNet flexibility allows system expansion as more sensors devices are deployed or new arising conditions require monitoring (Wood et al., 2008). Despite the innovative activity analysis method, AlarmNet system architecture has its problems. AlarmNet is a closed architecture, without focus to support third-party sensors devices or software, which limits the solution to the elements used in the design.

Assisted Cognition Environment project was developed by the University of Washington which specially targets studying the use of Artificial Intelligence (AI) techniques to enhance and provide support for older people's daily life who are living with cognitive disorders (Kautz et al., 2002). The developed system provides the ability to sense the surrounding environment, patient's location, interpret patient's behavioural patterns, and offer support to the patient through verbal and physical interventions. The system also is able to provide certain alerts to caregivers if the situation requires this.

The system consists of two main elements. The first is its ability to create an activity supervision model that helps patient to reduce their spatial disorientation both inside and outside the home environment. The second is its structured prompter that supports people in performing their everyday multi-step tasks (Qixin et al., 2006).

AWARE home project has been initiated by Georgia Institute of Technology in the USA aiming to conceptualise the living context of older people. It does this by introducing ubiquitous computing to provide important information to their family members who have concern about their status when living alone. One of the objectives of this project was to distinguish a particular individual from others and detect the person's location by using force sensitive load tiles on the floor, a so called *smart floor* that records foot step patterns. Data sets obtained from the tiles are called "ground reaction forces (GFR)", profiles that are used as the base information model for the unique footsteps pattern of each individual. This GFR model is then compared with new GFR input data in order to identify individuals. Analysis is based on a hidden Markov model (HMMs) and a simple feature-vector average technique. Another aim of this project was set as locating "frequent lost objects" such as keys and glasses within the home environment through the use of radio-frequency tags. Floor vibration sensors were placed in the laboratory to detect the position of the persons inside the laboratory environment, while researchers also defined how people lose their objects in the environment through combining the smart floor measurements and GFR techniques (Kidd et al., 1999).

CareWatch was developed by researchers at the University of Florida, department of Adult and older people nursing. The system focused on monitoring sleeping patterns of cognitive declined people and activating several notification systems for care providers. Sleeping pattern change is one of the frequently occurring symptoms in cognitive decline and dementia individuals, which affects their mental and physiological status and brings burdens to their care providers (Rowe et al., 2007).

CareWatch project aims to inform caregivers to provide the necessary required care information for older people who have cognitive impairment, while they are living in their own homes. CareWatch project is designed to prevent unsupervised home exits, especially during the night, and to release some of the burden from the care providers during night times. CareWatch is a novel technique that can be used by informal caregivers, such as relatives, to provide care to older people. It has proven to be adaptable in different home environments. The system is designed to increase the quality of life for both the care recipient and the caregiver at the same time, especially during night times.

BioMOBIUS research project was initiated by the technology research group for independent living at the University College Dublin, Ireland (BioMobus, 2011). The project is formed from open structure software linked with hardware that allows quick design and implementation for biomedical research purposes. BioMOBIUS research project is built on the open source Eyes Web XMI software, which was developed for research on gesture recognition, movement analysis, and multimodal interfaces at Genoa University. BioMOBIUS platform contains a sensing structure to monitor physiological parameters, a data processing platform that uses different techniques, and an intelligent agent that converts measurements into useful expressive information for the clinicians. The target is to monitor blood pressure, gait stability, risk alertness, and social activity. The system is adaptable for a variety of hardware through its generic use of mixed wired and wireless interface techniques.

CASAS research project was conducted by Cook et al. (2003a), from the School of Electrical Engineering and Computer Science at Washington State University. The project aimed at identifying the behavioural pattern of older people living with dementia, and analysing their distinctive behaviour by using machine learning techniques. The activities of older people who are cognitively healthy and those diagnosed with dementia problems are monitored by motion and other types of sensors, while the collected data are analysed to define “cognitive health” and “dementia” behaviour in the test environment. The results showed that the learning algorithm used can identify the differences between the performances of activities, however, it cannot distinguish the cause of these difference, whether it is a result of confusion due to dementia or simply just a mistake.

Lotfi et al., (2012), employed a different monitoring method to identify the abnormal behaviour of dementia individuals. They used sequence of monitoring signals from different locations in order to describe the flow of the occupant’s activity within the home, alongside the time duration of these signals. These are recorded for analysing the pattern of daily activities by using a clustering technique. Their method illustrates a better distinction in capability than method presented in Cook et al., (2003a) does.

Casattenta project was conducted by the laboratory for ICT technology transfer in Bologna to study Ambient Intelligence Technology (AIT), Sensor Systems Fusion, and Wireless Communication Networks to monitor inhabitants’ health and daily living activities. Their system consists of a set of location-fixed sensors distributed alongside the monitored environment, a set of wearable sensors devices, and a communication platform. The system’s main target was to trace inhabitants’ health and daily live movement aiming to support older people living alone (Farella et al., 2010). The fusion of all system elements was based on the famous ZigBee data communication wireless method, which allowed the system to track and recognize critical situations for older people, such as danger of falls and immobility situations.

CodeBlue wireless sensors for medical care project was initiated by Harvard University researchers (CodeBlue, 2011) and examined the application of wireless sensory networks technology usage for a range of medical applications that include stroke patient’s rehabilitation and disaster response. The project used a wireless sensory network (WSN) that consists of battery-powered sensors devices enhanced with enough computation and communication modules. The WSN used served the need for vital signs automatic collection, processing, and integration into the patient care record system for real-time medical use. Many commercially available wireless medical sensors such as gyroscopes, EMG sensors, pulse oximeters, EKG sensors, and accelerometers were used and linked to TinyOS operating platform (Wood et al., 2008). A secure software infrastructure was developed for wireless medical devices to secure information exchange with patient's medical recorders, PDAs, PCs, and other monitoring devices that could be used to monitor patient's health.

Gator-Tech smart house project was developed by the mobile and pervasive computing laboratory of the University of Florida (Helal et al., 2005). The Gator-Tech smart home is an intelligent environment designed to assist the older people in their daily live activities. The Gato-Tech smart home project is based on certain supportive features distributed in the home domain such as, smart appliances, plug-and-play sensors, actuators, and smart floors for position tracking. The overall system possesses a generic design for smart space environment that contains definitions of service for all sensors and actuators distributed in the monitored environment to form the required older people support.

Georgia-Tech aware smart home project was developed by The Institute of Technology in Georgia to address the aware home research initiative (Kientz et al., 2008). The Georgia-Tech smart home adopted different designs to improve the social interactions between older people and their families as well as the outside world. Moreover, indoor position tracking was implemented using simple RFID sensors and vision solutions. The Georgia-Tech project's research group created activity identification addressing general occupants' activities, such as watching TV, reading, preparing a meal, or blood glucose monitoring for the purpose of every day activity monitoring.

GERHOME gerontological smart home environment project was led by the French research organisation, Centre Scientifique et Technique du Bâtiment (CSTB, 2011).

The overall system intended to improve the feeling of independence for the people living with loss of autonomy. GERHOME used software platforms for automatic recognition of human behaviours using real-time video surveillance combined with other types of sensor data. The project presented a communication infrastructure that allows easy integration of different types of sensors within an existing system structure, based on intelligent agent architecture. GERHOME contains wired and wireless sensors implanted in furniture and appliances around the house to collect data on the use of these facilities to infer activities of the older people within the home environment. The collected data are analysed in order to pick any unusual behaviours or identify changing trends in behaviour. The GERHOME aimed to automate a remote medical supervision to delay older people entrance to nursing homes. To address this goal, three actions needed to be considered. Firstly, the system needed to perform an assessment of the older people's frailty using multi-sensors analysis for activity recognition to build a knowledge library of reference behaviours from 3D geometric information of the observed subject. Secondly, the system needs to detect alarming situations such as falls. Thirdly, the human behaviour profile should be identified and compared to the subject reference profile to detect any deviations from this profile. The system main objective was to improve automatic sensor data interpretation through assistive sensors such as video cameras for early detection of health status deterioration.

I-LivingTM is an assistive-living project developed by the University of Illinois (Bal et al., 2011a), aiming to design an assistive living infrastructure that allows distributed wireless sensor devices of different communication protocols to work together in a secure manner. The user interface was designed to provide various types of services to enable older people with different abilities to enhance their independence and/or assisted living requirements. The aim was to use already commercially available module technologies in sensing tasks such as RFID, localization, and presence identification modules, while using wireless communication networking technologies such as Wi-Fi, Infrared, Bluetooth, and IEEE 802.11devices, in open system architecture (Qixin et al., 2006).

MavHome is a project conducted by the University of Texas to achieve home automation for assisting daily living activities in which the pattern of individual's activities was modelled by machine learning (Cook et al., 2003b). The name of MavHome came from the phrase "*Managing an Adaptive Versatile Home*", while the focus of the project was to maximize the comfort feeling of the occupants while minimising the costs of hardware and software investment. In order to achieve the target, the system recognises and predicts the daily actions of the occupants. MavHome uses different intelligent activity identification algorithms that utilise environmental sensors and actuators to achieve this goal. Their identification algorithm architecture consisted of four layers, an information layer that collects and saves information from sensors, a data communication layer that controls data exchange between layers, a decision-making layer for executing actions, and a physical layer consisting of actuators deployed in the environments to achieve certain tasks.

MITHouse_n research project was developed at Massachusetts institute of Technology (MIT) focused on the design elements and associated technologies of a smart home to better serve the future for older people. A laboratory facility equipped with sensors in various locations was constructed near MIT for experimental trials. A software platform was implemented that was used to develop innovative types of user interfaces. The project studied the needs for environmental conditions monitoring, proactive healthcare, biometric monitoring, indoor air quality, and new construction solutions needs for health and activity monitoring (Chan et al., 2008). Various types of sensors devices were embedded in the environment, such as infrared transmitters, video cameras, microphones, and biometric sensors were all used to collect various data about the users and the environment they lived in. Sensors devices were utilised to monitor activities in the laboratory first so that researchers were able to study how people react to new devices located in the environment around them. Data visualisation and user interfaces to the system were established to allow many portable devices to communicate and interact with the system.

ORCATECH is a project initiated by the Oregon Aging Health and Science University. The project was devoted to study the development of technologies that support independent living for a wide range of requirements in older people's health monitoring and home care support. The system comprised intelligent bed sensors that were able to track older people sleeping pattern and prevent them from falling by turning on room lights automatically when they get up from bed. The system also offers remote controlled tele-presence for the purpose of older people living alone at home, to provide health support as well as social interactions with remote family members and caregivers (Nehmer et al., 2006).

SISARL (Sensor Information Systems/Services for Active Retirees and Assisted Living) project was established by three cooperating institutions in Taiwan: National Taiwan University, National Tsing-Hua University, and National Chao-Tung University (Bal et al., 2011b). The project focuses broadly on the use of consumer electronics to enhance the quality of life of older people and provide them with necessary help to achieve active and independent life. The project team tested several everyday living applications such as the location of objects, using medicine dispensers, monitoring personal vital signs, detecting pattern irregularities, sending specific appropriate notifications, and utilising robotic platforms to enhance older peoples' dexterity and reach-ability. Several off-the-shelf technologies were utilised in these tests such as RFID tags, interrogators, smart phone, PDAs, and Wireless Sensor Networks.

Smart Medical Home is a multi-disciplinary project conducted at the University of Rochester to advance interactive technologies used for home health care (Ricquebourg et al., 2006). The project is aimed at developing technologies to increase forward detection and anticipation of the patient's health and medical condition. The system used an interactive medical advisory system known as "Chester the Pill", to interact with the patient in the smart medical home as well as the present care providers to provide the level of support required to the patient. Using speech recognition and artificial intelligence techniques together with patient's available medical data, the interactive system advises residents to detect possible illness using structured interactive questions and answers in real time. The system also provides residents with information regarding possible medication that can be used, their side effects, and other health issues and in this way helps people and care providers better to understand a physician's instructions.

SOPRANO project is an European Union (EU) based project with its objectives set to build an "ambient assisted living" environment for older peoples' to support them live independently. A qualitative methodology is developed based on experience and application research objectives to identify the issues and needs of older people's living activity in the community. Older people are encouraged to join the research as participants in focus groups meetings, individual interviews, and assessment process throughout the research time (MÜLLER et al., 2008).

TAFETA (*Technology Assisted Friendly Environment for the Third Age*) project was developed at Carleton University (Tafeta, 2011). The primary testing facility was built in 2002 in the form of a smart apartment domain, which was loaded with various types of sensors and actuators placed to detect and control the environmental parameters. These sensors were of many types such as thermostats, accelerometers, microphones, magnetic switches, RFID tags, motion sensors, smart grab bars, and etc. The TAFETA project utilised pressure-sensitive floor pads, bed mats, and seating cushions to monitor movement continuously in the apartment domain. The bed mats were also used to monitor breathing rate to identify sleeping quality of occupants. The system also provided warning signals in case of possible health hazard issues based on the occupant's health records history.

WellAware is a project started in the year 2000 at the Medical Automation research centre, University of Virginia (Bal et al., 2011a). WellAware project provided an integrated structure that used sensory system and user interface to enable professional caregivers as well as relatives to remotely monitor and deliver support to older people. The system used many proximity and motion detectors that were distributed in the smart house and used the ZigBee wireless protocol to communicate with the main computer. Major components of WellAware are related to sensors that track the movement of the subject, wireless data networking, and controlling software with user interface for checking older people activities to normality. The system also provided web-site access to caregivers who could remotely monitor the condition of the older people and select earlier intervention requirements for serious health conditions.

TeleCARE is a project presenting a generic architecture for ambient assistive living environment (Whitten et al., 1998). The project provides abstraction for both hardware and software used without specified information about dealing with third-party hardware drivers. Regardless of its distributed and environmental fault-tolerant structure, TeleCARE does not group the sensor nodes, which if performed could allow lower power consumption of the overall system elements. Moreover, there is no clear information of the hardware requirements for the framework. This is an important issue when aiming for a solution designed to support older people citizens and to achieve real-time communication between them and their relatives.

CAALYX project is mainly concerned with how the older people will use the system. Trying to measure its usability from old-aged user's point of view (Rocha et al., 2013). CAALYX project sensors are positioned in a unique hardware structure to adapt to older people requirements. The CAALYX project relies on mobile phones, which generates a problem associated with the phone battery. It is difficult to guarantee that the older people will always remember to charge their phones, which can easily compromise the system. On the other hand, CAALYX shows a more accessible solution, which is easy to configure through the use of the TV set.

From previous sections, it is evident that a comprehensive system that uses all possible information and sensory networks, including image processing to provide comprehensive customised assistive system for older people, especially who are living with memory problems, is not present. Hence, conducting a research scheme to present a solution in this application is highly important, which is the scope of this thesis.

2.9.1 Commercial challenges

There are many barriers to technology uptake in smart home environment, especially for older people with specific needs such as Alzheimer's. There is a clear lack of suitable framework to address this problem and validate the installation of such system for assessing its technological solutions to meet their specific needs. Limited experience with tele-care technology initiatives has demonstrated that pilot projects do not necessarily lead to wide scale of technology application. There is a lack of commercial technological developments that can provide smart home solutions for people with special needs due to most of the required skills exist in academia and with professionals outside the commercial technology development environment (Linskell, 2011).

2.9.2 Technological challenges

One major challenge in home assisted technology is related to continuous identification of the subject's vital signs and health conditions via wearable devices (Chan et al., 2009, Chan et al., 2008). The challenge is basically related to the acceptability, durability, easiness of use, communication ability, and power requirements of these wearable devices. For instance, such devices need to be not only providing vital signs measurements, but also an assessment of the subject condition that are close to the doctor assessment when examining any patient. It needs also to be versatile in design with minimum weight, skin effect, and burden on the subject on their everyday life activities. Moreover, the power life of its battery and communication ability should be strong enough to be operated for days or weeks without the need for recharging. Additionally, it should be fault tolerant with high resistance to impact, heat, cold, and water. Combining all these requirements in the wearable devices is a high challenge for sensors technology developers, that if achieved will boost home assisted technology systems to further new dimensions.

Moreover, standards that are related to specifying elements of assistive living technology are almost unavailable for the system developers. Consequently, adaptability of different system components from sensors, communication protocols, decision support, and subject interaction method or language, is not maintained and every system is linked only to the developer initiatives. Availability of such standards will help system designers to integrate efforts and provide the market with the necessary devices and systems to meet the requirements.

2.9.3 Social challenges

Older people in general are often consciously aware of their privacy and any possible intrusion. Acceptance of AAL systems by older people may therefore be challenging, as the system may be perceived by them as intrusive. Most of the reviewed research appears to ignore this and to assume that users will accept the system in the way they design it. With limited available literature and surveys for user acceptance from the older people himself, this assumption is not always well regarded. Acceptability is culture dependant and will vary from one society to another. Gender and age have been found to influence people’s perception of space (Mourshed and Zhao, 2012), which may also affect the acceptability of a system, in particular where behaviour is continuously monitored. A high challenge for system developers is therefore in identifying the level of user acceptance.

2.10 Summary

In general most of research projects related to the assisted living systems set the objectives to mainly help older people to reduce the burden of their care givers, support their independent living, and to avoid harm to them. Recent projects that deal with this subject were reviewed in this chapter, with special emphasis on the sensors system and behavioural model creation from measurements and image processing. However, a comprehensive system that uses a combination of environmental monitoring devices, image processing, and wearable monitoring devices for older people including those with dementia daily living activity monitoring does not exist in the literature. Hence this thesis aims to deliver a step towards this aim.

Moreover, this survey illustrated that there is no strong clinical evidence defined so far for implementing new technologies that support a reduction in care-givers' burden, correctly identify patient's behaviour, and avoid any health risk to older people. Moreover, few researches have been conducted in relation to the influence of new technology implementation in the assisted living field to avoid harms and predict risks. As a solution to address these issues, creating causal networks and social influence analysis are needed not only for avoiding unnecessary risk of harm, but also building a common knowledge background among different disciplines for creating new assisted living technology. The requirements for assistive living technology have to be reviewed with care-givers, professionals, people, and relatives to define the common structure of the system during the design stages to build a comprehensive system that uses both environmental monitoring devices and wearable monitoring devices for older people daily living activity monitoring including those with Alzheimer's.

Chapter 3: Methodology

This chapter presents and discusses the methodology applied in this study. It also explains the research phases with a method for recognising common daily activities for older people including those with Alzheimer’s which will be introduced through performing a 24-hours continuous monitoring of their behaviour to identify these activities. Moreover, the environmental requirements for the older people are identified by capturing the health care-provider’s knowledge in order to adapt it into older peoples' homes and the smart assistive system.

3.1 Research approach

Quantitative research methods are concerned with investigating natural scientific phenomena, whereas qualitative research methods are related to perceiving human experience and knowledge associated with social and cultural phenomena. Qualitative research uses a systematic process to enable researchers to understand various aspects associated with people and cultural problems (Myers and Avison, 1997). Any research method could be influenced by the philosophical assumptions of the researcher and explains the way by which information will be collected and processed to achieve the objectives of the subject being examined. In general, there is no common philosophical research paradigm, while the three main principals are thought to be: positivism, interpretivist and critical theory positivism. Positivism is related to qualitative research while interpretivist interprets reality as a social construction by observations that differ from one person to another as a result of different social perspectives. Hence, it is more likely linked to qualitative research. The critical theory research was defined by Klein and Myers (1999) as interpreting the assumption that '*people can consciously act to change their social and economic condition'*. (Klein and Myers, 1999).

3.2 Data collection methods

For data collection, some researchers prefer quantitative methods, while others prefer a qualitative approach to stay close to the problem situation. However, the subject under investigation affects the choice of data collection methods. The most important issue is to collect reliable and valid data that is correct and relevant to the target study. The five main methods used for data collection are:

a) **Interviews:** An oral interview is also known as a face-to-face meeting with people at which the participants answers questions presented by the interviewer. Data collected from interviews contains direct quotations of respondents' opinions (Patter, 1990).

b) **Observation:** The researcher observes the participants performing certain activities and records their relevant observations (Whitten et al., 1994). Observations provide structured descriptions of peoples' behaviour, actions, and interactions.

c) **Questionnaire:** Structured questions are designed to collect data beyond the personal vision of the researcher to explore deep data within participants' minds, attitudes, feelings, experiences, and opinions. The difference between questionnaires and interviews lies in the fact that no direct link exists between researcher and respondents (Forsgren, 1989, Sekaran, 2000).

d) **Modelling:** Modelling is defined as simulating a particular feature or a problem using existing accepted knowledge to understand, define, and visualise it in existing knowledge (Cartwright et al., 1983, Hacking, 1983).

e) **Documents:** Documents are referred to as information available in official publications, memoranda, correspondence, program records, reports, diaries, and websites (Patter, 1990). It provides basic background information for the investigated subject.

Each data collection method has some limitations. For instance, conducting interviews is a time-consuming process that requires time for the interview sessions, preparation, making appointments, and travelling. On the other hand, structured questionnaires often do not allow flexibility, and are subject to misunderstandings due to language usage.

3.3 Research methods

Research methods for qualitative research include ethnography, grounded theory, case studies, and action research (Cassell, 2004).

Case study: *Case studies are "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*" (Yin, 2011). The case study method could be viewed as exploratory, descriptive or explanatory, depending on the researcher assumptions. An exploratory case study is used to test hypotheses and research questions, which is most appropriate if there is a lack of literature about the investigated subject.

Experimental studies: Experimental studies are used to study the relations between variables in certain quantitative phenomenon by controlling the tools and environment.

Survey-based studies: those that commonly utilise the questionnaire, interview, observation, and documentary analysis to generate data. Design of a survey study can go through six stages: data requirements, data generation method, sampling domain, sampling technique selection, response rate definition, and sample size identification (Oates, 2006).

This study uses common daily activities for older people including those with Alzheimer's to obtain an optimum behaviour model that can be used in intelligent home support systems, through the conducted observation survey, and to define the system monitoring devices for proper system implementation to detect these activities. This hybrid method (survey and monitoring) can be used to implement intelligent support agents for the older people including those with Alzheimer's that are able to provide the necessary support correctly in real time. It can be argued that the combination of qualitative and quantitative is highly appropriate to carry out such kinds of developments; this is because, it observes the accumulated experience and knowledge of expertise and subsequently verifies the level of the robustness and accuracy using a quantifiable tool based on monitoring.

3.4 Design factors

To improve AAL home designs there are some factors that may constitute an important element in the design process for the development of those homes, especially for the older people living with Alzheimer’s, and these factors were taken into account based on previous studies. Table 3.1 illustrates the factors that were collected from relevant literature to the topic under investigation that were considered during the survey structuring and conducting stages to make sure that efficient data was collected.

Table 3.1: Factors for effective data and environmental conditions

Factor	Impact and how to care for the patient
Safety	Safety is a comprehensive multi-dimensional task and is the basis of every action or work in a person's life. Older people will be delighted when they feel safe in the environment surrounding them. For older people including those with Alzheimer’s we must bear in mind that they have lost some of their capacity, which enables them to believe in themselves, so we have to eliminate any risks from the environment which may lead to injury by simplifying the living conditions (Vischer, 2007). Wherever possible, unnecessary furniture around the home should be removed and everything must be purpose-oriented. For example, the path to the toilet should be clear, illuminated, and obstacle-free. In addition, we have to consider compensation for different senses which are weakened or lost, such as, hearing, vision, and smell, which make them vulnerable to sudden risk (Dalke et al., 2006).
Vision	When talking about visual changes, we must consider that older people may not perceive objects in their proper position. While designing the environment surrounding them, we have to account for colour changes and eye muscle weakening in order to clearly show things in their proper form recorded in their mind. Thus, one level of lighting throughout the corridors leading to the rooms

	should be preserved (Zimring et al., 2008). In addition, there are strategic places of particular importance and should therefore have increased lighting, such as the bedroom, kitchen, and bathroom, with even pictures on the doors to identify room functions. The use of curtains and blinds to block direct sunlight to avoid blur-eye is also recommended (Shikder et al., 2012).
Sound	There are some concerns related to the hearing capacity of older people including those with Alzheimer's, in particular, the inability to cope with loud sounds or to distinguish between different sounds. So, noise reduction walls, floor, and ceiling present in the environment surrounding the older people is very important to enhance their hearing capacity. In the simplest form, automatic switching off, or sound level control of certain devices such as Radios, TVs, doorbell, and phones must be considered. Soft music or Quran recitation (for Muslims) around the older people relaxes their temper. Lighting is important in the process of hearing; the brighter the lighting is, the more possible it is for the older people to comprehend through the movement of the lips of the talking person. Sometimes, light signals are also recommended in place of audio signals, such as light flashing doorbells without a sounding bell (Dubbs, 2004).
Movement	Older people including those with Alzheimer's generally experience weakened muscles that constrain their movement and they have an irregular or unbalanced gait. Hence, their surrounding environment must be kept clean and simple in order to facilitate the movement. For example, carpets, rugs, and slippers should be slip-proof and firm to ground (Tzeng and Yin, 2009). Furniture should also be slip proof and firm in their position. Any obstacles that may result in trips or slips should be removed from the space. Grips should be placed in bathrooms, showers and in any place that poses a hazard to avoid falling, and to support ease of movement (Guenther and Vittori, 2008).
Olfactory	Some older people become very sensitive to bad smells with time and may feel discomfort if they perceive unpleasant smells (Ulrich, 1999). Such limitation can be avoided by ensuring automatic

	ventilation, pleasant fragrance release in toilets and kitchens, and air fresheners deploying in the environment around them at regular time intervals (Dancer, 2011). Also, some older people lack the smell sense, which jeopardizes their safety in the case of any gas leakage occurrences. Hence, gas leakage detectors should be deployed in the space around the patient, and not only limited to the gas supply inlets (Seppänen et al., 2006).
Organisation	Older people including those with Alzheimer's may lack the organizational capabilities with time (Mace and Rabins, 2011). This may result in objects being placed in wrong places around the house, resulting in difficulty in re-locating them when needed. Consequently, stress can overtake them if they cannot locate an important object within a reasonable search time. Hence, an assistive locating system is suggested to support identifying proper places for objects as well as location tags that are linked to the proper place. In this way, objects can flash light or produce noise whenever it is not in its proper place.
Orientation	Older people including those with Alzheimer's may have disorientation and may unnecessarily exit their home. This may result in unexpected exits from their home during the late hours (Warner, 2000). Consequently, stress can affect them if they went out of their home without a reason. Hence, a sophisticated door opening system should be used to prevent them from opening the door without being in full mind concentration and complete consciousness to prevent uncontrolled exits. Moreover, assistive locating devices attached to them is suggested to support alarming specific personnel in case the patient succeeded in getting out of the house at improper times, within a specific distance from the home. In this way, the disorientated, uncontrolled exit can be controlled and corrected if occurred.

3.5 Ethical considerations **Data protection**

Information supplied as part of this questionnaire will be held by Cardiff School of Engineering and Cardiff University and will remain secure and confidential. The details will only be used for academic research purposes and will not be passed on to any third parties or used for marketing purposes in accordance with the Data Protection Act 1998. All collected data are recorded in anonymous form so that persons participating in the study can't be identified.

3.5.2 Eligibility

To fill the questionnaire, people need to be professionally involved in the care of older people including those with Alzheimer’s in the Kingdom of Saudi Arabia for a minimum of 3 years as professionals care supporter.

3.5.3 Ethical approval

A two-stage ethical approval was obtained for this survey. In the beginning, ethical approval was obtained from the School of Engineering, Cardiff University. Another approval has been obtained from the managing committees for homecare and older people care support in the Kingdom of Saudi Arabia.

3.6 Proposed AAL system

The nature and requirements of developing such AAL in homes involves a process of multi-stage investigations. The research scope can be summarized as:

- Gathering professional’s opinions in relation to AAL requirements using questionnaires and interviews.
- Specifying system structure for observing daily activities of older people including those with Alzheimer’s in a case study in the Kingdom of Saudi Arabia.
- Utilising image processing and ambient distributed sensors for accurate human activity recognition for older people including those with Alzheimer’s.
- Constructing a reasoning model to implement decision support system.
- Developing a laboratory validation test case for targeted AAL system.

This study starts with a comprehensive literature review into current trends related to AAL systems that aim to support older people including those with Alzheimer’s. Further to this, a case study has been designed and implemented in the Kingdom of Saudi Arabia to collect older people including those with Alzheimer's activities information. Then, professionals' and professionals' opinions, in relation to the AAL system requirements, are collected and analysed. Later, image processing and distributed sensors data are combined to design and implement an effective AAL system. Finally, a laboratory validation experiment is implemented to test the suggested AAL system's performance. Figure 3.1 show the conceptual framework of the proposed system which is includes the following steps:

3.6.1 Stage one: Patient activities observation (case study)

In this stage, combined research instruments (e.g. Structured Questions, Interviews, and case studies) were used to highlight the challenges in observing older people including those with Alzheimer's daily activities span (Tappen and Williams, 2008). These challenges are related to the observation method, the people being observed, and the observation time, where the following considerations were taken into account:

a) Length of observation. It is challenging to observe older people including those with Alzheimer's for a long period of time. They feel uncomfortable when they are observed continuously (Hurley et al., 1992). However, to investigate the activities of the daily life of a patient, it is necessary to at least observe them for a consecutive 24-hours period. Therefore, we have chosen 24-hours to be the minimum observation period to minimise disruption to their daily life.

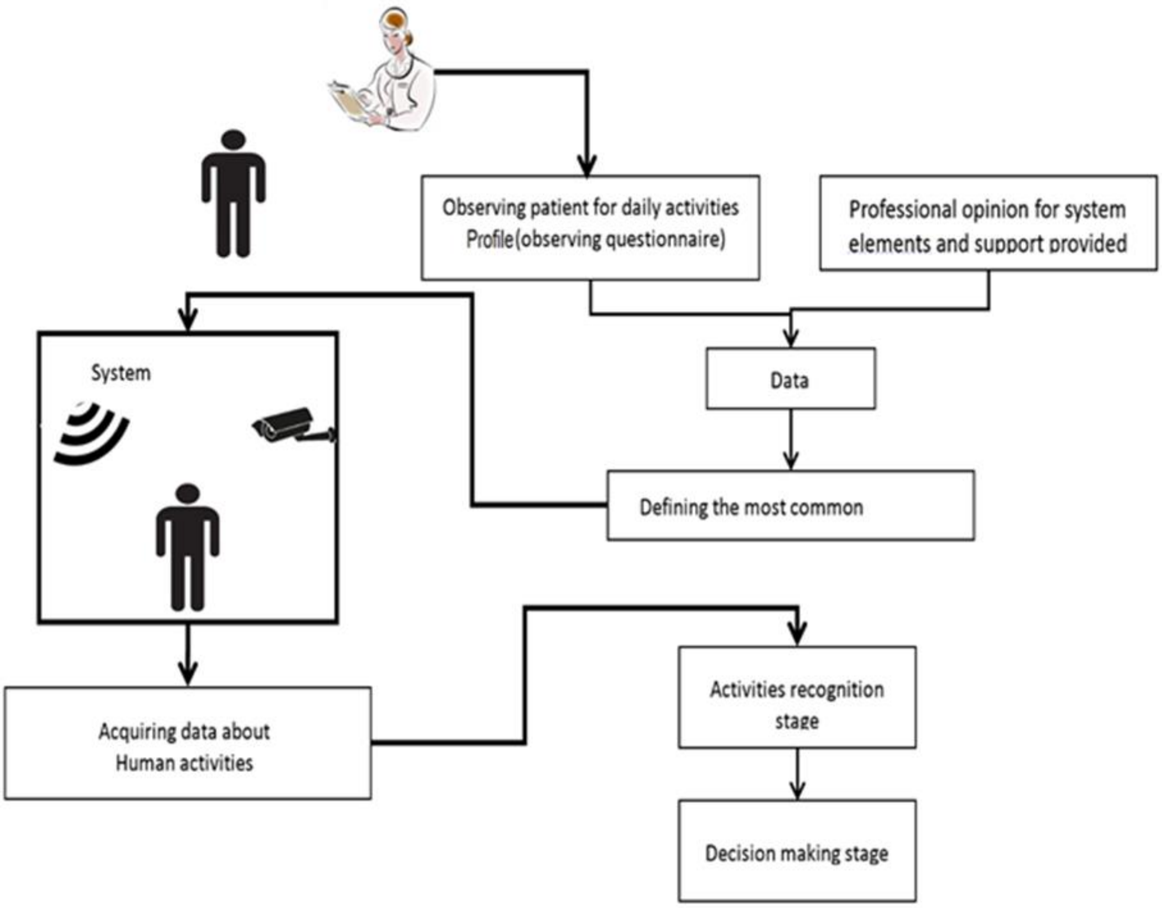

Figure 3.1: Flow of the processes of proposed AAL system.

b) **Observer.** It is normal for older people including those with Alzheimer's to be protective about their surroundings and cautious about allowing strangers in their living space. They may feel uncomfortable with a situation like this, and that may affect their daily activities. On the other hand, long-term care professionals (e.g. nurses) usually have established rapport and trusted relationship with their older people. They are more suitable to perform the observation task than the academic researcher.

The gender of the academic observer can also be an issue in conservative societies such as the Kingdom of Saudi Arabia, where strangers are not often allowed to have access to living quarters.

Due to all of these factors, observations were performed for consecutive 24-hours by healthcare professionals responsible for older people during their usual shifts. Training was provided to all healthcare observers through a workshop held at their workplace to give them the necessary information relating to the data collection process.

c) **Instruments for data collection**. Generally there are two main methods used to observe the daily activities of a person: Firstly, through electronic sensors and cameras (David and David, 1996), and secondly, by the use of a time diary (Bolger et al., 2003). Electronic sensors and cameras are effective when the range and nature of activities are known to be a priori (Ziefle et al., 2011, Townsend et al., 2011), also visible monitoring equipment (e.g. cameras) can also affect older people behaviour (Newman and Ward, 1992). In addition, the cost involved in the professional fitting monitoring equipment is prohibitive and time-consuming for a large sample. In contrast, the time diary is an effective instrument for recording activities over an observation period. Time diaries have been successfully deployed in many researches (Chilvers et al., 2010, Muller, 1995). Trained observers are also able to make notes, for a richer dataset.

d) **Structured questionnaires.** A structured questionnaire, combined with a 24-hours' time diary was used for collecting data. The purpose of the questions was to identify the common daily life activities (measure the older people activity during the day to identify the parameters for the decisions made) to define patterns of daily living.

The instrument used in this work for data collection from observing older people is based on structured questionnaire forms that the professional care-takers or supporters follow from working one shift to another. The structured questionnaire form was reviewed by professional Alzheimer's doctors who work in the hospital. In addition to the structured questionnaire form, an observation questionnaire form that extracts the vision and observations of the daily caretakers about the needs of older people including those with Alzheimer's, was constructed and reviewed by doctors. The result of such questionnaires is presented later as a pilot study, representing professionals' opinions.

The draft questionnaire form was constructed based on the purpose of the survey to analyse the clarity of the features related to the psychometric properties of the instrument. In general, it took one full day to complete observations, and adjustments were made to the survey tool to correct and clarify items in the final version. All participants were requested to mention any deficiencies in the content of the questionnaire. This stage resulted in a final survey with improved content. The survey was produced in both Arabic and English. The final survey form was then presented to the observers in Arabic; it was then re-translated into English for analysis and documentation. The final survey included eleven structured questions relating to the older people living profile, which is used to describe their activity, the need for assessment, and the observer's knowledge. The survey also contained an open-ended question to allow respondents to provide their ideas on how to improve the structure of the survey. General information such as age and gender were also included for categorisation purposes only. The objectives of the questions were developed from a review of research books and other related literature, and previous observers' records.

e) **Study participants and case study interviews.** The main subject of this study is an older people person who may be living with early or mid-stage Alzheimer's and the study is conducted to monitor their general everyday behaviour. The study was carried out among healthcare providers that included doctors, nurses, technicians, and administrative staff in the memory clinic healthcare department in Riyadh city in the Kingdom of Saudi Arabia.

The Kingdom of Saudi Arabia is located in the Middle East. It has an approximate area of 2,149,690 km^2 and an approximate population of nearly 27 million (CDSI 2010). About 99% of the population follow the Islamic faith, and the country's civil law is influenced by the Islamic Sharia Law (Madani et al. 2004). The administrative organisation of the country is organized as 13 provinces, namely: Makkah, Madinah, Riyadh (which is the capital city), the Eastern province, Asir, Jouf, Hudud Shamaliyah (North borders), Baha, Jizan, Najran, Hail, Qassim, and Tabuk provinces (MOI 2012). The healthcare centres concerned in this study were from four hospitals concerned with the welfare of older people including those with Alzheimer's in the Kingdom of Saudi Arabia, namely; King Faisal Specialist Hospital and Research Centre in Riyadh, the Centre of the City of Prince Sultan Armed Forces, the Centre of the Security Forces Hospital in Riyadh, and the Centre of the King Fahd Medical City in Riyadh. Healthcare providers in Prince Sultan Armed Forces were chosen for this research based on these factors: vast experience, education level, the clinic reputation in relation to world-standards, and a large number of staff and residences. Older people including those with Alzheimer's who the survey targeted were males and females who were living with the three stages of Alzheimer's.

f) **Data collection method and data analysis technique.** Forty-eight people were recorded from a total of 306 people who were linked to the clinic at the survey time. Data for this study was collected between the 13th of September and 29th of November 2013. Older people including those with Alzheimer's was selected randomly with a ratio of 1/6, which was found with sampling fraction given below; The sampling function is defined with the Equation 3.1;

$$SF = \frac{n}{N} \tag{3.1}$$

where SF denotes the sampling function, n is the sample size and N is the total size (Bryman, 2012).

In the case of observations, the sample size chosen was 48 people out of 306, thus the ratio is found of as 1/6 given in equation 3.2;

$$SF = \frac{48}{306} \cong 0{,}1569, (\text{ i.e. } 1 \text{ in } 6) \qquad (3.2)$$

Different data collection strategies were used, where some of the older people including those with Alzheimer's were randomly selected, 38% of the selected older people were living in their own home, and 63% were living with their family. Older people relatives and Administration Centre Personnel were communicated in writing, to confirm that their participation in the study was voluntarily and that data confidentiality was to be strictly maintained. All data were collected, and then entered into the statistical analysis program. Analysis of the data was mainly descriptive. The timetable was 8 weeks for data collection, 4 weeks for data entry, and 8 weeks for data analysis.

All statistical analyses were performed using Microsoft office Excel (2013) and SPSS Statistics version 19.0 for Windows (IBM-SPSS, 2009). For the purpose of analysing the collected data from the monitored older people, histograms and percentiles are calculated for various activities recorded. These results are then drawn in illustrative graphs to ease the analysis process.

After selecting the daily activities for older people including those with Alzheimer's at various stages, the importance of home design and environmental conditions for them was commensurate with these activities, such as room temperature, moisture, room's distribution, was reviewed to select the appropriate sensors for these activities.

After analysis, fourteen common daily life activities were identified. They are considered as normal activities for building the system to confirm some of the ideas of the previous two phases. In contrast to learning how to develop the system and making it appropriate for older people including those with Alzheimer's smart home design, came the third phase of the survey, as it shall be explained in the next stage.

3.6.2 Stage two: System requirements survey

In this stage, the study focuses on gaining information of professionals' and professionals' understanding in relation to the type of assistance required and general requirements for independent living for Alzheimer's people. To gather this information, a questionnaire and a survey was constructed for this purpose (Hasson et al., 2000) as follows:

a) Classification questions such as gender, age, level of education, employment status.

b) The personal behaviour of older people including those with Alzheimer's to be determined in their homes and their behaviour towards others in order to understand the thinking and interpretive processes to explore the emotional responses of them through their experience in dealing with older people including those with Alzheimer's.

c) Knowledge questions to determine what information a professional has about ideal environment design (universal design factors), based on their experience with the older people who live with Alzheimer's, especially those who are living alone. Moreover, identifying places which need sensors in smart homes that meet the needs of older people including those with Alzheimer's independent living.

The questionnaire was formed from 23 predominantly multiple choice questions. To avoid restricting or guiding participant's responses, the option ‘‘other, please specify’’ was offered where necessary. The questionnaire was tested by some participants in a pilot investigation, during July and august 2013. In general, it took 30–40 min to complete. When the ethical approval was obtained, the survey questionnaire was hosted online using ‘‘Survey Monkey’’ (www.surveymonkey.com) in both Arabic and

English languages for ease of use. The link was distributed via e-mail as well as hard copies being delivered by hand, and the snowball sampling technique was used to gain the target sample size from health professionals (male and female) during the period 10th September 2013 to the end of January 2014. Snowball is a non-probability sampling technique (Bird and Dominey-Howes 2008), which allows researchers to penetrate an anonymous community, identify, and recruit key informants (Bird 2009), where according to traditions in the Kingdom of Saudi Arabia, recruiting female respondents is quite difficult (Zabin 2010). Data were then collected through direct contacts, as well as e-mails with the respondents (Sadavoy et al. 2004).

3.6.3 Stage three: Activity recognition using image processing

An image processing-based human activity recognition process was developed to determine the most common daily activities. The proposed technique consists of an enhanced Phase-Correlation and Log-Polar (PCLP) transformation and an Artificial Neural Network (ANN). The proposed technique has two main stages; a pre-processing stage and an action recognition stage. The pre-processing stage utilised ANN to determine the correct action class. The action recognition stage is based on the PCLP transformation using the rotation angle information alongside with the class group information provided from the ANN. As PCLP transformation is an image registration technique to correct the image according to a template image, the absolute value of rotation angle should be close to zero (Yuce, 2012). Due to the background distractions, a threshold value was selected to determine correct action prediction chosen as 10 degrees or less. In some cases this threshold value was not enough. Therefore this threshold value was increased to 50 degrees and matched with ANN prior information.

In this third stage, this process was presented and implemented successfully, to recognize older people including those with Alzheimer's behaviours. To utilise the method on a real life problem, a raspberry-pi and a pi-cam based system were utilised to captured human images every five minutes and sent them to the server for image processing and perform human activity recognition using MATLAB platform. This stage focused on the most common three activities which cover about 72% of the total older people including those with Alzheimer’s daily activities time, which were standing (walking), sitting, and lying (sleeping) activities, to predict the correct activity type. These processes are presented in chapter 5 in details. Later, the activity-type information will be utilised as one of the major components for the AAL system to make decision using a rule based approach system.

3.6.4 Stage four: Alzheimer's monitoring system.

Older people including those with Alzheimer’s monitoring is one of the most important elements used to make decisions about the required safety conditions. The monitoring of an older person with Alzheimer's, is quite complicated which may need to cover several aspects to observe about the patient’s conditions such as, location, activity type in that location, vital signs conditions during that activity, and environmental conditions. Therefore these important aspects have been monitored with several sensors. The most important thing is to have wireless observation to avoid any hazards for them. This stage presents an extension of the activity recognition with location identification, vital signs, and environmental condition measurements.

To identify the patient's location, Radio Frequency Identification (RFID) technology based location identification is utilised. Therefore, three types of RFID sub-systems were developed to detect the location of the patient which was static RFID modules, mobile RFID module, and master modules.

a) Radio frequency Identification (RFID) module (Tag)

To identify the location, a SYNAPSE-based RFID wireless mesh network is implemented. In this stage, three RFID static modules were utilised and mounted in each room. These static modules receive the signal from a mobile RFID module.

According to the power strength between mobile RFID and individual static RFID module, the location of the subject was determined. The power signal information received by a master module which was attached to a server through RS232 communication port. To generate this process an RFID mesh network was implemented with different attenuation values as given in Figure 3.2.

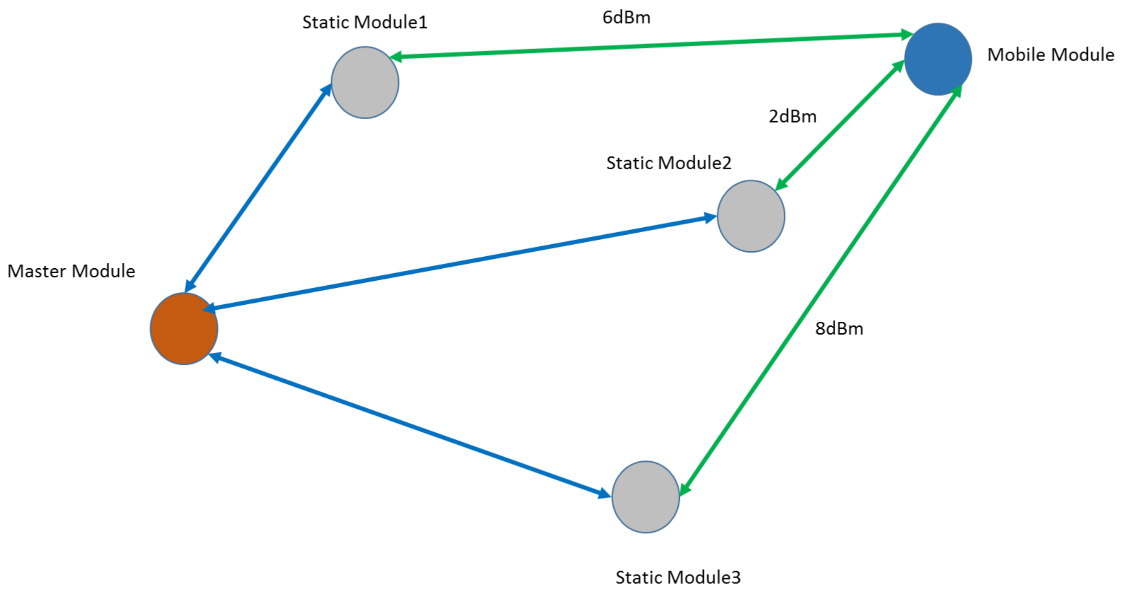

Figure 3.2: RFID mesh network for patient location identification.

The next stage was to develop a wireless vital signs measurement system such as measuring the heart rate of the patient. Older people who live with Alzheimer's are mostly of the age of 60 or above, where this age group of people also lives with chronic heart problems and high blood pressure. Therefore, the heart rate monitoring is important to saving their life.

b) Measuring vital signs

The Heart rate measurement system consists of two main units which are the wireless heart rate sensor/transmitter, and an appropriate sensor data receiver. In this work, a heart rate sensor (HRS) manufactured by Polar Company was used. The HRS is a popular measurement device used in the sports industry. A compatible receiver was developed using an Arduino microcontroller. The generated system has a range of 1.5 m. Therefore, it has been located in the bedroom to receive signals better. The main reason to locate this sensor in the bedroom was related to the activity observation. According to the observations, older people including those with Alzheimer's spend 45% of their daily activity as sleeping or lying down in the bedroom. Thus, positioning this sensor in the bedroom was the most convenient option.

The final stage of the extended sensory system design is to develop a wireless environmental condition measurement system to monitor the indoor environmental conditions such as room temperature and humidity.

c) Environmental condition recognition

In this work a Z-Wave communication protocol-based multi-sensing device was utilised that included both temperature and humidity sensors. To measure indoor conditions, a Z-Wave-based USB microcontroller was used to store temperature and humidity readings every five minutes. The Z-Wave system was used on one of the Raspberry-pi devices to communicate the readings through the MATLAB platform to the main server to record them in the MySQL database.

3.6.5 Stage five: Decision making rules

This stage presents the professionals decision-based rules. The medical professionals' knowledge was used to design the antecedent and consequent parts of the rules with the boundary limits. According to the professionals about 25 rules have to be used for a decision support system to avoid any hazards for the people. Most of the rules antecedent elements were represented as a range of values. The consequent part was designed as an integer option, such as abnormal condition or normal condition.

After the rule generation, an action interface was developed to read the sensors data from the MySQL database and search for the matched rules as to be fired. According to this decision support system, if more than one rule have matched with the sensors conditions, and if any of them has a consequent value for the abnormal conditions, then the system selects these option. If there is no abnormal condition among the fired rules, there is no need for further actions. This process is repeated every five minutes.

3.6.6 Evaluating proposed solution: Validation

After validation of the effectiveness of the system, it contributes to:

a. Using of the ANN-based image phase-correlation and log-polar transformation to detect human action.

b. Merging image activity recognition information with other sensors data to get a much more accurate monitoring process and to provide safety environment for the older people including those with Alzheimer's.

3.7 Summary

This chapter introduced the methodology for recognising common daily life activities for older people including those with Alzheimer's over 24-hours continuous monitoring period of their behaviour. It discussed the research paradigm, data collection methods, research methods, design factors, and ethical considerations. The chapter also introduced a new conceptual framework for an AAL system. In contrast to previous research, the proposed system employs image processing techniques as well as sensory network and sophisticated artificial intelligence method to provide assistance to older people including those with Alzheimer's.

Chapter 4: AAL System Requirements

This chapter presents the results from the conducted survey questionnaire and observation data collected for older people including those who live with Alzheimer's activities monitoring. This chapter also conducts the required analysis to identify the common daily activities of older people who are living with Alzheimer's through analysing the collected observation data. It also presents professionals perception in relation to the necessary design elements of the AAL system and its associated home environment. At this stage of the research, interviews with patient's relatives were conducted and followed by people' observation for their daily life activities recording over a certain length of time (see chapter 3 methodology section 3.3.2).

4.1 Introduction

Older people usually prefer to spend their remaining lifetime in their own home environment. According to the survey conducted by the Disabled Living Foundation (DLF) in 2009, over 40% of people have concerns about having to move into a care home when they become old and nearly 70% of them worry more about losing their independence or becoming dependent on others (DLF UK, 2009). The home is, therefore, a crucial focal point for ensuring independent, healthy, and socially inclusive living, and should be designed and/or equipped with the right infrastructure to support and host a variety of services that older people may require to meet their needs (Shikder et al., 2010). Moreover, easy access to the social environment (supermarkets, cultural centres, opportunities to socialise, etc.) whether from homes, or integrated into homes through adapted digital technologies, is important to offset potential challenges such as isolation, loneliness, and associated physical and/or mental decline. Furthermore, high quality information is also important for making informed choices, particularly for the older people who live with gradual memory loss (Chan et al., 2009). To address these limitations, it is essential to implement smart homes that secure all means of well-being and safety requirements using modern telecommunication technologies. In the Kingdom of Saudi Arabia, Alzheimer's affects over 50,000 people according to Saudi Association of Alzheimer’s. Their number is rapidly increasing, and their dependency on caregivers builds up as well, causing a major concern to the relevant authorities in the Kingdom. This forms economic burdens on the state in terms of care expenditures and health care, to achieve decent life, independence, and privacy for them. So this study focus on older people in general who are living with mild impairment in memory, such as Alzheimer’s and the possibility of achieving an independent supportive system for them in their own homes. In this chapter, professionals’ opinions are presented on the design of smart homes to enable older people including those with Alzheimer’s to live independently and the requirements of those houses through the questionnaire survey. Such a study presents a deeper understanding for these citizens in Saudi Arabia, and it also helps professionals to provide a better service for the older people. It also offers support for the design of an effective AAL system.

The dimensions and factors for the survey were as follow:

- ***Dimension:***

1. Personal behaviour of older people with Alzheimer's in their homes and their behaviour towards others (Common behaviours of older people including early and mild stage Alzheimer’s).
2. Closest ideal design based on professionals opinions for the homes of older people with Alzheimer’s.
3. Identify places that need sensors in the smart homes that meet the needs of Alzheimer's people’ independent living.

- ***Factors:***

1. According to the Alzheimer’s health assistance foundation (2013), the following behaviours are very common among Alzheimer’s people; such as getting lost (wandering), difficulty managing money, repetitive conversations, taking longer than usual to finish routine daily tasks, poor judgment, apathy, losing things, noticeable

changes in personality, change in mood, and falling. The behaviour of Alzheimer's people in hot climate (e.g. in KSA) is different from people in colder climates. Symptoms demonstrated by male and female Alzheimer's people are not the same at a given stage, while the behaviour of Alzheimer's people is affected if he/she has other aging-associated problems. Although Alzheimer's people at early and mild stages can live independently in his/her own home, it is sometimes necessary to have a family member living with them permanently.

2. Elements of the home design such as, the presence of stairs inside the home, the presence of doors separating different rooms, the presence of an elevator or stair lift, changes in level (floor) inside the home, bright interior lighting (e.g. high illumination), bright natural light (e.g. through bigger windows), bright coloured walls, spaciousness of rooms, opening/closing windows, ventilation system, furniture size, furniture shape, bathroom options, relationship between a bedroom and the kitchen, relationship between the bathroom and sitting room, and relationship between the kitchen and sitting room.

3. Monitoring technologies need to be integrated in a smart home such as pressure sensor/pads, motion sensors (infrared), smoke detectors, water flow sensors on taps, loop sensors on the patient to monitor vital signs (temperature, blood pressure, heart rate), cooker sensors, refrigerator sensors, door sensors to detect movement from/to spaces, and coded main door lock. Furthermore the spaces in the house should also be monitored, bedrooms, sitting room, office room, bathroom, toilets, Kitchen, laundry room, corridors, lobby/foyer, stairs, and interior spaces.

4.2 Alzheimer's people common activities

4.2.1 Observation data results

Most of the statistical analysis was performed with Microsoft Office Excel (2007) and PASW Statistics version 18.0 for Windows (IBM-SPSS, 2009). For the purpose of analysing the collected data from the monitored people, histograms, and percentiles are calculated for various activities recorded. These results are then drawn in illustrative graphs to ease the analysis process.

Figure 4.1 to Figure 4.3 illustrate the activity frequency distribution and average activity percentage over one complete day for a sample of 48 older people including those with Alzheimer's in the kingdom of Saudi Arabia collected in the summer 2013. The three figures represent the results for each Alzheimer's stage in order.

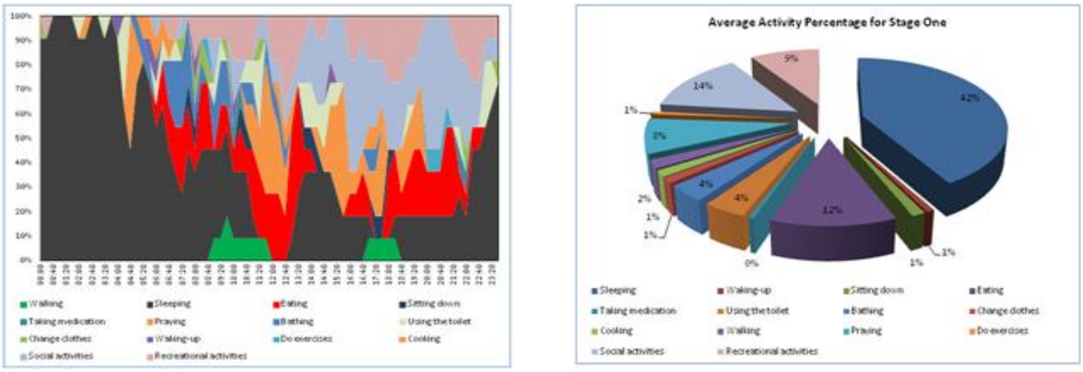

Figure 4.1: Activities frequency distribution for stage one people.

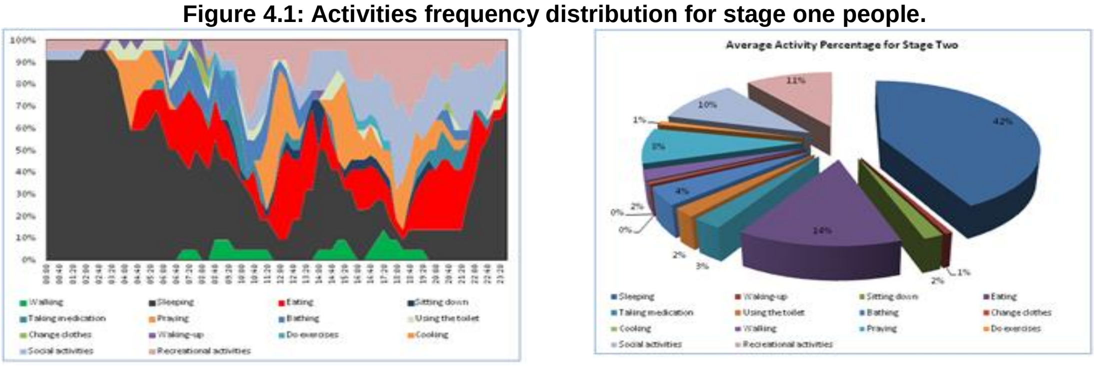

Figure 4.2: Activities frequency distribution for stage two people.

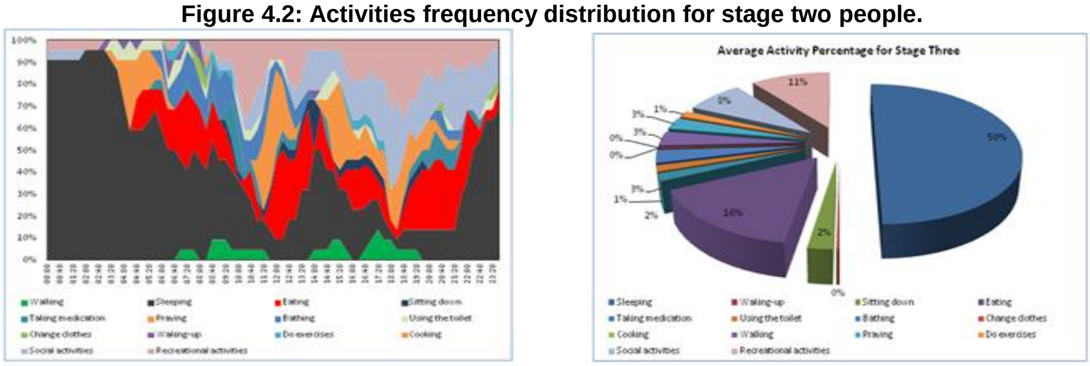

Figure 4.3: Activities frequency distribution for stage three people.

By examining Figure 4.1, results showed that sleeping activity forms a high percentage activity in comparison to other activities of around 42% on average, and contribute to a significant length of time and is distributed all over the 24-hours with small intervals where almost no one is asleep in the mid-day. Hence, sleeping activity is an important activity to be continuously monitored by the support system. Also from these results, the sleeping activity is not restricted to the bed room location and could be extended also to chairs and sofas around the house. Consequently, it should be detected in a manner that is not linked to the bed room location only, forcing special types of sensors such as image processing, gesture recognition, breathing rate detection, pulse rate, body temperature, and maybe voice detection as well. By examining Figure 4.2, results showed that the sleeping activity in this case for stage two people still forms a high percentage activity in comparison to other activities of around the same value of 42% on average, and contribute to a significant length of time and is distributed all over the 24-hours. Hence, the same requirements for monitoring apply in this case as well. However, by examining Figure 4.3, results showed that the sleeping activity average percentage is increased to around 50% for stage three people, while still distributed all over the 24-hours. Hence, the same requirements for monitoring apply in this case as well. Moreover, results showed in Figure 4.1 illustrates that the social activity is the second activity of high value of around 14% on average, and forms an important factor in quality of life for stage one people due to being still conscious and trying to keep engaged in life through social interactions.

The distribution of social activity over the 24-hours of the day seems to be in the interval from 6 AM up to late evening. Hence, social interaction activity is an important activity to be continuously monitored and assisted by the support system to make sure that the patient stage is not deteriorating. By examining Figure 4.2, results showed that social activity is not now the second priority activity for these stage two people contributing to around 10% average value, while eating activity becomes the second more important activity for stage two people with average value of 14%. As shown in Figure 4.3, it is clear that the second important activity is again eating activity for stage three people with an average value of 16%. By examining Figure 4.1, results showed that eating activity come in third place in importance for stage one people with average value of 12%.

Recreation activity comes afterwards for stage one people with an average percentage of 9%. For stage two people, recreational activity forms 11% on average on daily activities. For stage three people, the recreational activity again forms an average value of 11%. As illustrated, this recreational activity is not that important for stage one people due to being socially very active, while it is very important for stage two and stage three people due to being less socially active than stage one people. In fact, recreation activity is important for limiting the intense emotions that come from the patient feeling the progressing symptoms. By listening to quiet music or reading a story, people can resist the acceleration of the symptoms even with the lack of possible treatment drugs. This activity forces integration of special multi-media devices in the monitored environment with scheduled intervals to attract the patient to use them, especially in stage two and stage three.

Recreational activity may also require linking the physical parameters' detection of the patient by the environmental and multi-media devices operation time to form an assessment criterion for the effectiveness of delivering recreational activity to the patient. By examining Figure 4.1, praying activity for stage one people comes afterwards with an average value of 8%. From Figure 4.2, social activity comes afterwards with an average percentage of 10%, while praying activity comes after it with 8% on average. For stage three people in Figure 4.3, social activity come after recreational activity with an average value of 8%, while praying activity come afterwards with an average value of 3%.

These results imply that stage one people seem very active in praying activity and fully perform the five times prayers during the day with full conscious and determination. The same is also noticed for stage two people in respect of the praying activity, while it is clear that people in stage three lack losses determination in praying activity as the percentage of time spent in this activity drops to 3%, which could be linked to memory decline in this specific stage.

This is due to the fact that praying is compulsory for all adult Muslims and only drops when the person starts to lose control of his memory. Moreover, social activity is becoming important now for stage two patient as they tends to spend nearly three hours a day in social activities, while for stage three people the percentage is almost the same with a little drop in time spend in socializing. This result suggests that an increased engagement in praying activity for stage three people could help these people resist the advance of the symptoms and delay its effects on them. This is actually by boasting the spiritual feeling of the patient as well as having the praying in groups would also increase the feeling of social interaction that the patient is seeking. This is due to the fact that at this stage people need to be more communicative with either care providers or relatives. Hence, social interaction and group praying activity needs comprehensive detection and control from any assistive system through multi-media control and engagement. For example, the system could operate the TV on the channels that broadcast live or recorded group prayers, operate the Azan automatically in a timed fashion, and so on.

By examining Figure 4.1, we can deduce that bathing activity comes afterwards for stage one people with an average value of 4%, meanwhile in Figure 4.2, bathing activity has the same average value of 4% for stage two people, while in Figure 4.3, and bathing activity has an average value of 3% for stage three people. This implies that, although bathing activity is not taking much time during the day, less than an hour on average, it still an important activity to be scheduled and monitored by any assistive system due to the fact that being alone inside a closed toilet with hot running water and perhaps an operating boiler is a dangerous situation for a people' safety requirements and proper monitoring and scheduling should, therefore, be taken into consideration. Regardless of the safety requirement for monitoring bathing activity, the activity in itself is important for personal hygiene and comfort and fresh feeling for the patient has an influence on their mood and general wellbeing.

By examining Figure 4.1, we can find that walking activity is a less important activity for these stage people, with average value of 2% contributing to around half an hour each day. The same percentage may also noticed from Figure 4.2 for stage two people, while in Figure 4.3 it becomes 3% for stage three people. This result supports the idea that in this stage, people are more caring about their physical condition and ability to wander around the space they are living in for a short walk (Logsdon, Teri et al. 1998). For stage three people, this result may support the idea that in this stage, people are living with the wandering behaviour due to advance in the symptoms that results in increased walking activity (Logsdon, Teri et al. 1998). This walking activity in general is open space dependent and can be monitored via motion sensors distributed in the home domain as well as by gesture recognition equipment and other physiological signs detection, while the wandering state in itself may need more pattern recognition mechanisms to distinguish the wandering state from normal walking activity.

By examining Figure 4.1, 4.2, and 4.3, we can see that only stage two and stage three people have scheduled medication time. This means that any assistive system should have the ability to sort, alarm, and deliver medicines to people at proper scheduled times. This possibility can also be implemented in stage one people if needed, while in this stage, it is clear that people are still able to sort, alarm, and deliver medicines for themselves without need for assistance. The toilet usage activity, as indicated in Figure 4.1, has an average percentage value of 4% for stage one people, indicating normal dietary behaviour for people in this stage. By contrast, the toilet usage activity, as indicated in Figure 4.2, has an average percentage value of 2% for stage two people, indicating reduced dietary behaviour as a result of the progress of the symptoms. However, this toilet usage activity, as indicated in Figure 4.3, has an average percentage value of less than 1% for stage three people, indicating highly reduced dietary behaviour, because most of the people in the late stages eat less and so use urinal equipment less also.

By examining Figures 4.1, 4.2, and 4.3, we can see that cooking, sitting down, changing clothes, waking up and performing exercise activities come afterwards with an average value of 1% each. This is a realistic result because some of these activities are not from the basic daily life activities performed by the patient. In Figure 4.2 “do exercise” and “waking up” have the same average value of 1%. Also in Figure 4.3 “do exercise” has the same average value of 1%. So the monitoring of these activities is subjected to individual patient requirements, and in many cases is limited to safety needs of the people only.

Figure 4.4 summarises the fourteen identified common daily life activities distribution percentage over one full day for the observed people.

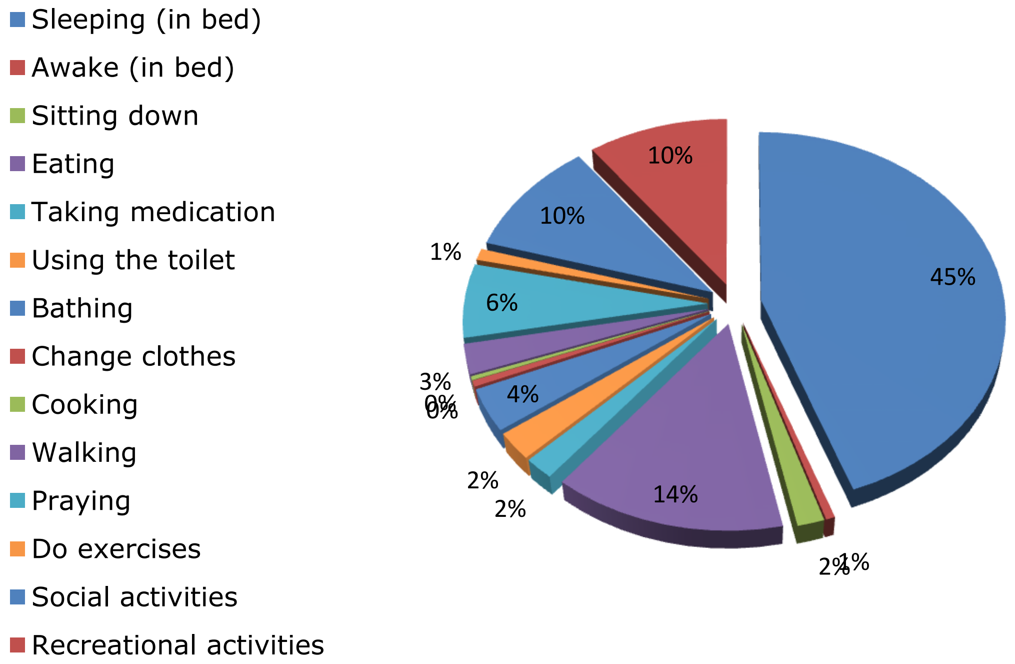

Figure 4.4 Common daily activities frequency distribution.

4.2.2 Observation data analysis

Observation samples specifications and work related characteristics of the subjects included in the study are given in Table 4.1. Among 48 observable subjects, 34 (71%) were male and 14 (29%) were female. Most of the subject's age falls between 50 and 80. There were around 8% between the ages of 50 and 60, another 19% between the ages of 60 and 70, around 49% between the ages of 70 and 80, where around 25% were over the age of 80. If we consider the stages of Alzheimer's, we find that 23% are at stage one, 46% are at stage two, while 31% are at stage three. All of the observed subjects were living in their own homes or with their family members, with around 38% living in their own homes. Of course it was expected that most or all of the observed subjects have different types of health problems in addition to Alzheimer's. Table 4.1, gives the percentage and type of each health related problems recorded among the observed subjects. More than three quarters of the observed subjects were living with

Diabetes Mellitus and Hypertension, where one quarter of them living with Hearing loss, Heart problems, or loss of vision disorder.

The distributions in different stages of Alzheimer's in both genders are illustrated in Figure 4.5. From the observation analyses, the idea is to locate any relationship between subjects activities in respect with others chronic and non-chronic problems of aging people. These relations are summarised in Table 4.2 for the presence of arthropathy with osteoporosis and their effect on daily life activities. Table 4.3 gives these relations in the case of heart problems, hypertension and stroke, Table 4.4 gives these relations in the case of sleep disturbance, diabetes, depression, Parkinson's disease and cancer, and Table 4.5 gives these relations in the case of lung disease, hearing loss and vision problems.

Table 4.1: Descriptive analysis of observations.

Variable	Scale/category	N	%®
Age (yrs.)	71-80 >80 61-70 51-60 <=40 41-50	23 12 9 4 0 0	47.9% 25% 18.8% 8.3% 0% 0%
Gender (—)	Male Female	34 14	70.8% 29.2%
Stage of the symptoms	Mild Alzheimer's Moderate Alzheimer's Mild cognitive impairment	22 15 11	45.8% 31.3% 22.9%
Place of residence	Live with family Own house Hospital Care home	30 18 0 0	62.5% 37.5% 0% 0%
Medical conditions*	Diabetes mellitus Hypertension Vision and eye diseases Heart disease Hearing loss Sleep disorder Depression Lung disease Osteoporosis Parkinson's disease Arthropathy Cancer Other disease	37 36 12 11 11 9 8 5 5 5 3 3 2	77.1% 75% 25% 22.9% 22.9% 18.8% 16.7% 10.4% 10.4% 10.4% 6.3% 6.3% 4.2%

* A respondent may have one or more conditions.
® Sorted in descending order.

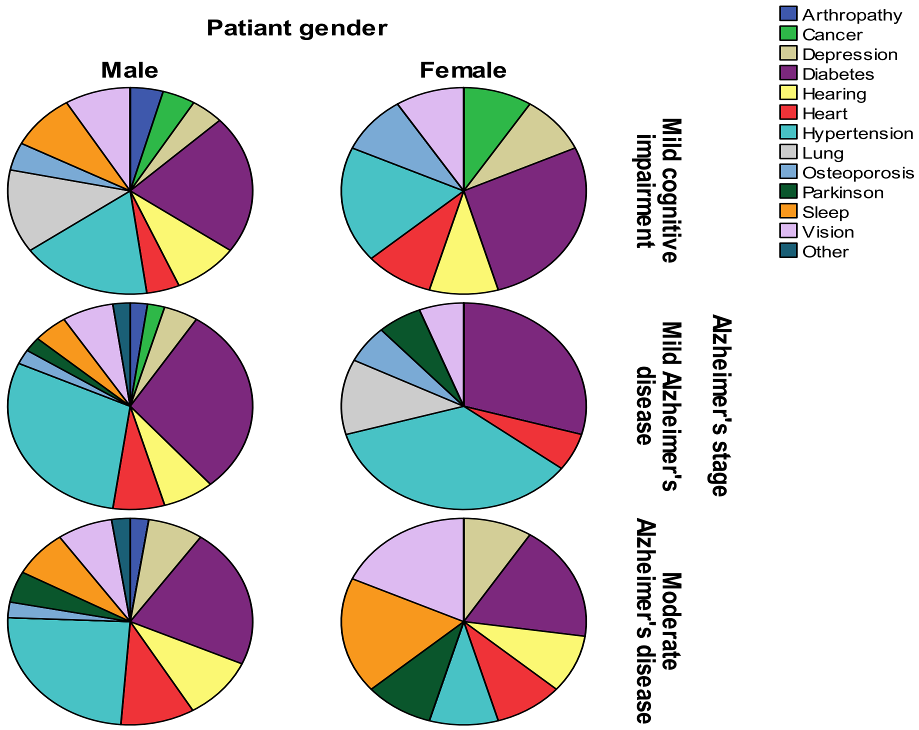

Figure 4.5: Symptoms distribution in different stage in both genders.

Table 4.2: Arthropathy with osteoporosis.

	Grouping variables													
	Bathing	Changing clothes	Cooking	Doing exercise	Eating	Praying	Recreational activities	Sitting down	Sleeping	Social activities	Taking medication	Using the toilet	Waking up in bed)	Walking
Arthropathy														
Mann-Whitney U	56	54	45	26	57	44	42	53	26	45	58	54	45	48
Wilcoxon W	1091	60	1080	1061	63	50	1077	59	32	1080	64	51	51.0	1083
Z	-.5	-.845	-3.873	-2.596	-.470	-1.0	-1.1	-.900	-1.7	-.971	-.454	-.623	-1.1	-1.06
Asymp. Sig†	.62	.398	**.000**	.009	.638	.309	.262	.368	.077	.331	.650	.533	.239	.288
Osteoporosis														
Mann-Whitney U	88	85	105	85	72	99	77	92	82	55	58	96	92	63
Wilcoxon W	102.5	100	120	100	1018	114	92	1038	97	1001	73	111	107	1009
Z	-.687	-1.11	-.341	-1.11	-1.20	-.292	-1.06	-.761	-.878	-1.81	-1.89	-.406	-.643	-1.94
Asymp. Sig†	.49	.26	.73	.26	.22	.77	.28	.44	.38	.07	.05	.68	.52	.05

	2	4	3	5	9	0	7	7	0	0	8	5	0	2

† 2-tailed
‡ 2*(1-tailed Sig.). Not corrected for ties

When analysing the results of bone disease with activities, we find that strong significance is present in cooking activity and with doing exercise activity. But no effect on the others activities. Meaning that this disease results in reduced cooking and exercising activity.

Table 4.3: Heart disease, hypertension, and stroke.

	Grouping variables													
	Bathing	**Changing clothes**	**Cooking**	**Doing exercise**	**Eating**	**Praying**	**Recreational activities**	**Sitting down**	**Sleeping**	**Social activities**	**Taking medication**	**Using the toilet**	**Waking up in bed**	**Walking**
Heart disease														
Mann-Whitney U	185	181	198	185	182	204	175	174	196	167	196	139	165	191
Wilcoxon W	251	247	264	888	885	270	878	240	899	870	262	205	231	894
Z	-.462	-.811	-.545	-.667	-.542	.000	-.735	-1.0	-.196	-.920	-.220	-1.66	-1.16	-.392
Asymp. Sig†	.644	.417	.586	.505	.588	1.00	.462	.308	.844	.358	.826	.096	.246	.695
Hypertension														
Mann-Whitney U	202.5	210.0	210.0	210.0	199.0	155.5	199.5	187.5	181.0	196.0	187.5	184.5	199.5	171.5
Wilcoxon W	280.5	288.0	288.0	288.0	865.0	233.5	277.5	853.5	847.0	274.0	265.5	262.5	277.5	837.5
Z	-.327	-.210	-.577	-.210	-.406	-1.45	-.406	-.95	-.83	-.483	-.761	-.784	-.483	-1.35
Asymp. Sig†	.743	.834	.564	.834	.685	.143	.685	.339	.404	.629	.447	.433	.629	.175
Stroke														
Mann-Whitney U	11.0	37.0	45.0	37.0	17.5	29.5	17.00	36.0	29.5	45.5	26.0	18.0	39.0	39.5
Wilcoxon W	14	40	48	40	20.5	1111	1098	39	1111	1127	29	21	1120	1121
Z	-1.83	-.682	-.209	-.682	-1.4	-.866	-1.54	-.72	-.85	-.026	-1.1	-1.5	-.444	-.429
Asymp. Sig†	.066	.495	.835	.495	.140	.386	.122	.467	.394	.979	.247	.131	.657	.668

† 2-tailed
‡ 2*(1-tailed Sig.). Not corrected for ties

When analysing the results of cardiovascular diseases, we find that there are no any significant affect between those diseases with any of the 14 activity.

Table 4.4: Sleep disturbance, diabetes, depression, Parkinson and cancer.

	Grouping variables													
	Bathing	Changing clothes	Cooking	Doing exercise	Eating	Praying	Recreational activities	Sitting down	Sleeping	Social activities	Taking medicatio	Using the toilet	Waking up in bed	Walking
Depression														
Mann-Whitney U	153	145	140	151	151	139	149	120	148	154	121	158	152	115
Wilcoxon W	189	181	960	187	187	175	185	156	968	190	157	978	188	935
Z	-.211	-.610	-2.2	-.366	-.250	-.591	-.329	-1.5	-.34	-.16	-1.21	-.05	-.28	-1.59
Asymp. Sig†	.833	.542	.025	.715	.803	.555	.742	.11	.729	.866	.226	.954	.773	.111
Cancer														
Mann-Whitney U	61	54	66	54	48	42	67	53	57	63	58	59	67	68
Wilcoxon W	1096	60	72	108	108	1077	1102	59	63	1098	64	65	73	74
Z	-304	-.845	-.258	-.845	-.833	-1.105	-.022	-.900	-.469	-.216	-.454	-.401	-.026	.000
Asymp. Sig†	.761	.398	.796	.398	.405	.269	.982	.37	.639	.829	.650	.689	.979	1.00
Sleep disturb														
Mann-Whitney U	171	135	156	137	130	87	118	156	135	152	158	131	130	173
Wilcoxon W	951	180	936	917	910	132	898	936	180	197	938	176	175	953
Z	-.121	-1.57	-2.08	-1.5	-1.2	-2.378	-1.570	-.74	-1.08	-.629	-.533	-1.24	-1.47	-.084
Asymp. Sig†	.904	.116	.037	.130	.228	.017	.117	.457	.278	.529	.594	.214	.140	.933
Parkinson														
Mann-Whitney U	93	106	105	85	78	87	90	83	106	93	106	66	86	82
Wilcoxon W	108	121	120	100	93	102	105	98	121	108	1052	1012	1032	1028
Z	-.498	-.074	-.341	-1.11	-1.01	-.721	-.628	-1.18	-.051	-.513	-.076	-1.48	-.891	-1.10
Asymp. Sig†	.618	.941	.733	.265	.310	.471	.530	.234	.960	.608	.940	.139	.373	.271
Diabetes														
Mann-Whitney U	201	178	198	199	198	176	163	173	186	198	175	149	165	176

Wilcoxon W	904	244	264	265	264	879	229	239	889	901	241	852	231	879
Z	-.075	-.919	-.545	-.180	-.135	-.699	-1.07	-1.07	-.430	-.149	-.784	-1.39	-1.16	-.878
Asymp. Sig†	.940	.358	.586	.857	.892	.485	.305	.284	.667	.881	.433	.162	.246	.380

† 2-tailed

‡ 2*(1-tailed Sig.). Not corrected for ties

When analysing the results of neurological diseases and chronic diseases of diabetes with activities, we find only significant effect on doing cooking and when the patient is doing praying but there are no effect on the others activities. Meaning that sleeping disorder can result in disturbed praying activity pattern. Also, depression can be detected from unusual cooking activity pattern.

Table 4.5: Lung disease, hearing loss and vision problems.

	Grouping variables													
	Bathing	**Changing clothes**	**Cooking**	**Doing exercise**	**Eating**	**Praying**	**Recreational activities**	**Sitting down**	**Sleeping**	**Social activities**	**Taking medication**	**Using the toilet**	**Waking up in bed**	**Walking**
Lung disease														
Mann-Whitney U	106	82	105	85	96	103	99	87	105	95	99	93	72	95
Wilcoxon W	121	1028	120	100	111	1049	1045	1033	120	1041	114	1039	1018	110
Z	-.069	-1.26	-.341	-1.11	-.406	-.155	-.314	-.975	-.101	-.445	-.341	-.511	-1.49	-.561
Asymp. Sig†	.945	.206	.733	.265	.684	.877	.754	.330	.919	.657	.733	.609	.136	.575
Hearing lose														
Mann-Whitney U	160	202	198	106	176	101	189	116	193	200	199	197	187	155
Wilcoxon W	863	905	264	809	242	167	892	819	896	903	902	263	253	221
Z	-1.08	-.054	-.545	-3.51	-.677	-2.558	-.380	-3.0	-.258	-.087	-.124	-.179	-.497	-1.5
Asymp. Sig†	.277	.957	.586	.000	.498	.011	.704	.002	.797	.931	.901	.858	.619	.128
Vision problem														
Mann-Whitney U	203	162	198	191	136	142	212	162	181	213	199	177	126	181
Wilcoxon W	869	240	864	857	802	220	878	828	259	879	277	255	204	847
Z	-.327	-1.88	-1.73	-.892	-1.9	-1.8	-.111	-1.82	-.846	-.084	-.454	-.970	-2.63	-1.0
Asymp. Sig†	.743	.059	.08	.372	.054	.07	.912	.06	.39	.933	.650	.332	.008	.287

			3			1		7	7					

† 2-tailed **‡ 2*(1-tailed Sig.). Not corrected for ties**	When analysing the results of chronic disease and its complications with the activities we find that strong significant effect on doing exercise in case of hearing lose disease and on praying activity as well as sitting down activity , while waking up is affected by vision problems, while there are no effect on the others activity.

4.3 Professionals' opinion results

In this study, fifty professionals' participants with the particular knowledge, expertise, and skills were selected to conduct the survey. Ten out of fifty participants' responses were excluded due to uncompleted questionnaires. In order to measure the agreement, the weighted average methods was used as a means of understanding the professionals decision on the importance of the standards (Greatorex and Dexter 2000). The standards were considered to be important with "*if ≥60 % of the respondents were in agreement*" (Alshehri 2015, Mundt and Connors 1999). The number of the professional's participant was 29 males and 21 females as given in Table 4.6.

Table 4.6: Professionals details.

Variable	Scale/category	N	%*
Gender (—)	Male Female	23 17	57.5% 42.5%
professionals' job title	Specialist-Family medicine Consultant – Geriatric Nurse – Other Physiotherapist Doctor – Geriatric Carer – Geriatric Nurse – Geriatric Consultant – Psychiatric Specialist – Geriatric Occupational therapist Specialist – Psychiatric Doctor – Psychiatric Nurse – Psychiatric Carer – Psychiatric	17 6 4 3 2 2 2 2 1 1 0 0 0 0	42.5% 15.0% 10.0% 7.5% 5.0% 5.0% 5.0% 5.0% 2.5% 2.5% 0.0% 0.0% 0.0% 0.0%
practice of the profession (yrs.)	Between 5 and 10 years More than 10 years Between 1 and 5 years Less than 1 year	17 9 7 7	42.5% 22.5% 17.5% 17.5%

The ability and willingness of the participants to follow the interview in the future if necessary.	Yes No	31 9	77.5% 22.5%
The way of communicate with the participants to follow the interview in the future if necessary.	Email Post Telephone	37 2 1	92.5% 5.0% 2.5%

* Sorted in descending order.

Table 4.7: Patient information from professional's records.

Variable	**Scale/category**	**N**	**%***
Gender (—)	Male Female Don`t know/ not sure	20 14 6	50.0% 35.0% 15.0%
Age groups for patient's reviewers	61-70 71-80 51-60 Over 80 40-50 Less than 40	14 10 7 4 3 2	35.0% 25.0% 17.5% 10.0% 7.5% 5.0%
Residence of people	In their own homes In a hospital In a specialized care home	28 8 4	70.0% 20.0% 10.0%

* Sorted in descending order.

According to the gender identification section in the questionnaires, the gender percentage of both sexes was found to be very close to each other as 57% and 43% for men and women, respectively, while their age hitting above 70 years for the majority of cases whereas it has been found that 5% of them were below 40 years old. The study shows that the majority of the surveyed subjects prefer to have the service provided to them in their homes with a percentage of 70%. Hence, the importance of designing intelligent assistive healthcare systems for older people in their own homes that reduced the dependency on relatives or care workers is highly appreciated by them to complete their life in an independent and safe way. For the professional's identification question, the study shows generally equal gender percentage between professionals. The study included professionals concerned with home healthcare in families and for older people. Most of the professionals specialise in family medicine and most of the hospitals surveyed contained a section classified under older people care and home healthcare assistance. Moreover, most of the professionals were of at least five years or more in the profession, while around 17% of the surveyed professionals were with more than ten years' experience in the profession.

4.3.1 Common behaviours' results

In this category of questions, the main aim was to collect professional's observations for subjects' daily life activities and provide opinion about common activities and with the possibility of performing some of these activities that required human support only with an artificial agent.

Table 4.8: Alzheimer's people common behaviours.

Option	Responders					Mean*
	1	2	3	4	5	
1. Taking longer than usual to finish routine daily tasks.	1	0	3	18	18	4.30
2. Getting lost (wandering).	1	1	3	19	16	4.20
3. Repetitive questions and conversations	1	0	7	15	17	4.18
4. Noticeable changes in personality or mood.	1	1	4	18	16	4.18
5. Losing things.	1	0	4	21	14	4.18
6. Difficulty managing money.	1	0	5	22	12	4.10
7. Poor judgment	1	2	4	19	14	4.08
8. Apathy	1	1	6	20	12	4.03
9. Falling	1	3	5	19	12	3.95

1= Strongly disagree, 2= Disagree, 3= Neither agrees nor disagrees, 4= Agree, 5= Strongly agree
* Sorted in descending order.

Table 4.9: Patient behaviour in different stages.

Option	Responders					Mean*
	1	2	3	4	5	
1. It is necessary to have a family member living with Alzheimer's people permanently.	2	1	3	14	20	4.23
2. The behaviour of Alzheimer's people changes if she/he lives with other aging-associated problems.	1	1	2	25	11	4.10
3. Symptoms demonstrated by male and female Alzheimer's people are same at a given stage.	1	5	13	18	3	3.43
4. Alzheimer's people in early and mild stages can live independently in his/her own home.	5	9	7	11	7	3.15

5. Early and mild stage Alzheimer's people may present danger to others.	2	12	9	14	3	3.10
6. The behaviour of Alzheimer's people in hot climate (e.g. in KSA) is different to people from colder climates.	4	8	16	9	3	2.98

1= Strongly disagree, 2= Disagree, 3= Neither agrees nor disagrees, 4= Agree, 5= Strongly agree
* Sorted in descending order.

Table 4.10: Patient religious practices.

Option	**Responders**					**Mean***
	1	**2**	**3**	**4**	**5**	
1. Daily religious practices may impact positively on Alzheimer patient's condition.	1	2	5	19	13	4.03
2. Early and mild stage Alzheimer's people engage normally with their religious practices, including prayer.	1	3	10	21	5	3.65
3. Early and mild stage Alzheimer's people may forget to pray or forget to perform ablution.	1	4	8	21	5	3.64
4. Fasting during Ramadan may have positive impact on Alzheimer's people' condition.	1	6	13	14	5	3.41
5. Fasting may amplify people' Alzheimer's symptoms, including memory loss and panic attack	1	8	12	14	5	3.35
6. During Ramadan, early and mild stage Alzheimer's people can fast as normal.	1	11	9	13	5	3.26
7. Early and mild stage Alzheimer's people can keep proper timing of the start and end of the fasting.	2	12	10	11	5	3.13

1= strongly disagree, 2= Disagree, 3= Neither agrees nor disagrees, 4= Agree, 5= Strongly agree, * Sorted in descending order.

In this group of questions, professionals were asked about the common behaviour which they have noticed in their people in coordination with the list provided in the questionnaire. It has been found that 88% of the professionals listed the common behaviours were common among their people. Further, it was found that 51% of Alzheimer's people can live independently in their house, especially if the illness is in the early or moderate stage. While the contradicting 49% of them clarified their opinion as a result of a lack of an intelligent support system that can support their life without risk and without human supervision, while around 89% of the professionals agreed with the proposition that the presence of a family member with the patient makes life smoother and easier for them. When asked about the behaviours of the people towards others, 53% of the professionals claimed that people form no risk or aggression towards other people, especially in the early and moderate stages. Moreover, half of the professionals agree that weather conditions has limited effect on the patient behaviour towards others, while 89% agreed that gender has no effect on general behaviour. Concerning the behaviour in Ramadan for people, professionals indicated that in early and moderate stages, people perform fasting and eating normally within the allowed hours with limited effect on behaviour change. Around 63% indicated that engaging in fasting activities in Ramadan has positive effect on their people. They indicated that in early stages, people are aware of their health condition and feel that engaging in fasting activities will give them the feeling of self-confidence that he or she still healthy enough to fast and practice the activities of Ramadan, while they encourage their people to engage in fasting activities to boast their emotional feelings to keep good health and to feel equality with healthy people. However, professionals indicated that fasting is not recommended in later stages due to dehydration possibilities that could affect blood circulation, which could affect brain functionality and increased bad temper behaviour. In late stages, fasting could also increase memory loss, and panic, with around 63% of the professionals in agreement to this. When asked about the ability of people to practice their religious activities such as praying, around 70% of the professionals indicated that in early and moderate stages there is no obligation or evidence against such activities. Moreover, around 80% of the professionals claimed that practicing religious activities has a positive effect on Alzheimer’s people, including reciting Quran sessions.

4.3.2 Home design results

This section presents the most important effects of home design on the Alzheimer's people. The main aim of this was to include this questionnaires to collect professionals observations for best environmental factors to support people assuming living alone, and to provide opinion about how these factors could affect the health and ease of life of them in case they live alone.

Table 4.11: **Factors affecting Alzheimer's people' behaviour.**

Option	Responders					Mean*
	1	2	3	4	5	
1. Opening and closing of windows.	1	4	6	17	12	3.88
2. Bright interior lighting (e.g. high illumination).	2	3	4	22	9	3.83
3. Ventilation system in the house.	1	3	8	18	10	3.83
4. Furniture size.	1	2	9	19	9	3.83
5. Bright natural light (e.g. through bigger windows).	2	3	8	17	10	3.75
6. Furniture shape.	2	2	9	18	9	3.75
7. Spaciousness of rooms or the lack of it.	2	1	7	24	5	3.74
8. Changes in level (floor) inside the house.	5	0	8	15	12	3.73
9. Bright coloured walls and surfaces.	1	3	10	18	8	3.73
10. The presence of doors separating different rooms.	3	3	7	17	10	3.70
11. The presence of elevator or stair lift.	4	3	10	13	10	3.55
12. The presence of stairs inside the house.	6	3	8	13	10	3.45

1= Strongly disagree, 2= Disagree, 3= Neither agrees nor disagrees, 4= Agree, 5= Strongly agree

* Sorted in descending order.

Table 4.12: Ideal design for the bedroom.

Option	Response Percent
Bedroom with ensuite bathroom	90.0%
Bedroom without ensuite bathroom	10.0%

Table 4.13: Relationships between bedroom and kitchen.

Option	Response Percent
Bedroom adjacent to the kitchen	47.5%
Bedroom far away from the kitchen	35.0%
Bedroom integrated with the kitchen (e.g. Studio)	17.5%

Table 4.14: Relationships between bathroom and sitting room.

Option	Response Percent
Bathroom adjacent the Sitting room	90.0%
Bathroom far from the Sitting room	10.0%

Table 4.15: Relationships between kitchen and sitting room.

Option	Response Percent
Sitting room adjacent the kitchen	50.0%
Sitting room far from the kitchen	27.5%
Sitting room integrated with the kitchen	22.5%

Furthermore, subjects' homes are also found to be one of the key aspects that need to be observed and analysed in detail from proper system design. According to the questionnaires response, the following factors were found to be important to be considered during design phase.

1- Presence of stairs inside homes, if any.

2- Presence of separating doors between areas, if any.

3- Presence of lifts, if any.

4- Change of floor level inside homes, if any.

5- Internal lighting intensity.

6- Natural light refection internally through wider windows.

7- Bright wall painting.

8- Area of rooms and spaces.

9- Ease of opening and closing windows.

10- Ventilation system effectiveness.

11- Size, layout, and shape of furniture.

The factors mentioned above are very important and have high impact on the patient's daily life activities. For example, the majority of people prefer bright wall painting, as well as in-suite bathroom facility within their bedroom. According to the questionnaires, it has been found that 98% of the people who live alone prefer to have the kitchen nearby to the bedroom. However, about the 50% of people who live as a couple prefer to have the kitchen nearby to sitting room. Further, it has been found that 90% of the people prefer to have the sitting room closer to the toilet.

4.3.3 AAL technology design results

In this category of questions, the main aim was to collect professionals' observations for the best sensing and monitoring practice for different variables needed to support patient's daily life, and provide opinion about the voice and vision sensors perception by people.

Table 4.16: Sensors needed for the development of AAL.

Option	Responders					Mean*
	1	2	3	4	5	
1. Smoke detectors to monitor the occurrence of fire.	0	2	2	12	24	4.45
2. Carbon monoxide detectors to monitor the risk of poor air quality and its impact on heart conditions.	0	3	3	13	21	4.30
3. Cooker sensors for monitoring the operation of oven and hobs	0	1	6	15	18	4.25
4. Water flow sensors on taps and water outlets to identify water leakage inside the house	0	2	6	14	18	4.20
5. Door sensors to detect movement from/to spaces, houses or escapes	0	1	7	16	16	4.18
6. Pressure sensor/pads in the bed are a convenient method to monitor cases of falls.	1	1	6	17	15	4.10
7. Coded main door lock to prevent the patient from leaving home	0	3	6	15	16	4.10
8. Motion sensor (infrared) in the room is useful to monitor patient's movement and location.	0	3	4	20	13	4.08
9. Loop sensors on the patient to monitor vital signs (temperature, blood pressure, heart rate).	0	3	6	18	13	4.03
10. Using Maze chain lock at the main door to prevent the patient from leaving home.	1	4	5	15	15	3.98
11. Sensors for monitoring the opening/closing of refrigerator.	0	2	12	13	13	3.93

1= Strongly disagree, 2= Disagree, 3= Neither agrees nor disagrees, 4= Agree, 5= Strongly agree

* Sorted in descending order.

Table 4.17: Spaces inside house that require monitoring

Option	Response Percent
Bathroom/ toilets	85.0%
Bedrooms	82.5%
Kitchen	75.0%
Stairs	75.0%
Corridors	55.0%
Laundry room	50.0%
Sitting room	40.0%
Study/ home office	25.0%
Lobby/ foyer	25.0%

Table 4.18: Spaces that should be monitored using CCTV

Option	Response Percent
Kitchen	77.5%
Stairs	72.5%
Bedrooms	70.0%
Corridors	62.5%

Sitting room	45.0%
Bathroom/Toilets	40.0%
Laundry room	40.0%
Lobby	35.0%

Table 4.19: Spaces that should be monitored using sound detection

Option	Response Percent
Bedrooms	37.5%
Bathroom/Toilets	27.5%
Sitting room	12.5%
Kitchen	7.5%
Corridors	5.0%
Lobby	5.0%
Laundry room	2.5%
Stairs	2.5%

Table 4.20: **Exterior space should be monitored by using CCTV**

Option	Response Percent
Yes all spaces including balcony and backyard	70.0%
Yes but only the balconies that are on the first floor	12.5%
Not sure/ don't know	12.5%
There is no need to monitor exterior spaces	5.0%

According to the results collected from professionals' opinion, the majority of the professionals agreed that the following elements are important for the success of the monitoring process:

1- Pressure sensors inside beds to monitoring sleeping quality and falling from bed detection.

2- Infrared sensors for motion detection of people inside rooms are important for location identification and motion pattern identification.

3- Smoke and fire detection system for general safety and early alarming in dangerous situations.

4-Carbon-Monoxide detection for ventilation quality detection to secure normal breathing environment.

5-Water flow sensors for flooding detection and early alarming.

6-Wearable sensors for vital signs monitoring on people' limbs.

7-Kitchen appliances sensors, especially hub and oven for gas and temperature identification.

8-Main door coded opening or chained for un-authorised patient exit prevention, especially for the people who live with orientation and focus deterioration illnesses.

Furthermore, it has been found that the majority of the professionals agreed that bathroom, bedroom, kitchen, and stairs have to be observed and monitored in the system. The importance of these places is ordered from most important to least important as bathroom, bedroom, kitchen, and stairs. To observe the places using vision system, the order should be kitchen, stairs, bedroom, and corridors. The importance of indoor sound recognition in living spaces and bedrooms was also highlighted by professionals. Furthermore, the outside of living place should also be observed using video surveillance to keep any intruders out of the patient's premises.

4.4 Discussion

4.4.1 Activities and behaviour characteristics

There are a lot of studies that considered older people with Alzheimer's and sleeping disorder (Foley et al. 2004) as a target to monitor and improve. In the conducted survey, results indicated that there is a high percentage of sleeping activity between older people, especially in the late stages of older people with Alzheimer's, hence it is important to observe patient's sleeping activity continuously using monitoring and decision support system to maintain patient safety. Moreover, social interaction is an important activity type to be continuously monitored and assisted by the monitoring and decision support system to make sure that the patient's wellbeing is not deteriorating.

Again, social interaction activity is not restricted to specific locations within the patient's home, while mostly being performed in the living room, special detection and monitoring means are required. Consequently, special types of sensors such as image processing, gesture recognition, breathing rate detection, pulse rate, body temperature, and voice detection are required for such activities to monitor and supply information to the decision support system. Moreover, it is clear that people in stage three of older people with Alzheimer's may lack determination in praying activity as the percentage time spent on this dropped to 3%. This is due to the fact that praying is compulsory for all adult Muslims and only drops when the person loses control over his memory. Moreover, social activity is becoming important now for stage two and three people as they tend to spend nearly three hours a day in social interactions.

This result suggests that an increased engagement in praying activity for stage three people could help them resist the advance of the symptoms and delay its effects on the patient. This accords with the idea that social interaction for Alzheimer's people delays the progress of the symptoms, as reported in (Teri et al. 2008).This is actually by boosting the spiritual feeling of the patient and hence praying in groups would also increase the feeling of social interactions that the patient is seeking. Additionally, the increase in eating time percentage with the advance of stage confirms the fact that with the advanced stage of the disease, people tend to eat more snacks frequently during the day due to lack of social or physical interactions with other as well as sometimes forgetting about already having eaten the required meals. Also, people tend to like having frequently snacks from time to time as a feeling of happiness is generated when they do. Also, results show that recreational activity is not that important for stage one Alzheimer's people due to being socially active, while it is very important for stage two and stage three people due to being less socially active than stage one people. In fact, recreational activity is important in terms of limiting the intense emotions that come from the patient feeling the progressing symptoms. Hence, recreational activity may also require linking the physical parameters detection of the patient to the environmental and multi-media devices operation to form an assessment criterion for the effectiveness of delivering recreational activity to the patient such as multi-tasking while walking (Camicioli et al. 1997). Walking activity as a recreational method is space dependent and can be monitored via motion sensors distributed in the home domain as well as gesture recognition equipment and other people physiological signs detection, while the wandering state in itself may need more pattern recognition mechanisms to distinguish the wandering state from normal walking activity.

Moreover, it has been found from the survey that the questions and observations are sufficient to identify the needs of older people including those with Alzheimer’s. The majority of the professionals agreed that Alzheimer's people in their early stages are harmless. Moreover the climate condition does not affect the behaviour of this group of people. However, it has been found in the literature that there is a correlation between death rates and climate condition for Alzheimer’s people (McGeehin and Mirabelli 2001, Van Hoof et al. 2010). Further, all the professionals agreed that the people' behaviours change with different extra aging problems. Also they agreed that people in the late stages cannot live independently without the help of relatives or technical assistance. Consequently, it is necessary to have a family member living with Alzheimer's people permanently in the advanced stages as indicated in (Lee 2003). According to these discussions, the requirements and specifications of an effective AAL system are identified and presented in Figure 4.6, which summarises the common opinions of professionals forming the main skeleton of the AAL system to provide a safety environment for older people including those with Alzheimer’s. The figure reflects the categorization of previous studies in relation to the application of the AAL system developed, the structure of the AAL system used, behaviours of older people, type of sensors used, and home layout functional design.

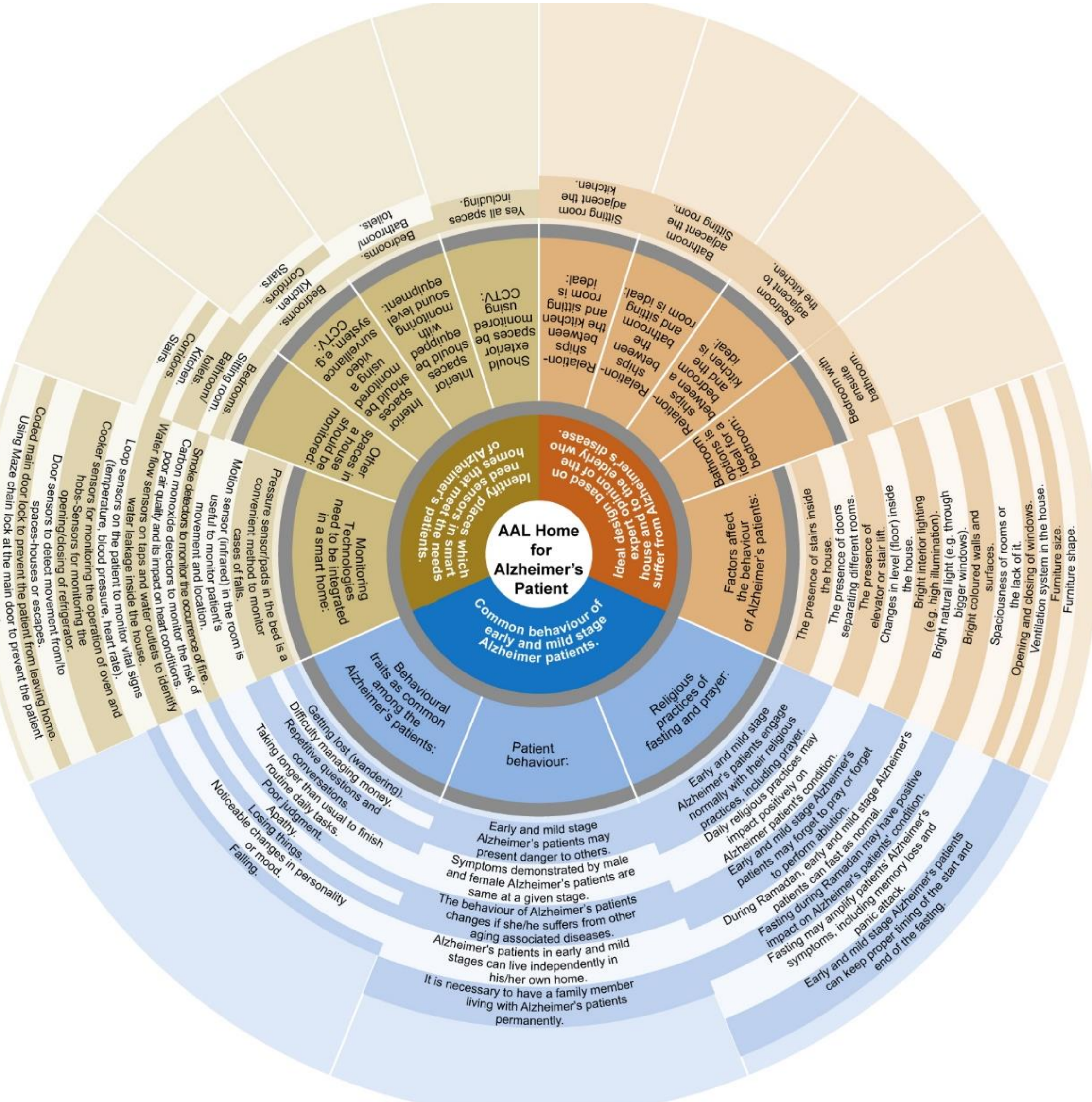

Figure 4.6: Ambient Assisted living for Alzheimer's people.

4.4.2 Environmental effect on design

It is important to have healthcare providers' opinions to design a safe condition for the patient to avoid hazards. Thus, questions are mostly focused on extracting the healthcare providers' opinions about environmental safety conditions for Alzheimer's people. As their assessment is based on their observation and understandings during the interaction with people in care homes, hospital spaces, and patient's behaviour over their working life. Healthcare providers were asked about the most effective factors in home layout for Alzheimer's people. The most important factors have been found as the presence of stairs is a dangerous situation for possible fall of the subject, style of the doors, presence of elevator, brightness of the interior lightening, colour of walls, number of the rooms, existence of the ventilation system, furniture types, and sizes. These are the most important factors needed to be considered while designing a house for Alzheimer people (Brawley 1992).

About 90% of the professionals agreed that the presence of the in-suite bathroom is required for this group of people. Furthermore about 47.5% of these professionals agreed that the presence of the bedroom adjacent to the kitchen is also another needs for these people. In addition to that, most of the professionals agreed that the presence of the bathroom adjacent to the sitting room is also required for these people. Moreover, half of the professionals agreed that the presence of the sitting room adjacent to the kitchen is also required for these people. In the questionnaires, professionals were asked about their opinion in relation to monitoring technologies. They all agreed that the suggested monitoring technologies for Alzheimer's people are adequate. They were also asked about the priority of the locations to be monitored. According to the results, Bathrooms/Toilets have to be monitored more than all others due to hazard of falling. The second important locations in the house should be any stairs, kitchens, and bedrooms. The third level priority should be given to corridors to monitor patient’s safety while walking (Lawton 2001).

Moreover, they were also asked about using video surveillance for continuous monitoring of people. According to professional's opinion, 77.5% of them agreed that the most important location to be monitored using this method is the main bedroom. The second important location was found to be the stairs. Kitchens were found to be the third important location to be observed in this way. Finally, corridors were selected as the fourth important place in the house to be monitored.

Lastly, professionals were asked regarding the use of sound sensors. About 37.5% of them greed that the bedroom is the best location to be equipped with sound sensors. The second important location found to be Bathroom/Toilets. The sitting room was the third place to be monitored with sound sensors, where 12.5% of professionals agreed about this. Finally, kitchen was the fourth important place to be monitored with sound sensors, where 7.5% of the professionals agreed to this monitoring. Furthermore, about 70% of the professionals agreed to have video surveillance on the balcony and backyard to monitor exterior spaces. Finally, Figure 4.6 illustrates a final questionnaire survey model for an AAL home design for older people including those with Alzheimer's.

From Healthcare professionals' response, it was clear that cleanliness of living space and ease of motion within the house were considered to be very important and had the highest concerns among people. With reference to 'air quality and freshness', it was found that it is the second important environmental factor for individuals living alone. The 'High Noise level' was found to be the third uncomfortable environmental factor for people Alzheimer's. The 'Thermal comfort' was considered as the fourth important environmental aspect for people' easiness. The sensation of comfort depends on many variables such as indoor air temperature, metabolism, clothing insulation, ability to modify/control the indoor environment, etc. The effect of environmental factors on thermal comfort is clear for naturally ventilated buildings, compared to fully air-conditioned buildings, especially in a domain like the Kingdom of Saudi Arabia.

The last important environmental factor was found to be 'adequate illumination' as well as 'availability of daylight' and 'spaciousness', where environmental stimuli such as indoor plants and interior/exterior landscaping were considered to be of high importance.

4.4.3 Patient's gender effect

Caregivers indicated that female people show greater sensitivity and/or physiologic responsiveness to stimuli in a number of sensory modalities than male people. Generally, women take more responsibility for environmental cleanliness at home, which may account them to have higher expectation of cleanliness than men. In other words, female people expect cleaner and quieter environments than male people. Among the spatial design factors, ‘location and ‘orientation of furniture in space’ were rated higher than most of the other factors by healthcare personnel. This may be due to cultural preference of the Saudis for coordinated location and orientation of a space and furniture in relation to the praying direction. Healthcare personnel noted that the design should account for a degree of acoustic separation between rooms and adjoining corridors. In essence, they referred to the ambient noise level, which could be brought down through careful design. From a spatial design perspective, visual and auditory links need to be maintained between rooms and patient living areas to reduce level of noise. Also, gender dedicated areas are of concern for the home layout for both people and relatives due to the cultural prospective of the society. They also indicated the preference for homes that oriented to the north direction, maybe as a requirement to avoid direct sunlight and to capture as much wind as possible in the home premises. This is an interesting finding, which illustrates the multidimensional and multi-objective nature of architectural design importance for an assistive living environment supported by the results reported in (Lawton 2001).

4.4.4 Limitations

Certain limitations of this study need to be pointed out. People’ observation was conducted in people houses and healthcare homes in the Kingdom of Saudi Arabia. The responses are, therefore, inherently the Saudis healthcare providers’ perception of environmental and behavioural factors and their relative importance to people. However, the differences in perception between respondents from Saudi Arabia and the rest of the world may be minimal, in particular for universal design factors that are not culturally significant; e.g., adequate illumination and daylight availability. Factors related to building services and systems such as thermal comfort is another example of such a variable. Moreover, Ramadan as the fasting month is one of the pillars of the

Islamic religion, which is much respected in Saudi culture and affects the normal human activities during this month. This implies different times for food, times of medication, cooking times, and performance of social or recreational activities that are affected severely during this month. Due to the limited time available, the field study did not allow time to study the activities of people during the month of Ramadan. The culture of the place and the customs and traditions of the country create a kind of reservation directly on the monitoring process, with caregivers in some circumstances of severe people problems and women observations. The relatively different number of experience years of the caregivers creates a kind of different accuracy in the process of monitoring subjects for 24-hours during the day. The nationality and original culture of the caregivers as well forces some limitations on the collected data and respondents' opinion. Also the acceptance of cooperation of the caregivers affected the accuracy and increased the cost of the survey.

4.5 Summary

Previous researches on physical behaviour and environments factors in hospitals and care homes focused on the analysis of people' satisfaction linked to the service quality. It has been found in very few studies an analysis and investigation of the people' living condition in their own homes instead of in a hospital or care home. However, this study provides a good understanding of the safety conditions of Alzheimer’s people homes requirements. Further results presented in this study clearly defined the required conditions, equipment and technologies to provide a safe environment for these people. This knowledge was extracted through professionals’ opinions and observations. Moreover, this research explored healthcare providers’ perception of environmental and behavioural aspects related to Alzheimer people' wellbeing, in case they are going to live alone in their own homes. Aspects related to the design of the environment control are perceived to be more important by healthcare providers than those related to spatial design. To develop a safe domain for Alzheimer's people, it is highly important to design a robust system such as robust monitoring, recognition, and decision support system.

People' behaviour in their own homes may be different from that in a care home. This is due to having more flexibility in their own home than in a care home. Therefore, a monitoring system-based observation would be highly necessary to observe and analyse any unexpected hazard condition.

Furthermore, some of the activities are found to be very important, that are periodically repeatable by the people according to the observation survey. Therefore an intelligent based solution for these repetitive actions would provide a better and safer environment for these people. According to the observation, the most common activity was found to be sleeping, which consists of 42% of the daily activity of this group of people. The second important activity was found to be walking and finally sitting is the third common activity among Alzheimer's people. Hence, for validation purposes, these activities will be used for validating the suggested system.

Chapter 5: Activity recognition using image processing

Chapter 5 presents human action recognition (HAR) techniques to be used as a precaution and warning system for older people including those with Alzheimer's. To recognize human actions, video-based tracking has been widely utilised. However, video processing techniques are highly time consuming methodologies and are state and time dependents. To reduce dependency and computational complexity, a single image based matching and comparison approach is one of the simplest ways to use. Phase-correlation and Log-polar (PCLP) transformation is a highly popular image registration technique used to compare and match two templates. However, this technique may have lower performance with object moving in the scene. To avoid this weakness, a trained neural network with PCLP transformation may have a better performance to overcome this weakness.

This chapter present the PCLP transformation based template matching process and an enhancement for this method using artificial neural network (ANN) as a pre-processing stage for PCPL transformation to extract prior information about human activity class.

5.1 Phase-correlation and log-polar transformation

Phase-correlation and log-polar (PCLP) transformation is one of the most popular image registration techniques used to correct and manipulate images according to a reference image scene which overcomes image translation, rotation, and scaling problems (Yuce, 2012).

Image translation, rotation, and scaling are the most common problems in the area of image processing. To solve these complex issues these problems have to be divided into two steps; the first step is to determine the scaling factor and rotation angle, while the second step is to determine the translation amount on both x and y direction.

Although the scaling factor and rotation angle is the first step, its determination is an extended form of the translation determination process in the Logarithmic-Polar domain. To determine the translation amount on a manipulated image according to a reference image is computationally complex and a hard task in the spatial domain. The mathematical relationship between translated image and reference image is given in equation 5.1. Reddy and Chatterji, (1996) proposed solving this complex task in the Fourier domain instead of spatial domain as defined in equation 5.2. Then the translation can be determined using inverse phase correlation between observed scene and the reference scene, as shown in equation 5.3. The inverse Fourier transform of this phase-correlation provide the translation amount between these two scenes, as given in equation 5.4 (Yuce, 2012).

$$I_{translated}(x, y) = I_{reference}(x - \Delta x, y - \Delta y) \tag{5.1}$$

Where $I_{translated}(x, y)$ and $I_{reference}(x, y)$ are the translated image and reference image, respectively; Δx and Δy are the translation amount on x and y directions, respectively.

$$F_{translated}(u, v) = e^{-i2\pi(u\Delta x + v\Delta y)} F_{reference}(u, v) \tag{5.2}$$

Where $F_{translated}(u, v)$ and $F_{reference}(u, v)$ are the Fourier transforms of $I_{translated}(x, y)$ and $I_{reference}(x, y)$, respectively.

The phase correlation between translated image and the reference image is calculated according to the Equation 5.3:

$$PhaseCorrelation = e^{i2\pi(u\Delta x + v\Delta y)} = \frac{F_{reference}(u, v) F_{translated}^{*}(u.v)}{\left| F_{reference}(u, v) F_{translated}^{*}(u.v) \right|} \tag{5.3}$$

Where $F_{translated}^{*}(u, v)$ is the complex conjugate of $F_{translated}(u, v)$.

$$(\Delta x, \Delta y) = \max \left\{ F^{-1}(PhaseCorrelation) \right\} \tag{5.4}$$

Where $F^{-1}(PhaseCorrelation)$ denotes the inverse Fourier transform of the phase - correlation.

As highlighted above, the determination of the scaling factor and rotation angle is an extended phase correlation process in the logarithmic-polar domain. Initially, these values can be determined with inverse phase-correlation. Then the translation in the x and y direction can be determined according to Equation 5.4. A general form of a translated, rotated and scaled image according to original position is defined according to Equation 5.5.

$$I_{scene}(x,y) = I_{reference}((x\cos(\alpha) + y\sin(\alpha))\gamma - \Delta x, (-x\sin(\alpha) + y\cos(\alpha))\gamma - \Delta y) \quad (5.5)$$

where $I_{scene}(x,y)$ and $I_{reference}(x,y)$ are the intensity value for (x,y) image pixels coordinates in the modified image and reference image respectively, $(\Delta x, \Delta y)$ is the translation amount for the image pixels coordinates, α is the rotation angle; and γ is the scaling factor.

To determine the translation, rotation, and scaling of a manipulated image according to the reference image is computationally complex and a hard task in the spatial domain. Therefore Reddy and Chatterji, (1996) proposed solving this complex task in the Fourier domain instead of the spatial domain. Therefore, this process has to be divided into two parts, the first part is to determine the scaling factor and rotation angle, while the second part is to utilise these values in the translation function to determine the translation values.

Thus, equation 5.5 can be redefined as in equation 5.6 in Fourier domain.

$$F_{scene}(u,v) = e^{-i2\pi(u\Delta x + v\Delta y)} \frac{1}{\lambda^2} F_{reference}(\frac{u\cos(\alpha) + v\sin(\alpha)}{\lambda}, \frac{-u\sin(\alpha) + v\cos(\alpha)}{\lambda}) \quad (5.6)$$

To determine the scaling factor and rotation angle, equation 5.6 has to be transformed into the polar domain which can be transformed as in equation 5.7.

$$F_{scene}(\rho,\theta) = e^{-i2\pi(u\Delta x + v\Delta y)} \frac{1}{\lambda^2} F_{reference}(\frac{\rho}{\lambda}, \theta - \alpha) \tag{5.7}$$

Where $F_{scene}(\rho,\theta)$ and $F_{reference}(\rho,\theta)$ are the polar domain value of the correspondent phase on *u* and *v* direction.

To simplify the above equation, the magnitude of the Fourier transform can be utilised, as in Equation 5.8:

$$M_{scene}(\rho,\theta) = \frac{1}{\lambda^2} M_{reference}(\frac{\rho}{\lambda}, \theta - \alpha) \tag{5.8}$$

The multiplicative factor $\frac{1}{\lambda^2}$ is ignored, and for computational simplicity both sides are expressed in a logarithmic form to produce subtraction operation (Yuce, 2012), as in Equation 5.9.

$$M_{scene}(\log_\alpha(\rho), \theta) = M_{reference}(\log_\alpha(\rho) - \log_\alpha(\lambda), \theta - \alpha) \tag{5.9}$$

From equation 5.9, both scaling factor and rotation angle can be determined using phase correlation as defined in Equation 5.3 and 5.4. These values are then used in Equation 5.6 to determine the translation amount using phase-correlation relation given in Equation 5.3 and 5.4. To test the PCLP transformation technique on modified images, four modified images were selected as given in Table 5.1.

Table 5.1: Selected modification combination for the test cases.

Image Number	**Translation**		**Rotation Angle (Degree)**	**Scaling Factor**
	X direction (Pixel)	Y direction (Pixel)		
1	10	10	10	1
2	25	25	25	0.9
3	50	50	50	0.75
4	75	75	75	0.5

To test the given cases, one real image (Researcher image) and one test case image (Lina image) were selected and modified according to Table 5.1 using GIMP 2.8 software. The reference image and modified images are given in Figure 5.1 to 5.5.

a) **b)**

Figure 5.1: The reference images of, a) Lena, b) Test person

Figure 5.2: Modified images with 10x10 pixels, 10° rotation and no scaling

Figure 5.3: Modified images with 25x25 pixels, 25° rotation and 90% scaling.

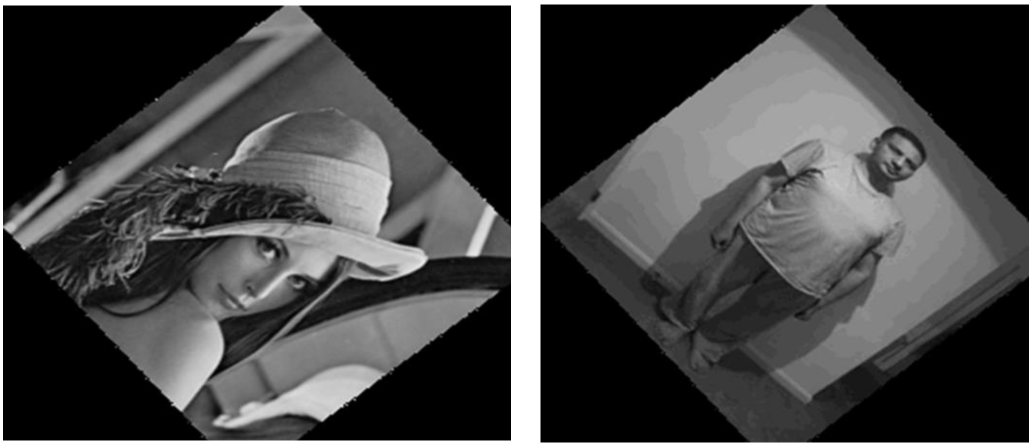

Figure 5.4: Modified images with 50x50 pixels, 50° rotation and 75% scaling.

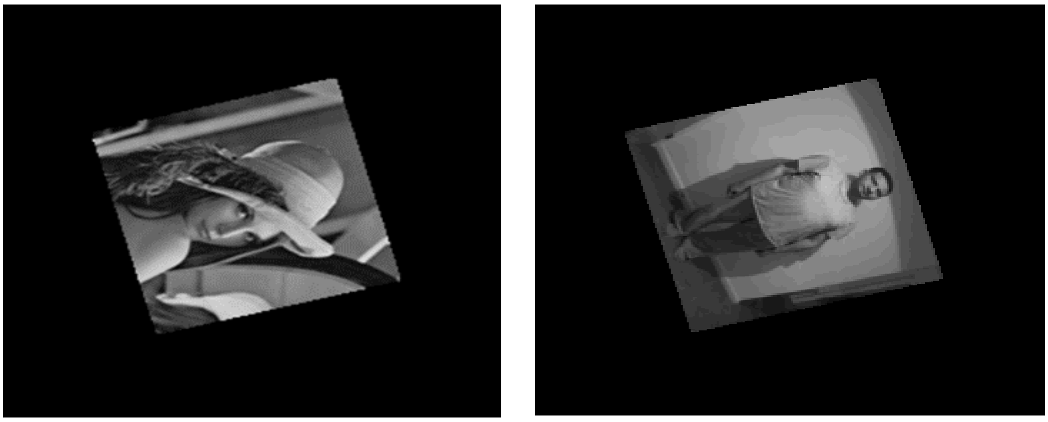

Figure 5.5: Modified images with 75x75 pixels, 75° rotation and 50% scaling.

The correction results for these four cases are illustrated in Figure 5.6 to 5.9, and the correction error for these cases is illustrated in Table 5.2.

Figure 5.6: PCLP for 10x10 pixels, 10° rotated and no scaled images.

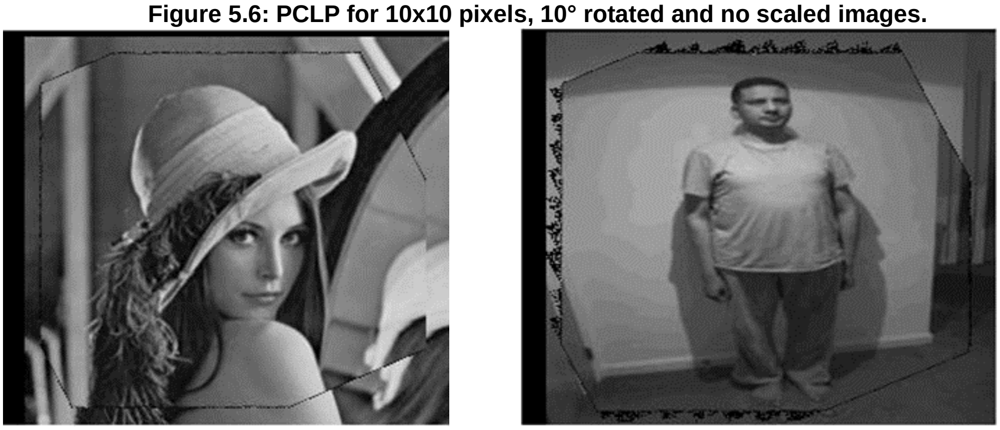

Figure 5.7: PCLP for 25x25 pixels, 25° rotated and 90% scaled images.

Figure 5.8: PCLP for 50x50 pixels, 50° rotated and 75% scaled images.

Figure 5.9: PCLP for 75x75 pixels, 75° rotated and 50% scaled images.

Table 5.2: Absolute error for translation, rotation, and scaling.

Image	Absolute Difference of Translation (Pixels)		Absolute Difference of Rotation (Degree)	Absolute Difference of Scaling Error (%)
	X direction	Y Direction		
Lena (Test Case 1)	11	8	0	0
Test Person (Test Case 1)	14	18	0	0
Lena (Test Case 2)	12	21	0	0
Test Person (Test Case 2)	12	24	0	0
Lena (Test Case 3)	19	25	72	28
Test Person (Test Case 3)	12	61	95	25
Lena (Test Case 4)	29	3	278	50
Test Person (Test Case 4)	103	153	291	50

According to Table 5.2, the PCLP transformation correction-based approach is able to correct an image which is not highly different from the reference image, highlighted with grey in Table 5.2. Therefore an image with minimum modifications can be matched with the template well with PCLP transformation. Although human behaviours for similar actions are not exactly the same as previous ones, the rotational angle for these scenario images should be very close to zero rather than a high value. Thus this rotation angle information can be utilised to determine human action by comparing the PCLP transformation results of the labelled template image and the captured scene image. In the next section, human action behaviour determination using the rotation angle will be explained in detail.

5.2 PCLP transformation-based activity prediction

PCLP transformation-based image correction is very popular for the image registration problem. To correct an image, the PCPL transformation determines the translation, rotation, and scaling factors according to the template, then the modified image is ready to be match with the reference template. This is an encouragement to use the process for human action recognition, especially for people who live with Alzheimer’s. According to the observation results for Alzheimer’s people, given in section 4.2.1, these people have 14 common daily life activities. However three of these activities, which are walking (standing) (7%), sleeping (45%) and sitting (20%) cover about ≅72% of their daily life activities. Therefore, these three main activities were selected for human recognition process using PCLP transformation. Although the movement and distance may not be the same as the image acquisition time step, the rotation angle of similar actions is equal to each other such as, if a person's image is captured during walking action, the rotation angle between this image and a reference walking image is almost zero. However, the translation could be different when the image captured and scaled can also be different according to the distance between human and the camera. Therefore the rotation angle-based comparison is the most appropriate methodology to determine the human action using PCLP transformation.

To utilise this methodology, low cost products have to be used. In this chapter, low cost systems called raspberry-pi and pi-cam were used to capture human images every 5 minutes and send to a server to process it on a Matlab platform. Raspberry-pi is a single board Linux-based system which has a powerful computational capability with lower cost of about £30 (Raspberry-pi, 2015) as shown in Figure 5.10. The block diagram and flow chart of the proposed solution are given in Figure 5.11 and 5.12.

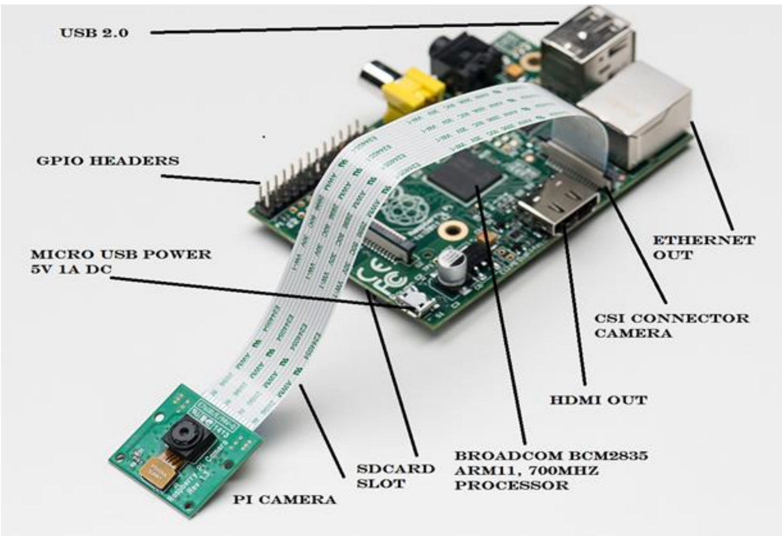

Figure 5.10: Single board Raspberry-pi and pi-Cam.

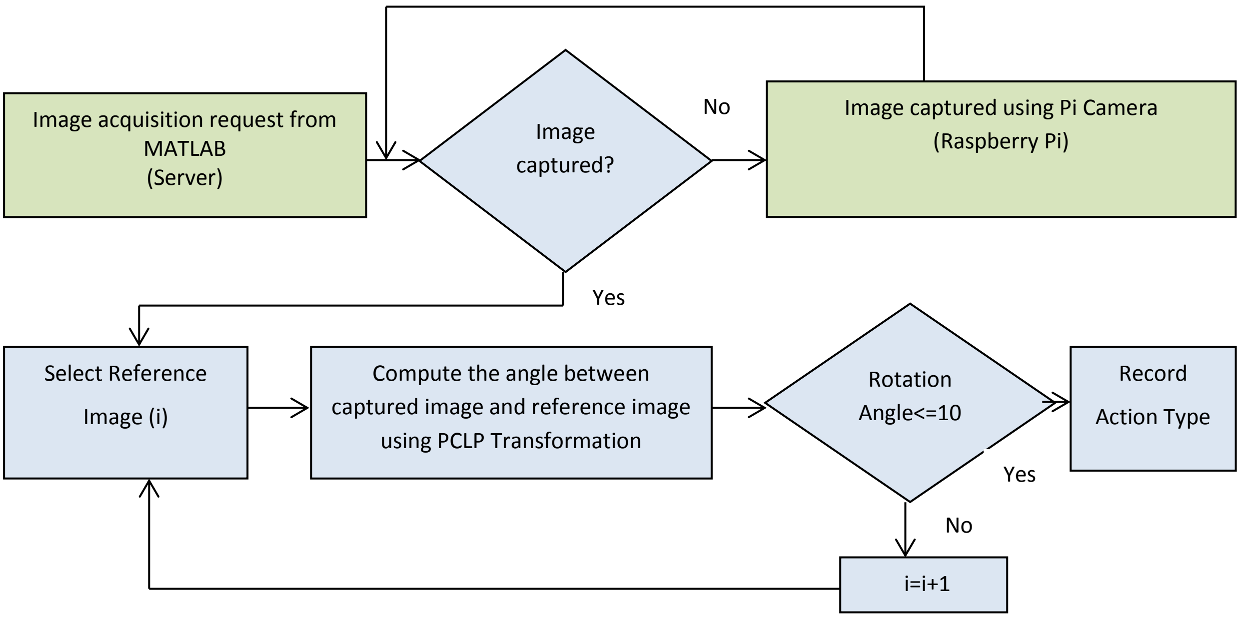

Figure 5.11: Proposed PCLP transformation block diagram.

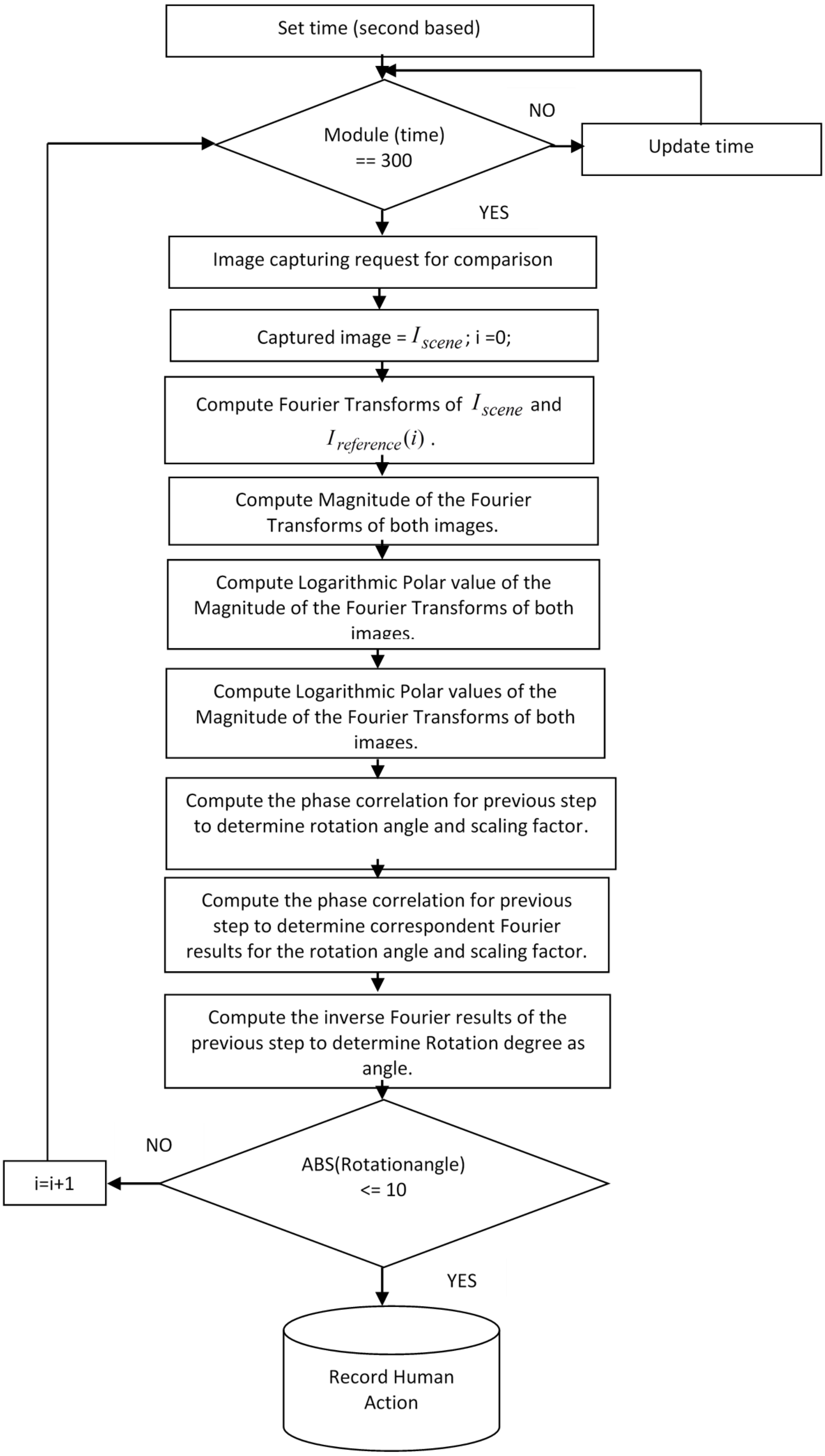

Figure 5.12: Proposed PCLP transformation flowchart.

To test the performance of the proposed algorithm, 30 reference images (10 for each activity standing, sitting, and lying) were stored to be utilised for comparison. To determine human actions in real life, three raspberry-pi with pi-cam were set in a pilot house and each case repeated for 50 times. The results of the prediction are illustrated in Table 5.3.

Table 5.3: Real life implementations results.

Activity type	Testing Number of Total Actions for Each Activity	Number of Correctly Matched Action	Correction Error Percentage
Lying (Sleeping)	50	7	86%
Sitting	50	13	74%
Standing (Walking)	50	44	12%
Total Error			57.3%

According to the results presented in Table 5.3, the proposed technique can predict human actions with around 42.7% efficiency. Moreover, it has an even better performance for standing actions; however the performance is very poor for lying actions. This may be related both to complexities of the background objects and the orientation changes of the person during lying.

To avoid this weakness, two pre-processing stage will be introduced in the next section which are boundary recognition and online learning-based Artificial Neural Network (ANN) to determine the actions similarity to the activity type. Then PCLP transformation will be utilised with the appropriate group of activity images and captured scene. The detail of the modified method will be explained in the following section.

5.3 ANN-based PCLP transformation activity recognition

This section presents an ANN-based pre-processed PCLP transformation technique for human activity recognition. The ANN-based pre-processing stage allows the system to identify the correct action index for the PCLP transformation. According to this information, PCLP transformation performs effectively to find the angle between the reference images of the determined class and the newly captured scene images. Therefore the number of misclassified images with this PCLP transformation will be reduced. If the absolute value of the rotation angle between any of the reference images utilised from the selected class and the current scene is less than 50 degrees, then the correct human action class has been found correctly. As it has been proposed that the absolute value of the rotation angle was found to be set at 10 degrees or less. However, some correct classes were in the range of higher angle ranges. Therefore 50 degrees has been chosen according to empirical tests. The block diagram of the proposed model is given in Figure 5.13.

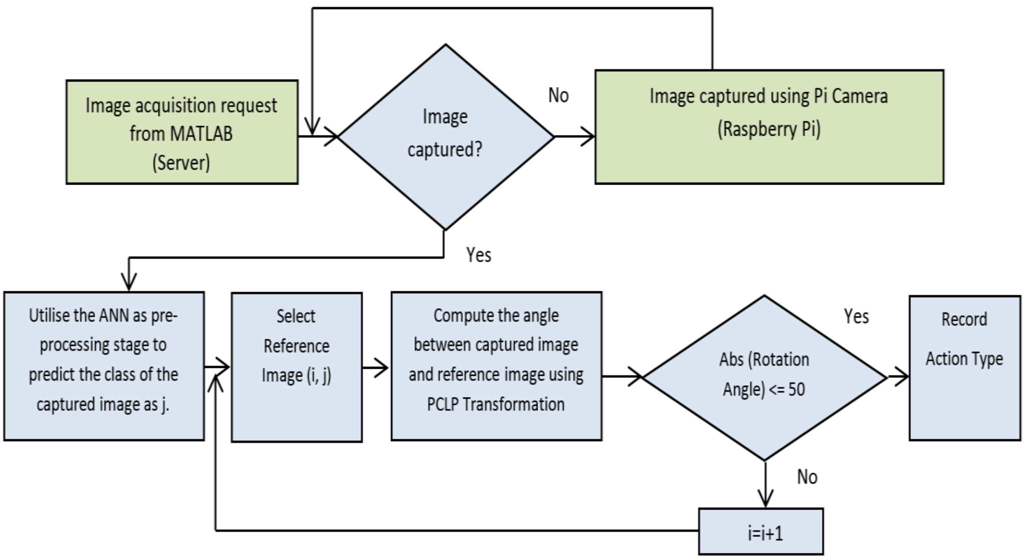

Figure 5.13: ANN-based PCLP transformations for activity recognition.

The ANN-based pre-processing stage is based on a Multi-Layer Perceptron (MLP) based Artificial Neural Network (ANN) implemented on the MATLAB platform. An ANN is one of the most popular techniques to deal with complex type problems including image processing (Yuce et. al., 2014). To utilise ANN effectively on any problem, it needs to be well-trained with the best performing configurations. To find the best performing configuration, the ANN design elements such as learning algorithm types, number of hidden layers, numbers of process elements in hidden layers, and transfer function types have to be determined experimentally. To determine the correct class of the captured image, the following topology is proposed as given in Figure 5.14.

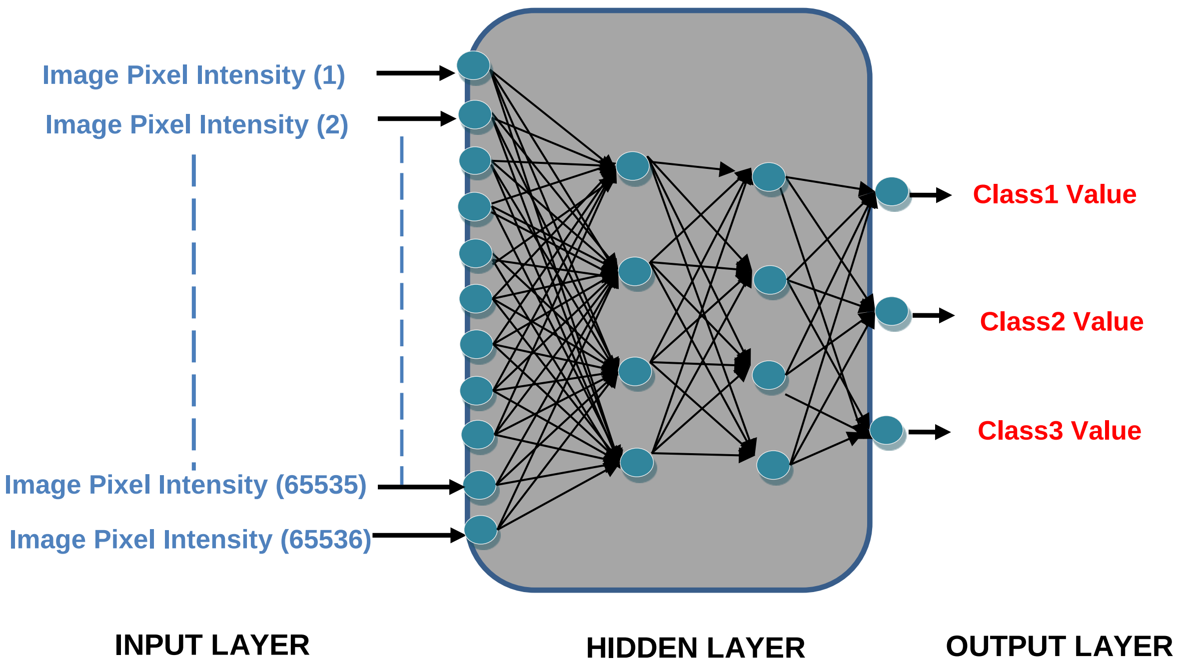

Figure 5.14: Proposed ANN model for image class determination.

5.4 Experiments

To utilise Artificial Neural Network (ANN) as a pre-processing stage, a back propagation algorithm with several different combination of the ANN topologies was utilised and tested using 30 reference images (10 for each activity class). During testing 80% of these images (24 images) were selected as a training set and the rest were used for testing and validation.

In order to find the best performing ANN, the first group of experiments are based on the learning algorithm determination while keeping the number of hidden layers fixed to 2, the transfer functions for hidden layers and output layer as logarithmic sigmoid function, and the number of process elements in each layer as 5. During the experiments, the number of maximum epoch and the error rate were set to 10000 and 0.001, respectively.

5.4.1 Learning algorithm determination

The following learning algorithms have been tested to determine the best performed learning function:

- BFGS quasi-Newton back-propagation (trainbfg),
- Conjugate gradient back-propagation with Powell-Beale restarts (traincgb),
- Conjugate gradient back-propagation with Fletcher - Reeves updates (traincgf),
- Conjugate gradient back-propagation with Polak-Ribiere updates (traincgp),
- Gradient descent back-propagation (traingd),
- Gradient descent with adaptive learning rate back-propagation (traingda),
- Gradient descent with momentum back-propagation (traingdm),
- Gradient descent with momentum and adaptive learning rate back-propagation (traingdx),
- Levenberg-Marquardt back-propagation (trainlm),
- Scaled conjugate gradient back-propagation (trainscg).

The results for these functions are presented in Table 5.4.

Table 5.4: Performance of the learning algorithms for ANN training.

Learning Algorithm	Expected Error Level	Error Level of Algorithm	Number of Epoch
trainbfg	0.001	NaN	NaN
traincgb	0.001	0.0027	10000
traincgf	0.001	0.0039	10000
traincgp	0.001	0.0058	10000
traingd	0.001	0.3060	10000
traingda	0.001	0.167	10000
traingdm	0.001	0.2891	10000
traingdx	0.001	0.0010	5146
trainlm	0.001	NaN	NaN
trainscg	0.001	0.0008	396

According to Table 5.4, two algorithms were able to train the neural network before meeting the termination conditions using the testing images. The best performing algorithm was "***trainscg***" which learned after 396 epochs. However, two of the algorithms were not able to run on the current image data set due to lack of memory on the utilised machine which is an i7 processor with 3.1 GHz speed and 8GB memory. Therefore the further testing will be carried out using "***trainscg***" as the fixed learning algorithm in the ANN.

5.4.2 Number of hidden layers determination

The next stage is to determine the number of the hidden layers for the ANN. To carry out this experiment, the learning function was set to "***trainscg***", the number of process elements was set to 5 for any of the hidden layers, and transfer functions were set to logarithmic sigmoid function for both hidden and output layers. The results were given in Table 5.5.

Table 5.5: Performance of the hidden layer number for ANN training.

Number of Hidden Layer	Expected Error Level	Error Level of Algorithm	Number of Epoch
1	**0.001**	**0.0010**	**286**
2	**0.001**	**0.0008**	**392**

According to Table 5.5, the best performance was achieved with two hidden layers. However, the target level was achieved using either of the hidden layers. Moreover, the performance of the single hidden layers was better than two single layers based on the number of epochs. Therefore the further experiments were carried-out using single hidden layer.

5.4.3 Transfer function determination

The next experiment was carried-out to determine best performed transfer function on the hidden and output layers. The utilised transfer function combination and the results are given in Table 5.6.

Table 5.6: **Performance of the transfer function types for ANN training.**

Hidden Layer Transfer Function	Output Layer Transfer Function	Expected Error	Error of Algorithm	Number of Epoch
Linear	**Linear**	0.001	0.0028	10000
Linear	**Tangent Sigmoid**	0.001	0.0024	10000
Linear	**Logarithmic Sigmoid**	0.001	0.0021	10000
Tangent Sigmoid	**Linear**	0.001	0.0013	10000
Tangent Sigmoid	**Tangent Sigmoid**	0.001	0.0010	1081
Tangent Sigmoid	**Logarithmic Sigmoid**	0.001	0.0010	576
Logarithmic Sigmoid	**Linear**	0.001	0.0023	10000
Logarithmic Sigmoid	**Tangent Sigmoid**	0.001	0.0001	616
Logarithmic Sigmoid	**Logarithmic Sigmoid**	0.001	0.0009	472

According to Table 5.6, the performance of the logarithmic sigmoid function in the hidden and output layers provided the best performance according to the number of epoch and accuracy. Thus, this transfer function was selected to be utilised in both layers for further experiments.

5.4.4 Number of processing elements determination

The last experiment to determine the best configuration is to change the number of process element in the hidden layer. To carry out this experiment, the learning function was set to "***trainscg***", only one hidden layer, and transfer functions were set to logarithmic sigmoid function for both hidden and output layers. The results were illustrated in Table 5.7.

Table 5.7: **Performance of process elements number in the ANN training.**

Number of Process Elements	Expected Error Level	Error Level of Algorithm	Number of Epoch
5	0.001	0.0008	393
10	0.001	0.0010	280
15	0.001	0.0008	317
20	0.001	0.0001	291
25=<	0.001	NaN	NaN

According to the experiment given in Table 5.7, the best performance neural network was found to be with neurons 10 in the hidden layer. The training result of the best performed ANN is given in Figure 5.15-16.

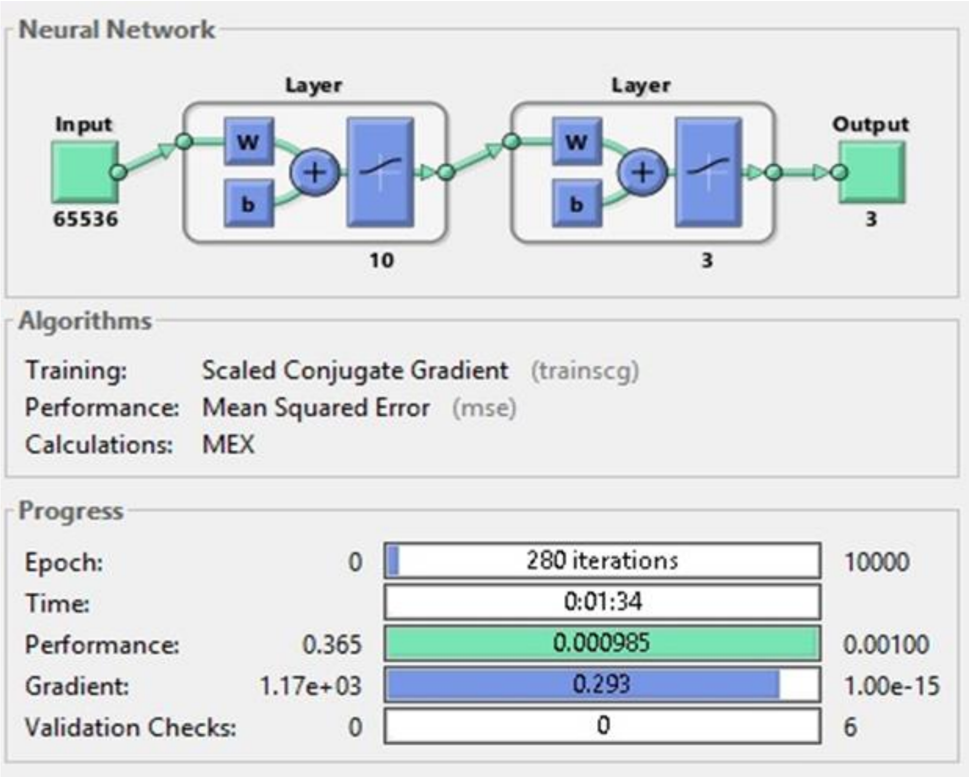

Figure 5.15: **Topology and performance of the ANN with MATLAB.**

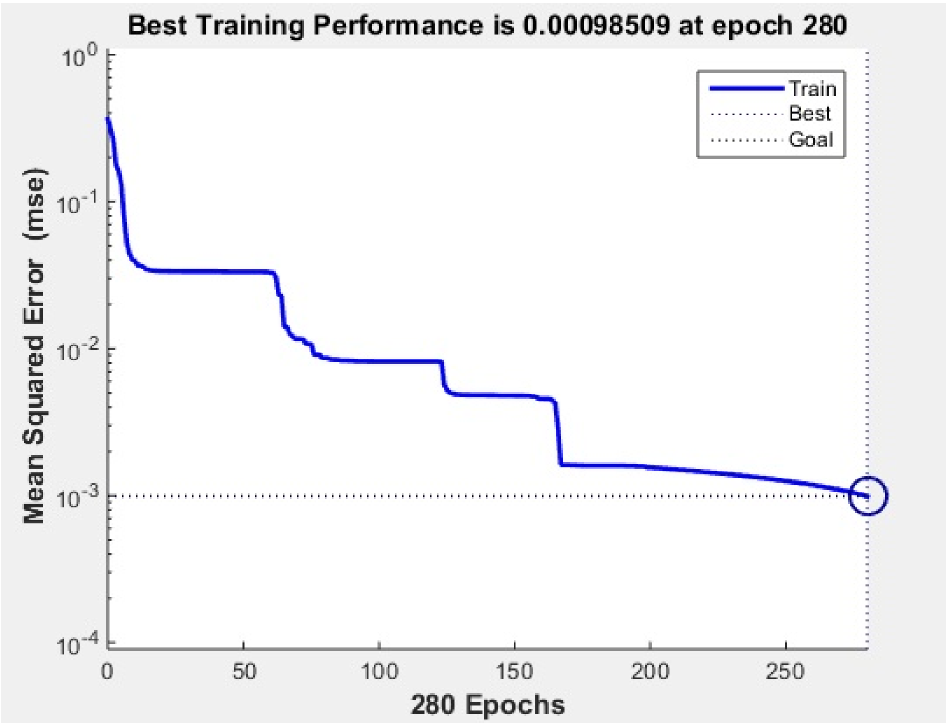

Figure 5.16: Training performance of the best configured ANN model.

The best performing ANN was then tested to determine the accuracy of the algorithm for the remaining 20% of the images (6 images). According to the testing results, the trained ANN model found 5 out of 6 images class correctly, which is about 83.3% accurately.

After this stage, the trained ANN was utilised as a pre-processing stage for PCLP transformation algorithm. To test the proposed algorithm for the real cases, again threes raspberry-pi captured 150 different image activities (50 images for each). To test the performance of the proposed algorithm 30 reference images (10 for each activity-standing, sitting, and lying) have stored to be utilised for comparison. To determine human action in real life scenarios, three raspberry-pi with pi-cam have been set for a pilot house, as shown in Figure 5.17, and each image activity cases was repeated for 50 times, the results illustrated in Table 5.8.

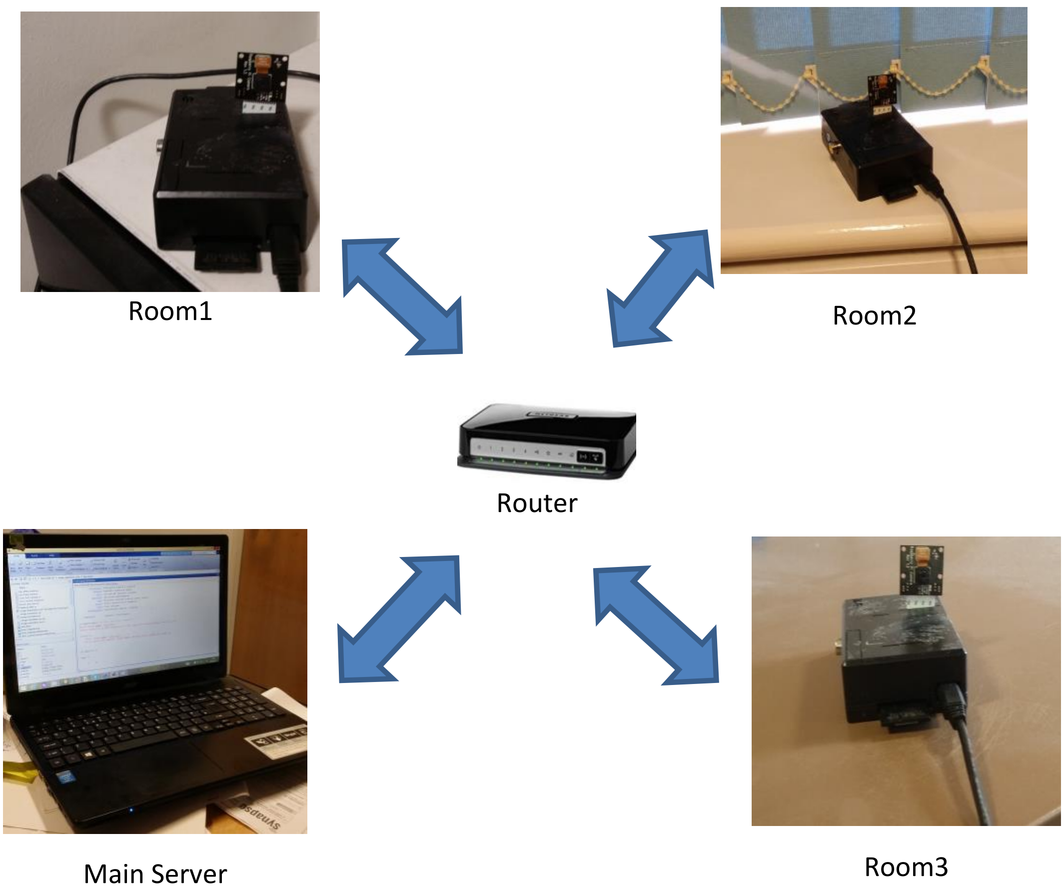

Figure 5.17: Raspberry-pi test system for each room.

Table 5.8: Proposed solution implementation result.

Activity type	Testing Number of Total Actions for Each Activity	Number of Correctly Matched Action	Correction Error Percentage
Lying (Sleeping)	50	34	32%
Sitting	50	39	22%
Standing (Walking)	50	47	6%
Total Error			20%

According to the ANN-based pre-processed PCLP transformation, the prediction of all the activities increased gradually and total system error found to be 20%. Moreover the system can predict standing (walking) activity with 6% error rate. The highest error rate was found with lying (sleeping activity) as 32%. However, the overall system prediction is acceptable. Therefore the proposed method will be utilised as one of the main elements for the decision making process in the next chapter.

5.5 Summary

In this chapter, the focus was to predict human activity recognition with a single image instead of a video scene using Phase-correlation and Log-polar (PCLP) transformation based approach. The idea was to determine an image rotation angle, comparing it with reference images, and then determine the correct activity class according to the rotation angle for the three most common activities which were identified before as standing (walking), sitting, and lying (sleeping).

The PCLP transformation algorithm was utilised on 150 activities (50 for each activity). According to the rotation angle analysis, if the rotation angle between captured scene and any reference image is less than 10 degrees, the minimum of these matches were selected as the activity image. According to the experimental results, the proposed technique was accurate by about 42.7%.

To improve the accuracy of the proposed technique, an ANN-based pre-processing stage was introduced. Initially, the design, training, and testing of ANN for the human activity recognition was carried out using 30 reference images. Several different combinations of the ANN parameters were tested to determine the best performing topology for this particular problem. According to training experiments, the best performing ANN was found using **trainscg** (scaled conjugate gradient based) as learning function, single hidden layer with 5 process elements, and logarithmic transfer function in both of the hidden and output layers. This configuration was then utilised to predict the class of activity which was utilised as prior information for the PCLP transformation algorithm. The rotation angle results between the captured scene image and the reference class of images predicted by the proposed ANN can be accepted within the range of 50 degrees. This class was identified as the correct class of human actions. According to experimental results, the average accuracy of the system was found to be 80%, which is an acceptable range to be utilised for further analysis. Therefore this methodology will be utilised in chapter 6 as one of the main elements in the decision support system for older people including those with Alzheimer's.

Chapter 6: Rule-based decision support system

This chapter presents the multi-sensors usage for human activity recognition for older people including those with Alzheimer’s, as previous studies were based on the usage of machine learning techniques. However average accuracy with machine vision techniques was found to be around 57.65%, where the accuracy of the system was increased by 8% using mixed type of sensors, such as illumination sensors and motion sensors (Crispim-Junior et al., 2012). Therefore, this chapter focuses on extending sensors types to achieve robust activities identification. Moreover, it presents a rule based decision support approach, using mixed-sensors information to support older people including those with Alzheimer’s in their own homes.

The chapter initially presents the overall model of the proposed system, and then each sensor type design and topology is presented in details. Finally, a rule-based system with available test scenarios and validation implementation are presented.

In this chapter the following sensors groups were considered:

- Vision sensors, such as raspberry-cam,
- Location identification sensor, such as wireless tags,
- Vital signs sensor, such as heart rate sensor,
- Environmental sensors, such as room temperature and humidity sensors.

These sensors information are recorded every five minutes to be utilised in the rule-based system. The rules were generated using professionals' knowledge, such as medical doctors and health care providers.

6.1 Rule-based care support system

The proposed framework of the older people including those with Alzheimer’s safety decision support system consists of three main components, the first component is the data acquisition component which is based on the vision sensor, location identification sensors, vital signs sensors and environmental sensors, the second component is the rules engine containing professionals rules, and finally, the action and activation component as illustrated in Figure 6.1.

In data acquisition module, three cameras were utilised through raspberry-pi for three different rooms (living room, bedroom, and kitchen) to receive human activities using single image acquisition. The captured image is post-processed with MATLAB platform using ANN-based enhanced phase-correlation and log-polar (PCLP) transformation algorithm. After image processing, the determined human activity is recorded in the MySQL database.

Moreover, one of the raspberry-pi is also utilised to receive the living room ambient temperature and humidity every five minutes using Z-Wave wireless protocol and transfer it to the main server to be stored in the MySQL database.

To identify the location, a SYNAPSE based RFID wireless mesh network is created for these three rooms. In the mesh network, three static RFID wireless transmitter and receiver modules are utilised and designed as a static tags for these three rooms. Moreover one extra RFID module is designed as a mobile tag to track the subject according to the signal strength between this tag and any of the rooms' static tags. Moreover, one extra RFID module is also assigned as a head master of the mesh network, which is connect to the server to receive the signal strength between mobile tag and each room static tags. The signal strength was utilised to determine the human location and is also recorded into the MySQL database.

The last sensory group designed for this work is the vital signs sensory system. This sensory system consist of two units, the first unit is a wireless transmitter which is a mobile wearable heart rate measurement sensor, while the second unit is a wireless sensor receiver, which is controlled using an Arduino based microcontroller. This sensor has a range of 1.5 meters; therefore it is located to the bedroom to receive the signal better during sleeping. The main reason to locate this sensor in bedroom is related to the survey given in section 4.2.1. According to the survey, the sleeping/ lying down activity cover about 45% of daily activity for the older people who live with Alzheimer’s. When the heart rate information is received, it is also recorded in the MySQL database to be utilised later in the rule based system.

In rule based module, professionals knowledge is utilised which is converted into decision rules and embedded into the rules engine coded using C language. The rules engine consists of 25 professionals rules, each elements in the antecedent part of the rules is designed as a range for variables in the environment and vital signs. The consequent part is designed as an integer option.

The action module consists of two parts; the first part is the data reading from the sensory system database. The second part is to search for the matched rules to fire it and generate an output. If any of the rules condition is met, these rules consequent part will be activated. This process is developed using C language and is activated periodically every five minutes.

The detailed for each data acquisition module and subsections, professionals rule design, and activation module will be given in detail in following sections.

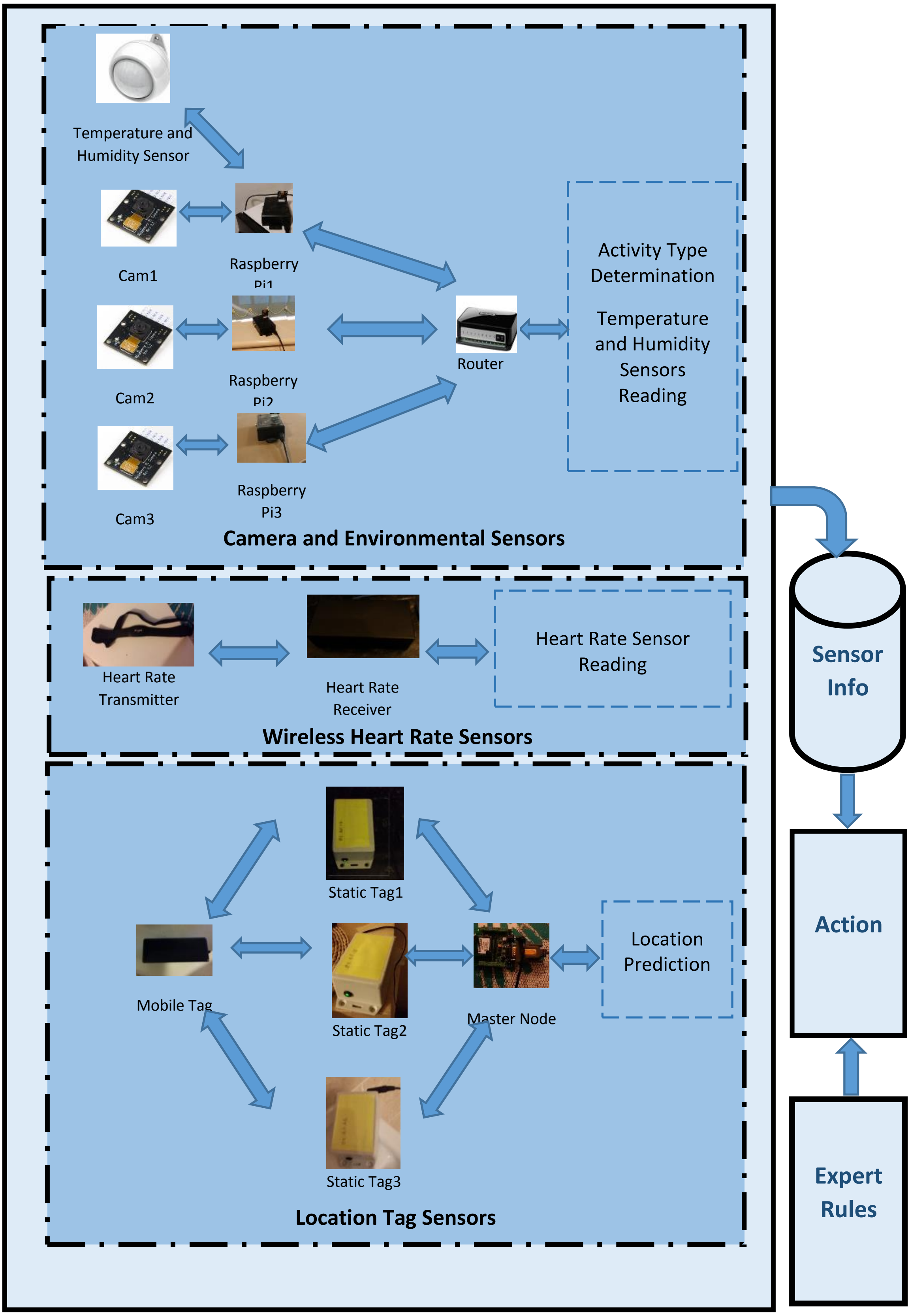

Figure 6.1:Proposed decision support system.

6.2 Data acquisition modules

Data acquisition modules are the key elements in the decision support system to receive the monitored information. These modules consist of four different types of sensory groups;

- Camera sensors to recognize the human activity,
- Location identification sensors to determine the human location in the house,
- Heart rate measurement sensors to monitor the heart rate of the human,
- Zone ambient temperature and humidity sensors to monitor the room.

6.3 Location Identification Sensors

In literature, several studies have been proposed to track human location using different technologies, such as mobile cellular systems (Cong and Zhuang, 2002), Global Positioning System GPS (Van der Spek et al., 2009), ZigBee (Yao et al., 2007), Wi-Fi (Husen and Lee, 2014), Bluetooth (Opoku, 2011), and RFID tags (Toplan and Ersoy, 2012). In this study, an RFID based human location determination technology is selected to determine human location inside the house. The following advantages have been found in using RFID based approaches (Kauf et al., 2011):

- The detection process is autonomous does not need human interventions,
- Low cost systems,
- Flexible to read and overwrite the RFID based technologies,
- Simultaneously process the data transmission and receiving,

In this study, three groups of RFID Synapse RF200 modules are used, the first group is three static RFID modules, which are located in each room. The second group is mobile RFID tag attached to the subject. The last group is the master module which receives the signal strength between static modules and mobile module. The master module's signal strength information is recorded to the MYSQL database. The overall mesh network configuration is shown in Figure 6.2.

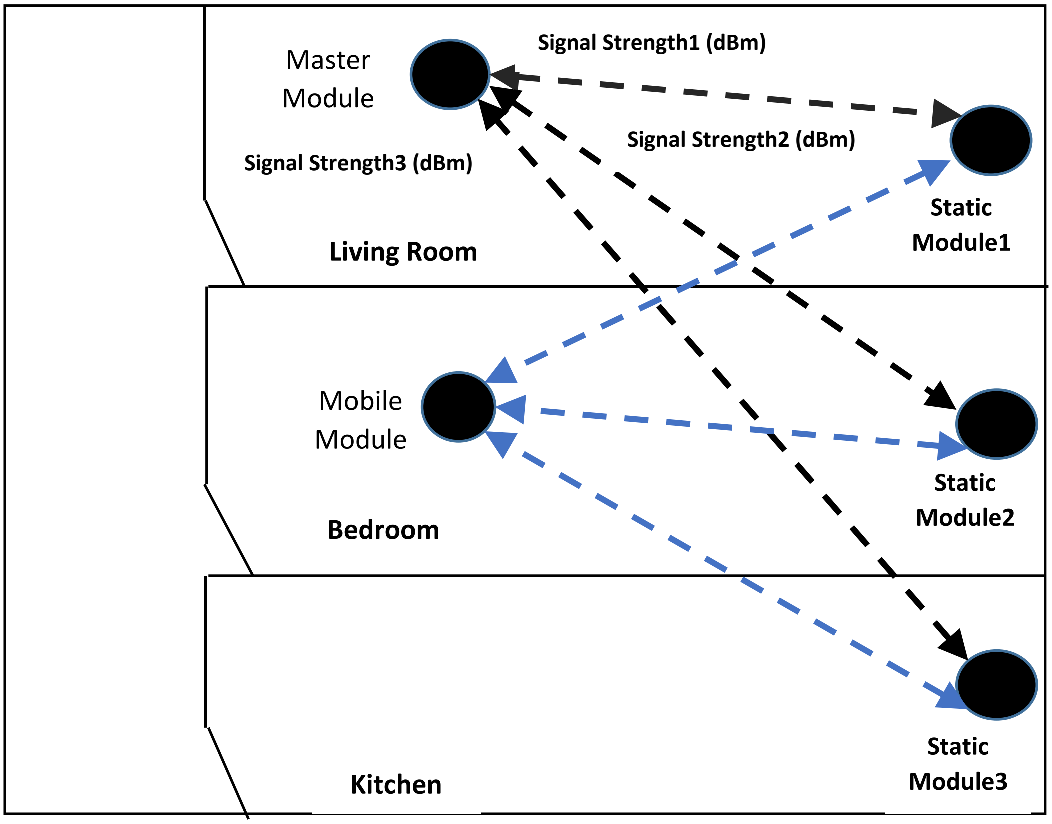

Figure 6.2: The proposed RFID based mesh network.

6.3.1 Static RFID modules for location identification

In this study, the static RFID modules consist of three Synapse RF200 SNAP engine. This SNAP engine based on an ATmega128RFA1 microcontroller with 24 pins. The image of this module is shown in Figure 6.3.

Figure 6.3: Image of the static RF200 SNAP RFID module.

Each static RFID module is connected to the workstation through an SN-171 Synapse Proto-Board illustrated in Figure 6.4, which connect to the computer via an RS232 serial connection. Then, it has been programmed as a static signal transmitter and sender through the SYNAPSE platform called *Portal* using Python Language.

Figure 6.4: Image of Synapse SN-171 board interface

.

The algorithm for the static module is given below:

- Initialise and set the LED light ON,
- Connect to mobile module,
- Turn the LED light OFF,
- Get signal quality,
- Wait 500 millisecond.

After the code is uploading to the module, the module is then powered with a 3V independent power supply through pin 14 as positive and pin 16 as negative and localised in a fixed point in each room.

6.3.2 Mobile RFID modules for location identification

To develop a mobile module, a Synapse RF200 SNAP engine is utilised as explained in previous section. The mobile RFID module is also developed through the *Portal* platform using Python language with an SN-171 Synapse Proto-Board. The algorithm is given below;

- Initialise the LED light ON,
- Connect to static modules,
- Turn the LED light OFF,
- Compute the signal strength between static module 1 and mobile module,
- Wait 100 milliseconds
- Compute the signal strength between static module 2 and mobile module,
- Wait 100 milliseconds
- Compute the signal strength between static module3 and mobile module,
- Wait 100 milliseconds

After the code is uploaded to the module, the module is then powered with a 3V independent power supply through pin 14 as positive and pin 16 as negative.

6.3.3 Master RFID modules for location identification

The master module is the main communication node between static modules and main server. The master module consists of an RF200 SNA Engine and an SN-171 Synapse Proto-Board. Both programming and communication of the master module is carried out with an SN-171 Synapse Proto-Board. Again, the programming of this module is carried out through Synapse *Portal* using Python language. The algorithm is given below;

- Initialise the node,
- Create an UART serial port communication between RF module and computer to use RS232 cable,

- Read the signal strength value of Static Node1 as decibel milli-Watt (dBm),
- Wait 200 milliseconds,
- Read the signal strength value of Static Node2 as decibel milli-Watt (dBm),
- Wait 200 milliseconds,
- Read the signal strength value of Static Node3 as decibel milli-Watt (dBm).
- Wait 200 milliseconds,

Further, a C language based communication system is also carried out to access the signal strength and record it in the MySQL database.

The developed system was tested on 150 different cases (50 for each room) and the results are illustrated in Table 6.1.

Table 6.1: Results for location identification using RFID modules

Room Number	Number of Correctly Predicted Cases	Error Percentage (%)
1	50	0
2	50	0
3	50	0

According to the Table 6.1, the proposed RFID human location identification approach predicted human location with100% accuracy. Thus, the usage of this sensory system in the rules will be trustable approach to make a correct decision.

6.3.4 Heart rate sensor

The heart rate sensor is one of the major sensors type to assess the safety conditions for older people who live with Alzheimer's to generate response during hazards and critical conditions.

In this project, a polar T34 wearable wireless transmitter and compatible receiver is utilised for this purpose. T34 is one of the most popular and available sensors in the market to record the heart rate data through the compatible receiver. The range between transmitter and receiver is slightly limited to around 1.5 meters. Thus these two systems should be as close as possible to each other. As the transmitter is ready made system, the receiver is designed using an Arduino based microcontroller and powered with a 3V power supplier. The image for the receiver and transmitter is shown in the Figure 6.5 and Figure 6.6.

Figure 6.5: The Polar T34 wearable transmitter.

Figure 6.6: The Polar T34 wearable sensor wireless receiver.

The designed receiver unit using Arduino microcontroller is shown in Figure 6.7.

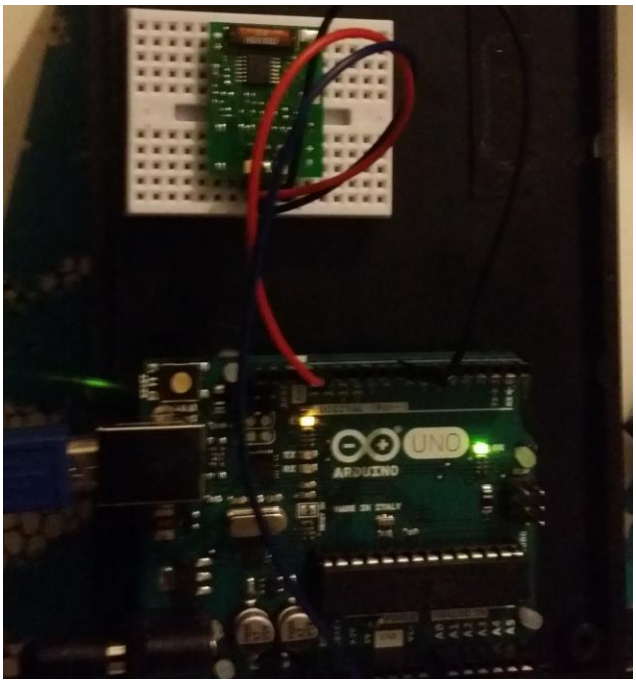

Figure 6.7: **The Polar T34 wearable sensor compatible wireless receiver.**

The designed system has been programmed through Arduino 1.6.5 IDE. The algorithm to receive heart rate from Polar T34 transmitter is given below;

- Initialise the pin 7 (wireless module connect pin)
- While(Pin number==7)
- Read heart beat in periodic beats per minute
- Record data to MySQL database

6.3.5 Temperature and Humidity sensors

The temperature and humidity sensors information are the two main environmental sensors information which help the decision support system to make a clear judgement. Therefore, it has been designed that these sensors information is to be used in the antecedent part of the rules base system. To monitor the zone temperature and humidity, a wireless Aeon Labs Multi-sensor is utilised with a Z-Wave based wireless Aeon Labs series USB microcontroller. Z-Wave is one of the most recent wireless communication protocols. Z-Wave based devices recently become popular for the smart home concepts. Therefore, the sensors and microcontroller were selected to use this protocol. The system is developed using one of the raspberry-pi microcontrollers which is located in the living room. The USB microcontroller is connected to the raspberry-pi. The communication between USB controller and Z-Wave Multi sensor is carried out using an open source library called Open Z-Wave (Open Z-Wave, 2015) as shown in Figure 6.8.

Figure 6.8: The Aeon USB Stick with raspberry-pi.

Sensors reading is recorded to a text file in the raspberry-pi board, and then retrieved to the main server through MATLAB platform. The block diagram of this process is given in Figure 6.9.

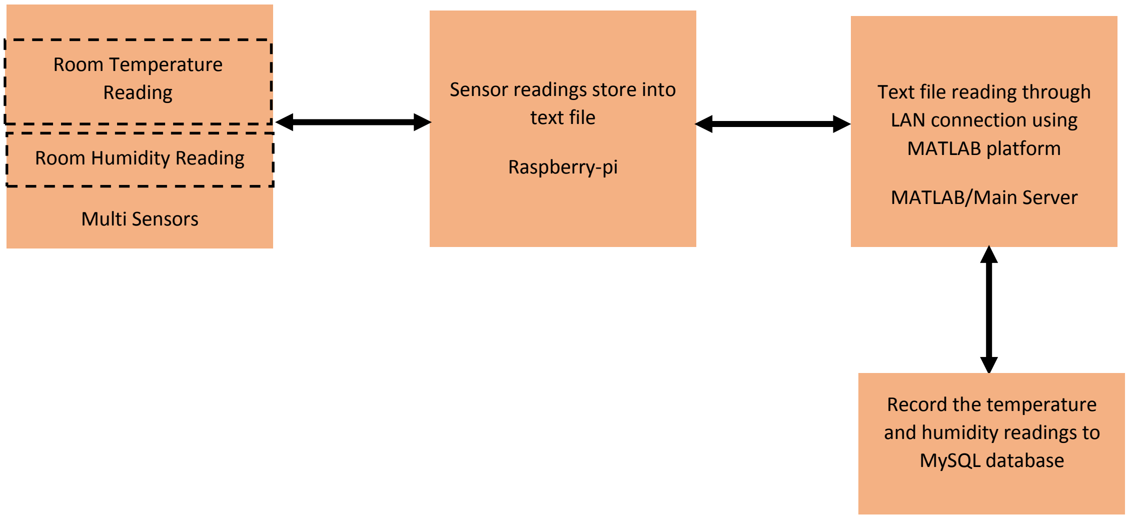

Figure 6.9: Proposed process block diagram.

The temperature and humidity sensors design and integration is the last step in the data acquisition modules. These sensors information will be utilised in the application module with the rule based system to activate the decision support for the older people.

6.4 Rules for decision support system

This section presents the rule generation process for the older people including those who live with Alzheimer's. The rule generation process is carried-out using medical professionals' knowledge. According to the professionals' knowledge, there are 25 rules to identify the older people including those who live with Alzheimer's condition as normal or abnormal. The antecedent parts of the rules consist of the multi sensors information, and the consequent part is defined as normal condition or abnormal condition. The generated rules are given in Table 6.2.

Table 6.2: Professionals' rules for the proposed decision support system.

No	Rules
1	**IF** ActivityType= 1 AND Temperature<35 AND Temperature >15 **THEN** ConditionType = 1
2	**IF** ActivityType= 1 AND Temperature<35 AND Temperature >15 AND Heart rate >70 AND Heart rate < 130 **THEN** ConditionType = 1
3	**IF** ActivityType= 1 AND Humidity<70 **THEN** ConditionType = 1
4	**IF** ActivityType= 1 AND Humidity<70 AND Heart rate >70 AND Heart rate < 130 **THEN** ConditionType = 1
5	**IF** ActivityType= 1 AND location=3 AND Heart rate >70 AND Heart rate < 130 **THEN** Condition Type = 1
6	**IF** ActivityType= 2 AND Temperature<35 AND Temperature>15 AND Heart rate >70 AND Heart rate <130 **THEN** ConditionType = 1
7	**IF** ActivityType= 2 AND Humidity<70 **THEN** Condition Type = 1
8	**IF** ActivityType= 2 AND Humidity<70 AND Heart rate >70 AND Heart rate < 130 **THEN** ConditionType = 1
9	**IF** ActivityType= 2 AND Location=3 AND Heartrate >70 AND Heartrate <130 **THEN** ConditionType = 1
10	**IF** ActivityType= 3 AND Temperature<35 AND Temperature>15 AND Heart rate >70 AND Heart rate <130 **THEN** ConditionType = 1
11	**IF** ActivityType= 3 AND Temperature<35 AND Temperature>15 AND Heart rate >70 AND Heart rate <130 **THEN** ConditionType = 1
12	**IF** ActivityType= 3 AND Humidity<70 **THEN** ConditionType = 1
13	**IF** ActivityType= 3 AND Humidity<70 AND Heart rate >70 AND Heart rate < 130 **THEN** ConditionType = 1
14	**IF** ActivityType= 3 AND Location=3 AND Heart rate >70 AND Heart rate <130 **THEN** ConditionType = 1
15	**IF** ActivityType= 3 AND Temperature<35 AND Temperature>15 AND Heart rate >70 AND Heartrate <130 **THEN** Condition Type = 1
16	**IF** ActivitiyType= 1 AND Heart rate <70 AND Heart rate >130 **THEN** ConditionType = 2
17	**IF** ActivitiyType= 2 AND Heart rate <70 AND Heart rate >130 **THEN** ConditionType = 2
18	**IF** ActivitiyType= 3 AND Heart rate <70 AND Heart rate >130 **THEN** ConditionType = 2
19	**IF** ActivitiyType= 3 AND Location=3 **THEN** Condition Type = 2
20	**IF** ActivitiyType= 3 AND Temperature>35 AND Temperature<15 **THEN** ConditionType = 2
21	**IF** ActivitiyType= 3 AND Humidity>80 **THEN** ConditionType = 2
22	**IF** ActivitiyType= 3 AND Location=1 **THEN** ConditionType = 2
23	**IF** ActivitiyType= 3 AND Location=2 **THEN** ConditionType = 2
24	**IF** ActivitiyType= 3 AND Location=2 Temperature>35 AND Temperature<15 **THEN** ConditionType = 2
25	**IF** ActivitiyType= 3 AND Location=2 Humidity>80 **THEN** ConditionType = 2

In Table 6.2, the activity type in the antecedent part of the rules have three values as 1, 2, and 3 for standing sitting and sleeping activities respectively, which is extracted from the information comings from ANN-based pre-processed Phase correlation and Log-

Polar (PCLPT) transformation algorithm. Furthermore, the location elements of the antecedent part have three values as 1, 2, and 3 for the living room, bedroom, and kitchen, respectively. The temperature and humidity are the sensors values for the room temperature and humidity sensors. Moreover, the heart rate sensor value is denoted as “Heart rate”. Finally, the consequent part of the rule has only one variable called “ConditionType” which defines the older people including those with Alzheimer’s condition as 1 or 2 for normal or abnormal condition, respectively. The action module reads the sensors values and search the matched condition in the rule base. If any of the conditions is met, the condition type will be generated by the system. If the condition type is abnormal condition, then decision support system offers a paramedic to check the patient. If the condition is normal then, no action is required. If more than one rule is fired and at least one of the rule’s consequent part is abnormal condition then the action will send paramedic, otherwise any of these rules will be randomly illustrated and no action will be generated. In the next section, the action scenario based experimental study is presented to proof the concept of the proposed decision support system for the people.

6.5 Experiments

In the experimental section, the system was tested on one people who have heart condition. The system is set for this case and tested over him for one week. The patient’s heart rate, environmental sensors conditions, and action information are recorded. The performance of the system is measured according to the fired rules types. If the patient needs an action, and if there is no rule fired, it will assume system response is not correct, or if the rule fired for a wrong action, then it will be counted as misclassified rule. The rule firing process is carried out every 5 minutes over a week between 9am and 8pm. The proposed decision support system (DSS) generated 144 rules for one day between 9am and 8pm. According to the generated rules results, the proposed DSS generated 43 abnormal conditions and 101 normal conditions.

According to the doctor observations, the system generated 8 abnormal conditions which were false alarms for the patient. The results histogram is illustrated in Figure 6.10. According to one day results, the performance of the system was found to be around 94.4% (8 false, 136 correct response) accuracy.

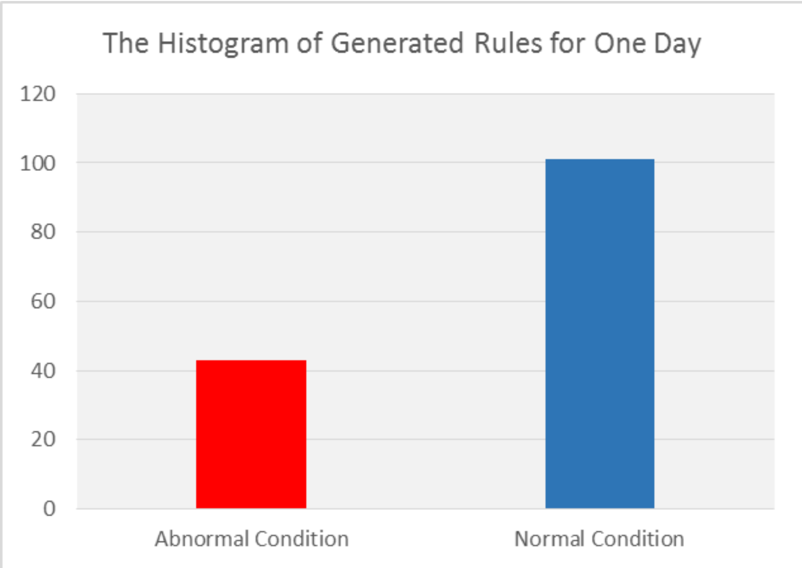

Figure 6.10: Daily rules generated of the proposed system.

After the one day testing results, the experiments were extended for one week for the same patient between 9am -8pm time scales. During this one week testing conditions, the system generated 1008 actions, which were 211 abnormal conditions and 797 normal conditions. The results are illustrated in Figure 6.11.

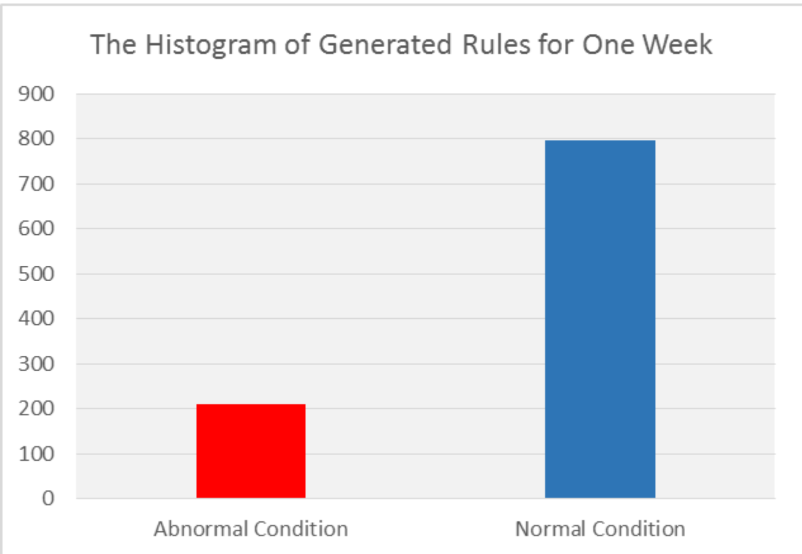

Figure 6.11: Weekly rules generated of the proposed system.

According to doctors' observation, it has been found that the system generated 129 false alarms for the people during the week. The observation shows that system generated 116 normal condition as abnormal and 13 abnormal conditions as normal. This is highly related to the sensors readings, communication problems, and lack of enough professionals' rules. The accuracy of the system during this one week was found as 87.2%. Although the accuracy of the system is quite high, it still needs to be enhanced for the false alarms generated, especially for the abnormal conditions counted as normal conditions.

6.6 Summary

This chapter presents a decision support system (DSS) using extended sensory information and rules based support system. The proposed system consists of three main parts. The first part is the extended sensory system development. The second part is the professionals' knowledge rules base system development. And the final part is the action development according to the sensory information and rules base of the system. The extended sensory system consists of four main sensor groups including vision sensors developed and tested in chapter 5 to recognize the subject's activity. The second sensory development is concerned with the subject's location identification based on RFID identification system. Third sensory group is related to environmental information such as room temperature and humidity utilizing Z-Wave communication protocol. Finally, a heart rate sensor was also developed to monitor the patient heart rate conditions. Moreover, a rule based was developed using medical professionals' knowledge. According to professionals’ decision, 25 rules were generated and programmed using C language. Finally, rules firing and action output was developed to activate support systems. The rule firing system read the recorded data every five minutes and generates an action according to the rule base and sensory information. The system was also tested for one week on a chronical heart problem patient. According to experiments, the proposed system performance was 87.2% successful.

Chapter 7: Conclusions and future work

This chapter presents the main contribution of this research, summarising how the objectives have been met. Concluding remarks are made considering the experience and insights gained while carrying out this work. The limitations that bounded the execution of this research are presented. Finally, the directions of future research and development in this specific area are discussed.

7.1Contribution to knowledge

Past research on assisted living was mainly aimed at reducing the workload of caregivers in supporting independent living by older people experiencing one or more impairments. Moreover, most frameworks focused on activity monitoring for assessing immediate risks, while the opportunities for integrating environmental monitoring for analytics and decision-making, especially for long-term care were often overlooked. On the other hand, recent advances in telecommunication, computing and sensor miniaturization, as well as the ubiquity of connected wearable devices embodying the concept of the Internet of Things (IoT) offer significant potential for end-to-end solutions for ambient assisted living. In addition, there is no substantial clinical evidence on the said benefits of assisted living in reducing caregivers' workload, the correct identification of the subject's activity pattern, and the avoidance of harm and health risks among older people with cognitive impairment, while enhancing positive outcomes. The following contributions to knowledge have been made in this thesis in ambient assisted living.

A critical synopsis of the developments in ambient assisted living systems and directions of future research. The first contribution of this work relates to the comprehensive systematic literature review on ambient assisted living systems for older people focussing on: (a) the objectives of the frameworks and sensor systems, (b) methods for activity recognition, (c) implementation challenges, and (d) the relationships with care and clinical systems. Key findings include the lack of: the integration between environmental and activity monitoring; strong supporting clinical evidence on the benefits of implemented technologies; and the consideration of socio-cultural aspects such as divergence among groups, acceptability and usability of AALS.

Identification of common daily activities of older people with Alzheimer's. The successful development of an AAL system depends on the identification of the nature, duration and extent of daily activities performed by the intended users. A time-of-use survey was carried out with the help of registered healthcare professionals over a 24-hour period among 48 older people with Alzheimer's to identify common daily activities. The results of this survey were analysed against the existing literature and cross-validated through consultations with relevant medical professionals. The outcome is a comprehensive list of the most common activities performed by older people with Alzheimer's, which is the basis for the methodological development of activity recognition in this work. It is envisaged that the identified daily activities will also serve as the basis for future related works on ambient assisted systems.

An ANN-based activity recognition system. The third contribution of this work is the development of an effective activity recognition process that utilises an artificial neural network, based on pre-processed phase-correlation and log-polar transformation. At the pre-processing stage, a detailed topology analysis was carried to find the best-performed network structure. The best performed ANN then was utilised to supply prior information about the activity type class for PCLP transformation, which predicts the activity using the rotation angle information. The system was successfully implemented on the most common activities representing about 72% of total daily activities.

An extended sensor-based monitoring system. The fourth contribution of this work is the development of an extended sensor-based system for monitoring locations, vital signs and activities of older people, as well as environmental parameters. An RFID mesh network was implemented for the identification of locations, which were supplemented with a vision-based sub-system for activity recognition. Wearable wireless sensors provide vital signs such as heart rate. Finally, ambient temperature and humidity were measured with sensors that communicate via Z-Wave protocol. The novelty of the monitoring system is in: (a) the integration of the body area network (BAN) with home area network (HAN) through multi-protocol (WiFi, Z-Wave and RFID) communications, and (b) the implementation in a low-power, low-cost, and extensible SoC-based computation platform**.**

A rule-based system for integrating medical knowledge with AALS. The fifth contribution of this is the development of a rule base system that integrates medical professionals' knowledge with data from sensor-based monitoring and the ANN-based activity recognition systems to provide decision-support in the developed AALS. The objective of the decision support system is to protect the older people including those with Alzheimer's from unexpected risks and mitigating circumstances.

7.2 Achievement of the objectives

All the objectives stated in chapter one have been met as follows.

Objective 1: Investigate the state-of-the-art in ambient assisted living to identify gaps in the literature and directions for future research. A comprehensive systematic review of the literature was carried out on ambient assisted living systems for older people focussing on technological frameworks and sensor systems, methods for recognising activities, challenges for implementation and evidence on the effects of AALS on independent living. The review is published in *SpringerPlus*.

Objective 2: Investigate the daily life and activities of older people with Alzheimer's in order to identify opportunities and areas where ambient assisted living systems could contribute to their Independent living life style. Daily life and activities of older people with Alzheimer's were investigated using a ToU survey. The results were analysed using statistical methods to investigate the relationships, if any, between pre-existing medical conditions and activities. Per the analysis, fourteen common daily activities have been identified, of which three main activities accounted for about 72% of total daily activities of older people with Alzheimer's.

Objective 3: Engage with care providers and professionals to identify the requirements for independent living home design and associated systems. A questionnaire was conducted among healthcare professionals involved in the delivery of care for older people with Alzheimer's to identify the requirements and intended characteristics of home design and associated systems for independent living. In addition, interviews were conducted to corroborate questionnaire findings that suggested non-intrusive monitoring as key to the wider adoption of AALS — pointing towards the adoption of machine vision based techniques fused with environmental sensing and monitoring data.

Objective 4: Cross-reference (2) and (3) to develop a conceptual framework for an efficient AAL system that is able to support older people with Alzheimer's to live independently through performing activity recognition. Findings from objectives (2) and (3) were combined to develop an idealised framework for ambient assisted living system, with deliberations on how the framework can be extended to provide decision support within a continuous monitoring system.

Objective 5: Develop a robust method for older people activity recognition using environment distributed sensors and image processing. To achieve this objective, a human activity recognition system was developed by fusing data from vision, environmental, vital signs and location sensors for improved accuracy of activity recognition. Further, a rule based decision support system was developed to aid decision making by integrating monitoring information with rules extracted from medical professionals.

Objective 6: Validate the developed framework using realistic case studies. Finally, the developed activity recognition and decision support system was tested through a case study to assess system performance. The tests showed that the system is successful in recognising human activities to a high degree that can be used to support independent living by older people, including those with Alzheimer's.

7.3 Concluding remarks

The work reported in this thesis has demonstrated the possibility of using relatives and/or caregivers' observations in conjunction with machine vision techniques to identify activities of older people. The developed activity recognition system combines machine vision with the data from body area network and environmental sensing to enable non-intrusive monitoring of activities and location. The integration of expert rules extracted from caregivers' observations and medical history with the activity recognition system has been demonstrated through a case study validation in this thesis, leading to effective decision support and personal assistive systems for older people living independently. Advanced data mining based on machine intelligence played a crucial role in identifying patterns in this work, which highlights the potential of ambient home assistive technologies and automation to be extended to the personalized healthcare that may contribute to reducing the numbers of older people in care homes, as well as provide them with necessary social interaction, safe environment, and care support needed within their own homes. This will reduce the dependency on care homes and associated costs while empowering older people to live independently. With advances in internet of things, every element in the home environment has the potential to be connected to the internet and AALS, as well as the care decision support systems. The wider integration of sensing, monitoring and decision support will not only support caregivers and professionals but can also enable social and family interaction through the connected environment.

7.4 Limitations

There are several ethical and logistic challenges of conducting healthcare related research involving older people with pre-existing conditions, resulting in research limitations. One of the limitations of this work relates to the time of use survey conducted. Although a reasonable sample size (n = 48) was achieved, the observation period for each surveyed person was limited to 24 hours, which did not allow for the observation of weekly or seasonal patterns in activities. The other limitations for the ToU survey relate to the constrained observation performed by caregivers only, and the cultural limitation due to sex segregation practice in the Kingdom of Saudi Arabia. In addition, data collection performed by caregivers limits the data collected to the subjective judgment of the observer, which often varies from person to another.

Regarding the validation of the developed system, the limited range of *vital sign* sensors constrained the activity monitoring to short distance communication between the person and the receiving platform, where activities that needed longer distances of communication could not be tested.

The algorithms developed for vision-based activity recognition only compared time-sequenced images as the registration technique as a proof of concept, primarily due to the limited availability of compute power in SoC systems. The use of video streaming fused with sounds can be utilised in a more powerful computing platform. Finally, as a socio-technical system, AALS are potentially affected by variations in culture, social norms and language, as well as how the wider society interacts with technology. This research was limited to KSA and, therefore, the global issues of AALS adoption could not be investigated.

7.5 Future work

This research demonstrated the potential of integrating environmental monitoring for enhanced activity recognition considering the identified daily activities of older people, with the rule-based decision support to assist independent living, opening up new avenues of future research and development, as follows.

The identification of daily activities and their relationship with pre-existing medical conditions, social norms and cultural variations is an important first step in designing effective ambient assisted living systems. Considering the limitations of the Time of Use survey in this research, future work can extend the observation-based data collection to cover longer periods for identifying weekly and seasonal patterns of daily activities, as well as incorporate observations by both caregivers and researchers while including all possible measurements that can be linked to the activity perception model, such as detailed environmental conditions and all possible vital signs.

The second recommendation for future work is related to the human activity recognition process. PCLP transformation is a popular image registration technique, which can be extended with other intelligent system approaches to recognise human action with higher accuracy. Moreover, the PCLP transformation can be implemented in a smaller region of interest to extract more details about the human features to recognise more activities, such as bending, turning, and praying. Such positions/status may be necessary to be identified, especially for safety reasons.

The third recommendation is to extend the vital sign sensors to cover more measurements with extended area coverage, instead of the 1.5 m radius implemented in this research, using low-power, and long-distance communication systems.

The fourth recommendation is related to the boundary identification of expert rules. As a rule's antecedent parts consist of value ranges, which could be better defined with a fuzzy system, resulting in a more accurate solution for the rule activation process.

The final recommendation is to extend the work carried out in this research thesis to include recent advances in internet of things (IoT), especially the miniaturisation and ubiquity of sensors, to: (a) extend the coverage in terms of factors/aspects monitored, and (b) integrate smart home technologies with AALS.

REFERENCES

Abu-Shabeen, N. N. (2008). Development of multi-criteria decision analysis models for bidding and contractor selection (Doctoral dissertation, Edinburgh Napier University).

Aggarwal, J. K. and Ryoo, M. S. (2011). “Human activity analysis: a review”. ACM Comput. Surv (CSUR). vol. 43, no. 3, pp.1-43.

Agoulmine, N., Deen, M. J., Lee, J. S., & Meyyappan, M. (2011). U-health smart home. Nanotechnology Magazine, IEEE, 5(3), pp. 6-11.

Alarmnet. (2011). [Online]: Available from: www.cs.virginia.edu/wsn/medical/ (Accessed: 21 May 2014).

Algase, D. L., Beattie, E. R., Leitsch, S. A., & Beel-Bates, C. A. (2003). Biomechanical activity devices to index wandering behaviour in dementia. American journal of Older people with Alzheimer’s and other dementias, 18(2), pp.85-92.

Allameh, E., Jozam, M. H., de Vries, B., Timmermans, H., & Beetz, J. (2011). Smart Home as a smart real estate: a state of the art review. In 18th Annual European Real Estate Society Conference, Eindhoven, The Netherlands.

Alm, N., Astell, A., Gowans, G., Dye, R., Ellis, M., Vaughan, P., & Riley, P. (2009). Engaging multimedia leisure for people with dementia. Gerontechnology, 8(4), pp. 236-246.

Alm, N., Astell, A., Gowans, G., Dye, R., Ellis, M., Vaughan, P., & Newell, A. (2007). An interactive entertainment system usable by older people with dementia. Universal Access in Human-Computer Interaction. Ambient Interaction, Springer, pp. 617-623.

Alshehri, S. A., Rezgui, Y., & Li, H. (2015). Delphi-based consensus study into a framework of community resilience to disaster. Natural Hazards, 75(3), pp. 2221-2245.

Arai, K. (2013), Frequent Physical Health Monitoring as Vital Signs with Psychological Status Monitoring for Search and Rescue of Handicapped, Diseased and Eldery Persons, International Journal.

Arai, K. (2014). Vital sign and location/attitude monitoring with sensor networks for the proposed rescue system for disabled and older people persons who need a help in evacuation from disaster areas. sensors, 3(1)

Aytac, I. A., McKinlay, J. B., & Krane, R. J. (1999). The likely worldwide increase in erectile dysfunction between 1995 and 2025 and some possible policy consequences. BJU international, 84, pp.50-56.

Azarbayejani, A. and Pentland, A. (1996) "Real-time self-calibrating stereo person tracking using 3-D shape estimation from blob features," in proc. of 13th International IEEE Conference on Pattern Recognition, vol.3, no., pp.627-632, Vienna, Austria.

Bal, M., Shen, W., Hao, Q., & Xue, H. (2011). Collaborative smart home technologies for senior independent living: a review. In Proceedings of the 2011 15th International Conference on Computer Supported Cooperative Work in Design (CSCWD).pp. 481-488.

Barney, G. (1992). Basics of Grounded Theory Analysis. Mill Valley: Sociology.

Beard, J., Biggs, S., Bloom, D. E., Fried, L. P., Hogan, P. R., Kalache, A., & Olshansky, S. J. (2012). Global population ageing: Peril or promise? (No.8912). Program on the Global Demography of Aging.

Bharucha, A. J., Anand, V., Forlizzi, J., Dew, M. A., Reynolds, C. F., Stevens, S., & Wactlar, H. (2009). Intelligent assistive technology applications to dementia care: current capabilities, limitations, and future challenges. The American journal of geriatric psychiatry, 17(2), pp.88-104.

Blaschke, C. M., Freddolino, P. P., & Mullen, E. E. (2009). Ageing and technology: A review of the research literature. British Journal of Social Work,39(4), pp.641-656.

Blaya, J. A. B., Palma, J., Villa, A., Perez, D., & Iborra, E. (2009). Ontology based approach to the detection of domestics problems for independent senior people. In Bioinspired Applications in Artificial and Natural Computation. Springer Berlin Heidelberg, pp. 55-64

Bleda, A. L., Maestre, R., Jara, A. J., & Skarmeta, A. G. (2014). Ambient Assisted Living Tools for a Sustanaible Aging Society. In Resource Management in Mobile Computing Environments. Springer International Publishing. pp. 193-220

BiomobusI, (2011). BioMobus Research Platform [Online] Available from: *http://biomobius.trilcentre.org/index.php*(Accessed: 21 Jun 2015).

Bischoff, U., Sundramoorthy, V. & Kortuem, G. Programming the smart home. Intelligent Environments, (2007). IE 07. 3rd IET International Conference on, 24-25 Sept. 2007.

Blum, F. H. (1955). Action research--A scientific approach? Philosophy of science, pp.1-7.

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: Capturing life as it is lived. Annual review of psychology, 54(1), pp.579-616.

Bose, S. (2013). Creation of an Assisted Living Environment for Older people using Ubiquitous Networking Technologies.

Bryman, A. (2006). Integrating quantitative and qualitative research: how is it done? Qualitative research, 6(1), pp.97-113.

Bryman, A. (2012). Social research methods. Oxford university press.

Buchner, D. M., & Larson, E. B. (1987). Falls and fractures in people with Alzheimer-type dementia. Jama, 257(11), pp.1492-1495.

Cartwright, N., & Cartwright, N. (1983). How the laws of physics lie (p. 135). Oxford: Clarendon Press.

Chang, W. L., Yuan, S. T., & Li, E. Y. (2009). iCare home portal: An extended model of quality aging e-services. Communications of the ACM, 52(11), pp.118-124.

Chan, M., Campo, E., Estève, D., & Fourniols, J. Y. (2009). Smart homes—current features and future perspectives. Maturitas, 64(2), pp.90-97.

Chan, M., Estève, D., Escriba, C., & Campo, E. (2008). A review of smart homes—Present state and future challenges. Computer methods and programs in biomedicine, 91(1), pp.55-81.

Cheek, P., Nikpour, L., & Nowlin, H. D. (2005). Aging well with smart technology. Nursing administration quarterly, 29(4), pp.329-338.

Chernbumroong, S., Cang, S., Atkins, A., & Yu, H. (2013). Older people activities recognition and classification for applications in assisted living. Expert Systems with Applications, 40(5), pp.1662-1674.

Chen, L., Hoey, J., Nugent, C. D., Cook, D. J., & Yu, Z. (2012). Sensor-based activity recognition. Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, 42(6), pp.790-808.

Chen, L., & Nugent, C. (2009). Ontology-based activity recognition in intelligent pervasive environments. International Journal of Web Information Systems,5(4), pp.410-430.

Chikhaoui, B., Wang, S., & Pigot, H. (2012). ADR-SPLDA: Activity discovery and recognition by combining sequential patterns and latent Direct allocation. Pervasive and Mobile Computing, 8(6), pp.845-862.

Chilvers, R., Corr, S., & Singlehurst, H. (2010). Investigation into the occupational lives of healthy older people through their use of time. Australian Occupational Therapy Journal, 57(1), pp.24-33.

Codeblue, T. (2011). Wireless Sensor Networks for Medical Care [Online]. Available from: *http://fiji.eecs.harvard.edu/CodeBlue.* (Accessed: 10 July 2014).

Cong L. and Zhuang, W. (2002). Hybrid TDOA/AOA mobile user location for wideband CDMA cellular systems, IEEE Transactions on Wireless Communications, vol.1, no.3, pp.439-447.

Cook, D. J., Youngblood, M., Heierman III, E. O., Gopalratnam, K., Rao, S., Litvin, A., & Khawaja, F. (2003). MavHome: An agent-based smart home. IEEE.In null p. 521.

Cooper, C., Campion, G., & Melton III, L. (1992). Hip fractures in the older people: a world-wide projection. Osteoporosis international, 2(6),pp. 285-289.

Crabtree, B. F., & Miller, W. L. (Eds.). (1999). Doing qualitative research. Sage Publications.

Crispim-Junior, C. F., Bremond, F., & Joumier, V. (2012). A multi-sensor approach for activity recognition in older people. In The Second International Conference on Ambient Computing, Applications, Services and Technologies-AMBIENT 2012. XPS/ThinkMindTM Digital Library.

Dalke, H., Little, J., Niemann, E., Camgoz, N., Steadman, G., Hill, S., & Stott, L. (2006). Colour and lighting in hospital design. Optics & Laser Technology, 38(4), pp.343-365.

Dalton, A. & Olaighin, G. (2012). A Comparison of Supervised Learning Techniques on the task of Physical Activity Recognition IEEE J Biomed Health Inform, (1),pp. 46-52.

Dancer, S. J. (2011). Hospital cleaning in the 21st century. European journal of clinical microbiology & infectious diseases, 30(12), pp.1473-1481.

David, D., & David, Z. (1996). U.S. Patent No. 5,544,649. Washington, DC: U.S. Patent and Trademark Office.

De Miguel-Bilbao, S., García, J., López, F., García-Sagredo, P., Pascual, M., Montero, B. ... & Salvador, C. H. (2014). Home Monitoring of Older people for Early Detection of Changes in Activity and Behaviour Patterns. In XIII Mediterranean Conference on Medical and Biological Engineering and Computing 2013 Springer International Publishing. pp. 1205-1208.

Demiris, G., & Hensel, B. K. (2008). Technologies for an aging society: a systematic review of "smart home" applications. Yearb Med Inform, 3, pp.33-40.

Dengler, S., Awad, A., & Dressler, F. (2007). Sensor/actuator networks in smart homes for supporting older people and handicapped people. In Advanced Information Networking and Applications Workshops, 2007, AINAW'07. IEEE. 21st International Conference on Vol. 2, pp. 863-868.

Dibley, M., Li, H., Rezgui, Y., & Miles, J. (2012). Cost effective and scalable sensor network for intelligent building monitoring. International Journal of Innovative Computing, Information and Control, 8(12), pp.8415-8433.

Dinh, C., & Struck, M. (2009). A new real-time fall detection approach using fuzzy logic and a neural network. In Wearable Micro and Nano Technologies for Personalized Health (pHealth), 2009 6th International Workshop on, pp. 57-60. IEEE

DLF UK. (2009). Losing independence is a bigger ageing worry than dying [Online] Available from: https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CCoQFjAA&url=http%3A%2F%2Fwww.dlf.org.uk%2Fblog%2Flosing-independence-bigger-ageing-worry-dying&ei=FNntUqvEH83Y7AbzpYHoBg&usg=AFQjCNFk-4MVugTQaT0HXhq4gCuMEmP_2w (Accessed: 25 July 2012).

Dubbs, D. (2004). Sound effects: design and operations solutions to hospital noise. Health facilities management, 17(9), pp.14-18.

Dudzinski, D. Kryjak, T. and Mikrut Z. (2013). “Human Action Recognition Using Simple Geometric Features and a Finite State Machine”. Image Processing & Communication, vol. 18, no.2 pp. 49-60.

Dwyer, M., Renwick, M., & Gray, A. (2000). Factors affecting the ability of older people to live independently: A report for the international year of older persons. Ministry of Social Policy.

Efros, A., Berg, A. Mori, G. and Malik. J. (2013). “Recognizing action at a distance”. In proc. of IEEE 9th International Conference of ICCV, Nice, France, pp. 726-733.

El-Hakim, S. F., Beraldin, J.-A., Godin, G. and Boulanger, P. (1996). "Two 3-d sensors for environment modeling and virtual reality: calibration and multi-view registration ", In proc. of Int. Arch. Of Photogram and Remote Sensing, vol. 31, Part B5, pp. 140-146, Vienna, Austria.

Ettinger, R. L., & Chalmers, J. M. (2015). Oral health care programs for homebound people, nursing home residents and older people inpeople. Textbook of geriatric dentistry, 2, 536-59.

Fahim, M., Fatima, I., Lee, S., & Lee, Y. K. (2012). Daily life activity tracking application for smart homes using android smartphone. In Advanced Communication Technology (ICACT), IEEE, 2012 14th International Conference on pp. 241-245.

Farella, E., Falavigna, M., & Riccò, B. (2010). Aware and smart environments: The Casattenta project. Microelectronics Journal, 41(11), pp. 697-702.

Feldman, H., Gauthier, S., Hecker, J., Vellas, B., Subbiah, P., & Whalen, E. (2001). A 24-week, randomized, double-blind study of donepezil in moderate to severe Older people with Alzheimer’s. Neurology, 57(4), pp.613-620.

Fink, J., Kobsa, A., & Nill, A. (1998). Adaptable and adaptive information provision for all users, including disabled and older people. New review of Hypermedia and Multimedia, 4(1), pp.163-188.

Foroughi, H., Yazdi, H.S., Pourreza, H., and Javidi, M. (2008). “An eigenspace-based approach for human fall detection using integrated time motion image and multi-class support vector machine," In proc. of IEEE the 4th International Conference on Intelligent Computer Communication and Processing, Cluj-Napoca, Romania, pp. 83-90.

Foundation, D. L. (2009). "Losing independence is a bigger ageing worry than dying." [Online] Available from: *https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CCoQFjAA&url=http%3A%2F%2Fwww.dlf.org.uk%2Fblog%2Flosingindependence-bigger-ageing-worry-dying&ei=FNntUqvEH83Y7AbzpYHoBg&usg=AFQjCNFk-4MVugTQaT0HXhq4gCuMEmP_2w* (Accessed: 21 July 2013).

Franco, C., Demongeot, J., Villemazet, C., & Vuillerme, N. (2010). Behavioural telemonitoring of the older people at home: Detection of nycthemeral rhythms drifts from location data. In Advanced Information Networking and Applications Workshops (WAINA), 2010 IEEE 24th International Conference on pp. 759-766. IEEE.

Gaddam, A., Mukhopadhyay, S. C., & Gupta, G. S. (2010). Smart home for older people using optimized number of wireless sensors. In Advances in Wireless Sensors and Sensor Networks, pp. 307-328. Springer Berlin Heidelberg.

Gavrila. D. M. (1999), “The Visual Analysis of Human Movement: A Survey”. Computer Vision and Image Understanding, vol. 73, no. 1, pp. 82-98.

GERONTOLOGICAL. (2011). Gerontological Smart Home Environment (GERHOME) [Online]. Available from*: http://gerhome.cstb.fr/*.(Accessed: 15 Augest 2013).

GLASER, B. 1992. Basics of grounded theory analysis. Mill Valley, CA: Sociology Pre.

Greatorex, J., & Dexter, T. (2000). An accessible analytical approach for investigating what happens between the rounds of a Delphi study. Journal of Advanced Nursing, 32(4), pp.1016-1024.

Gross, H. M., Schroeter, C., Mueller, S., Volkhardt, M., Einhorn, E., Bley, A & Merten, M. (2011). Progress in developing a socially assistive mobile home robot companion for the older people with mild cognitive impairment. In Intelligent Robots and Systems (IROS), 2011 IEEE/RSJ International Conference on pp. 2430-2437. IEEE.

Guenther, R., & Vittori, G. (2008). Sustainable healthcare architecture. John Wiley & Sons.

Guo, Y., Xu, G., and Tsuji, S. (1994) “Understanding human motion patterns”, in Proc. of IEEE International Conference on Pattern Recognition, Jerusalem, Israel, pp. 325-329.

Gupta, G. S., Mukhopadhyay, S. C., Sutherland, M., & Demidenko, S. (2007). Wireless sensor network for selective activity monitoring in a home for the older people. In Instrumentation and Measurement Technology Conference Proceedings, 2007. IMTC 2007. IEEE, pp. 1-6. IEEE.

Hacking, I. (1983). Representing and intervening: Introductory topics in the philosophy of natural science (Vol. 5, No. 1). Cambridge: Cambridge University Press.

Haley, W. E., Roth, D. L., Coleton, M. I., Ford, G. R., West, C. A., Colllins, R. P., & Isobe, T. L. (1996). Appraisal, coping, and social support as mediators of well-being in black and white family caregivers of people with Older people with Alzheimer’s. Journal of consulting and clinical psychology, 64(1), p121.

Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. Journal of advanced nursing, 32(4), pp.1008-1015.

Haub, C. (2012). Fact sheet: World population trends 2012.

Hayutin, A. (2009). Critical-Demographics-of-the-Greater-Middle-East.

Helal, A., Cho, K., Lee, W. J., Sung, Y., Lee, J. W., & Kim, E. (2012). 3D modeling and simulation of human activities in smart spaces. In Ubiquitous Intelligence & Computing and 9th International Conference on Autonomic & Trusted Computing (UIC/ATC), 2012 9th International Conference on, pp. 112-119. IEEE.

Helal, S., Lee, J. W., Hossain, S., Kim, E., Hagras, H., & Cook, D. (2011). Persim-Simulator for human activities in pervasive spaces. In Intelligent Environments (IE), 2011 7th International Conference on, pp. 192-199. IEEE.

Helal, S., Mann, W., King, J., Kaddoura, Y., & Jansen, E. (2005). The gator tech smart house: A programmable pervasive space. Computer, 38(3), pp.50-60.

Helmi, M., & AlModarresi, S. M. T. (2009). Human activity recognition using a fuzzy inference system. In Fuzzy Systems, 2009. FUZZ-IEEE 2009. IEEE International Conference on, pp. 1897-1902. IEEE.

Henn, M., Weinsttein, M. & FOARD, N. (2008). A short introduction to Social Research, London, Sage Publications Ltd.

Hurley, A. C., Volicer, B. J., Hanrahan, P. A., Houde, S., & Volicer, L. (1992). Alzheimer People. Research in nursing & health, 15, pp.369-377.

Husen, M. N. and Lee, S. (2014). Indoor human localization with orientation using WiFi fingerprinting. in the proc. of the Eighth International Conference on Ubiquitous Information Management and Communication, Siem Reap, Cambodia, pp.109-115.

lBeiruti, N., & Al-Begain, K. (2014). Using Hidden Markov Models to Build Behavioural Models to Detect the Onset of Dementia. In Computational Intelligence, Communication Systems and Networks (CICSyN), 2014 Sixth International Conference on, pp. 18-26. IEEE.

Ichapurapu, R., Jain, S., John, G., Monday, T., Lie, D. Y., Banister, R., & Griswold, J. (2009). A 2.4 GHz non-contact biosensor system for continuous vital-signs monitoring. In Wireless and Microwave Technology Conference, 2009. WAMICON'09. IEEE 10th Annual. pp. 1-3. IEEE.

Jain, A., & Dweep Chand Singh, M. (2014). Resilience and quality of life in caregivers of schizophrenia and bipolar disorder people. Global Journal of Human-Social Science Research, 14(5).

Jara, A. J., Lopez, P., Fernandez, D., Zamora, M. A., Ubeda, B., & Skarmeta, A. F. (2013). Communication protocol for enabling continuous monitoring of older people through near field communications. Interacting with Computers, iwt030.

Jorm, A. F., Korten, A. E., & Henderson, A. S. (1987). The prevalence of dementia: a quantitative integration of the literature. Acta psychiatrica scandinavica, 76(5), pp.465-479.

Junker, H., Amft, O., Lukowicz, P., & Tröster, G. (2008). Gesture spotting with body-worn inertial sensors to detect user activities. Pattern Recognition, 41(6), pp.2010-2024.

Kahn, R., Swain, M., Prokopowicz, P. and Firby, J. (1996). “Gesture recognition using the persesus architecture”, in proc. of IEEE Conference on Computer Vision and Pattern Recognition, San Francisco, US, pp. 734–741.

Kanamori, M., Suzuki, M., Yamamoto, K., Kanda, M., Matsui, Y., Kojima, E., ... & Oshiro, H. (2001). A day care program and evaluation of animal-assisted therapy (AAT) for the older people with senile dementia. American journal of Older people with Alzheimer’s and other dementias, 16(4),pp. 234-239.

Kao, T. P., Lin, C. W., & Wang, J. S. (2009). Development of a portable activity detector for daily activity recognition. In Industrial Electronics, 2009. ISIE 2009. IEEE International Symposium on (pp. 115-120). IEEE.

Katzman, R., & Fox, P. J. (1999). The World-Wide Impact of Dementia. Projections of Prevalance and Costs. In Epidemiology of Older people with Alzheimer's: From gene to prevention, pp. 1-17. Springer Berlin Heidelberg.

Kaur, M., Sandhu, M. Mohan, N. and Sandhu, P. (2011). RFID Technology Principles, Advantages, Limitations & Its Applications, International Journal of Computer and Electrical Engineering, Vol.3, No.1, pp.152-157.

Kautz, H. (1987). "A Formal Theory of Plan Recognition". Ph.D. Thesis, University of Rochester, NY, USA.

Kautz, H., Fox, D., Etzioni, O., Borriello, G., & Arnstein, L. (2002). An overview of the assisted cognition project. AAAI-2002 Workshop on Automation as Caregiver: The Role of Intelligent Technology in Elder Care.

Khan, Z. A. and Sohn, W. (2011). Real Time Human Activity Recognition System based on Radon Transform. IJCA Special Issue on "Artificial Intelligence Techniques - Novel Approaches & Practical Applications", vol.4, no. 7-13, pp. 31–37.

Khazaei, N. B., Tavakoli, T., Ghassemian, H., Khoshtaghaza, M. H. and Banakar, A. (2013). Applied machine vision and artificial neural network for modeling and controlling of the grape drying process". Computers and Electronics in Agriculture, vol. 98, pp. 205-213.

Kidd, C. D., Orr, R., Abowd, G. D., Atkeson, C. G., Essa, I. A., MacIntyre, B., & Newstetter, W. (1999). The aware home: A living laboratory for ubiquitous computing research. In Cooperative buildings. Integrating information, organizations, and architecture, pp. 191-198. Springer Berlin Heidelberg.

Kientz, J. A., Patel, S. N., Jones, B., Price, E. D., Mynatt, E. D., & Abowd, G. D. (2008). The georgia tech aware home. In CHI'08 extended abstracts on Human factors in computing systems, pp. 3675-3680. ACM.

Kim, E., Helal, S., & Cook, D. (2010). Human activity recognition and pattern discovery. Pervasive Computing, IEEE, 9(1), pp. 48-53.

Kinsella, K., & Velkoff, V. A. (2001). An Aging World: 2001: International Population Reports. US Cencus Bureau, Economic and Statistics Administration, Department of Commerce.

Klein, H. K., & Myers, M. D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. MIS quarterly, pp.67-93.

Krishnan, N. C., & Cook, D. J. (2014). Activity recognition on streaming sensor data. Pervasive and mobile computing, 10, pp.138-154.

Kruger, V., Kragic, D., Ude, A., and Geib, C. (2007). “The meaning of action: a review on action recognition and mapping”. Advanced Robotics, vol. 21, no. 13, pp. 1473-1501.

Kumari, S. and Mitra, S. K. (2011). "Human Action Recognition Using DFT," in IEEE proc. Third National Conference on Computer Vision, Pattern Recognition, Image Processing and Graphics (NCVPRIPG), Hubli, Karnataka, pp.239,242.

Kwan, A. (2012). Using mobile technologies for healthier aging. mHealth Alliance and Pfizer.

Lacko, D. (2011). “Motion Capture and Guidance Using Open Source Hardware”. MSc Thesis, Artesis University College of Antwerp, Antwerp, Belgium.

Lam, J., Liamputtong, P., & Hill, K. (2015). Falls, falls prevention and the role of physiotherapy and exercise: perceptions and interpretations of Italian-born and

Australian-born older persons living in Australia. Journal of cross-cultural gerontology, 30(2), pp.233-249.

Lara, O. D. and Labrador, M. A. (2013). "A Survey on Human Activity Recognition using Wearable Sensors," IEEE Communications Surveys & Tutorials, vol.15, no.3, pp.1192-1209.

Lara, Ó. D., Pérez, A. J., Labrador, M. A., & Posada, J. D. (2012). Centinela: A human activity recognition system based on acceleration and vital sign data. Pervasive and mobile computing, 8(5), pp.717-729.

Lauriks, S., Reinersmann, A., Van der Roest, H. G., Meiland, F. J. M., Davies, R. J., Moelaert, F.,& Dröes, R. M. (2007). Review of ICT-based services for identified unmet needs in people with dementia. Ageing research reviews, 6(3), pp. 223-246.

Le, X. H. B., Di Mascolo, M., Gouin, A., & Noury, N. (2008). Health smart home for elders-a tool for automatic recognition of activities of daily living. In Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE, pp. 3316-3319 . IEEE.

Lie, D., Lopez, J., Griswold, J., Ichapurapu, R., Banister, R., Jain, S., & Nguyen, T. (2011). A 2.4 GHz Non-Contact Biosensor System for Continuous Monitoring of Vital-Signs. INTECH Open Access Publisher.

Linskell, J. (2011). Smart home technology and special needs reporting UK activity and sharing implementation experiences from Scotland. In Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2011 5th International Conference on, pp. 287-291. IEEE.

Liu, A & FellowsF,R. (2008). Research Method for Construction, ISBN: 978-1-4051-7790-0. Singapore. Wiley-Blackwell.

Logsdon, R. G., Teri, L., McCurry, S. M., Gibbons, L. E., Kukull, W. A., & Larson, E. B. (1998). Wandering: a significant problem among community residing individuals with Older people with Alzheimer's. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 53(5), pp.294- 299.

Lotfi, A., Langensiepen, C., Mahmoud, S. M., & Akhlaghinia, M. J. (2012). Smart homes for the older people dementia people: identification and prediction of abnormal behaviour. Journal of Ambient Intelligence and Humanized Computing, 3(3), pp.205-218.

Luo, B. Zhang, Y., Yu, G. and Zhou, X. (2007). ANN Ensembles Based Machine Vision Inspection for Solder Joints, in proc. of IEEE International Conference on Control and Automation, Guangzhou, CHINA, pp.3111-3115.

Mace, N. L., & Rabins, P. V. (2011). The 36-hour day: A family guide to caring for people who have Alzheimer disease, related dementias, and memory loss. JHU Press.

Mahadevan, M., Hartwell, H. J., Feldman, C. H., Ruzsilla, J. A., & Raines, E. R. (2014). Assisted-living older people and the mealtime experience. Journal of Human Nutrition and Dietetics, 27(2), pp.152-161.

Matsuyama, Y., Taniyama, H., Fujie, S., & Kobayashi, T. (2009). System design of group communication activator: An entertainment task for older people care. In Proceedings of the 4th ACM/IEEE international conference on Human robot interaction, pp. 243-244. ACM.

Mba, C. J. (2013). Determinants of living arrangements of Lesotho's older people female population. Journal of International Women's Studies, 3(2), pp.1-22.

McCurry, S. M., Logsdon, R. G., Teri, L., Gibbons, L. E., Kukull, W. A., Bowen, J. D., ... & Larson, E. B. (1999). Characteristics of sleep disturbance in community-dwelling

Older people with Alzheimer's people. Journal of Geriatric Psychiatry and Neurology, 12(2), pp.53-59.

Metz, D. H. (2000). Mobility of older people and their quality of life. Transport policy, 7(2), pp.149-152.

Mitseva, A., Kyriazakos, S., Litke, A., Papadakis, N., & Prasad, N. R. (2009). ISISEMD: Intelligent System for Independent living and self-care of Seniors with mild cognitive impairment or Mild Dementia. The Journal on Information Technology in Healthcare, 7(6), pp.383-399.

Montemerlo, M., Pineau, J., Roy, N., Thrun, S., & Verma, V. (2002). Experiences with a mobile robotic guide for the older people. In AAAI/IAAI, pp. 587-592.

Mourshed, M., & Zhao, Y. (2012). Healthcare providers' perception of design factors related to physical environments in hospitals. Journal of Environmental Psychology, 32(4), pp.362-370.

Muller, J. H. (1995). Care of the Dying by Physicians-in-Training An Example of Participant Observation Research. Research on Aging, 17(1), pp.65-88.

MÜLLER, S., SANTI, M., & SIXSMITH, A. (2008). Eliciting user requirements for ambient assisted living: Results of the SOPRANO project. P. CUNNINGHAM und M. CUNNIGHAMN (Herausgeber): Collaboration and the Knowledge Economy: Issues, Applications, Case Studies, Part, 1, pp.81-88.

Mundt, J. P., & Connors, J. J. (1999). Problems and challenges associated with the first years of teaching agriculture: A framework for pre-service and in-service education. Journal of Agricultural Education, 40, 38-48.

Muñoz, A., Augusto, J. C., Villa, A., & Botía, J. A. (2011). Design and evaluation of an ambient assisted living system based on an argumentative multi-agent system. Personal and Ubiquitous Computing, 15(4), pp.377-387.

Myers, M. D. (1997). Qualitative research in information systems. Management Information Systems Quarterly, 21,pp. 241-242.

Nehmer, J., Becker, M., Karshmer, A., & Lamm, R. (2006). Living assistance systems: an ambient intelligence approach. In Proceedings of the 28th international conference on Software engineering, pp. 43-50. ACM.

Newman, S., & Ward, C. (1992). An observational study of intergenerational activities and behaviour change in dementing elders at adult day care centers.The International Journal of Aging & Human Development. 36**,** pp. 321-333.

Nilsson, N. J. (2014). Principles of artificial intelligence. Morgan Kaufmann.

Nunamaker Jr, J. F., & Chen, M. (1990). Systems development in information systems research. In System Sciences, 1990., Proceedings of the Twenty-Third Annual Hawaii International Conference on, Vol. 3, pp. 631-640. IEEE.

Oates, B. J. (2006). New frontiers for information systems research: computer art as an information system. European Journal of Information Systems, 15(6), pp. 617-626.

OECD (2005). Ageing Populations : High Time for Action Meeting of G8 Employment and Labour Ministers. Paris, France: : Organisation for Economic Co-operation and Development.

Ogale, A. S., Karapurkar, A. and Aloimonos, Y. (2007), View invariant modeling and recognition of human actions using grammars. Lecture Notes in Computer Science, vol. 4358, pp. 115-126.

Ohta, S., Nakamoto, H., Shinagawa, Y., & Tanikawa, T. (2002). A health monitoring system for older people living alone. Journal of telemedicine and telecare, 8(3), pp.151-156.

Oliver, D., Foot, C., & Humphries, R. (2014). Making our health and care systems fit for an ageing population. London, UK: King’s Fund.

OpenZwave. 2015. Open Zwave: Home. [Online] Available from, , http://www.openzwave.com/, (Accessed: 20 May 2015).

Opoku, S. K. (2011). An Indoor Tracking System Based on Bluetooth Technology, Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Telecommunications (JSAT), vol. 2, no. 12, pp. 1-8.

Or, C. K., & Karsh, B. T. (2009). A systematic review of patient acceptance of consumer health information technology. Journal of the American Medical Informatics Association, 16(4), pp.550-560.

Papamatthaiakis, G., Polyzos, G. C., & Xylomenos, G. (2010). Monitoring and modeling simple everyday activities of the older people at home. InConsumer Communications and Networking Conference (CCNC), 2010 7th IEEE, pp. 1-5. IEEE.

Phua, C., Foo, V. S. F., Biswas, J., Tolstikov, A., Aung, A. P. W., Maniyeri, J., ... & Chu, A. K. W. (2009). 2-layer erroneous-plan recognition for dementia people in smart homes. In e-Health Networking, Applications and Services, 2009. Healthcom 2009. 11th International Conference on, pp. 21-28. IEEE.

Pieper, M., Antona, M., Cortes, U. (2011). Introduction to the Special Theme. Ambient Assistive Living. In ERCIM News, 87, pp. 18 – 19.

Pirttikangas, S., Fujinami, K., & Nakajima, T. (2006). Feature selection and activity recognition from wearable sensors. In Ubiquitous Computing Systems, pp. 516-527. Springer Berlin Heidelberg.

Pollack, M. E. (2005). Intelligent technology for an aging population: The use of AI to assist elders with cognitive impairment. AI magazine, 26(2), p9.

Pollard, E., & Liebeck, H. (1994). The Oxford paperback dictionary. Oxford University Press London.

Prince, M., Prina, M., & Guerchet, M. (2013). Journey of Caring: an analysis of long-term care for Dementia (Doctoral dissertation, N/A Ed; London: Older people with Alzheimer's International).

Ramsey, R., Hin, A., Prado, C., & Fernandez, M. (2015). Understanding and Preventing Falls: Perspectives of First Responders and Older Adults. Physical & Occupational Therapy In Geriatrics, 33(1), pp.17-33.

Rashidi, P. (2011). Scaling activity discovery and recognition to large, complex datasets (Doctoral dissertation, Washington State University).

Rashidi, P., Cook, D. J., Holder, L. B., & Schmitter-Edgecombe, M. (2011). Discovering activities to recognize and track in a smart environment.Knowledge and Data Engineering, IEEE Transactions on, 23(4), pp.527-539.

Raspberrypi. (2015). "Raspberry Pi" [Online], Available from: https://en.wikipedia.org/wiki/Raspberry_Pi , (Accessed: 21 July 2015).

Ricquebourg, V., Menga, D., Durand, D., Marhic, B., Delahoche, L., & Loge, C. (2006, December). The smart home concept: our immediate future. In E-Learning in Industrial Electronics, 2006 1ST IEEE International Conference on, pp. 23-28. IEEE.

Rivera-Illingworth, F., Callaghan, V., & Hagras, H. (2006). Automated discovery of human activities inside pervasive living spaces. In Pervasive computing and applications, 2006 1st international symposium on, pp. 77-82. IEEE.

Rocha, A., Martins, A., Freire, J. C., Boulos, M. N. K., Vicente, M. E., Feld, R., ... & Rodríguez-Molinero, A. (2013). Innovations in health care services: The CAALYX system. International Journal of Medical Informatics, 82(11), pp.307-320.

Rowe, M., Lane, S., & Phipps, C. (2007). CareWatch: A home monitoring system for use in homes of persons with cognitive impairment. Topics in geriatric rehabilitation, 23(1), p.3.

Sayuti, H., Rashid, R. A., Mu'azzah, A. L., Hamid, A. H. F. A., Fisal, N., Sarijari, M. A., ... & Rahim, R. A. (2014). Lightweight Priority Scheduling Scheme for Smart Home and Ambient Assisted Living System. International Journal of Digital Information and Wireless Communications (IJDIWC), 4(1), pp.114-123.

Seppänen, O., Fisk, W. J., & Lei, Q. H. (2006). Ventilation and performance in office work. Indoor air, 16(1), pp.28-36.

Shikder, S. H., Mourshed, M., & Price, A. D. (2010). Luminaire position optimisation using radiance based simulation: a test case of a senior living room. COMPUTING IN CIVIL AND BUILDING ENGINEERING, Nottingham.

Shikder, S., Mourshed, M., & Price, A. (2012). Therapeutic lighting design for the older people: a review. Perspectives in public health, 132(6), pp.282-291.

Si, H., Kim, S. J., Kawanishi, N., & Morikawa, H. (2007). A context-aware reminding system for daily activities of dementia people. In Distributed Computing Systems Workshops, 2007. ICDCSW'07. 27th International Conference on, pp. 50-50. IEEE.

Statistics, O. F. N. (2008). Social Trends [Online]. Available from: http://www.ons.gov.uk/ons/rel/social-trends-rd/social-trends/no--38--2008-edition/social-trends-full-report.pdf (Accessed: 2 July 2012).

Steinke, F., Fritsch, T., & Silbermann, L. (2012). Trust in Ambient Assisted Living (AAL)-A Systematic Review of Trust in Automation and Assistance Systems. International Journal on Advances in Life Sciences Volume 4, Number 3 & 4, 2012.

Suman, S. and Pamela, D. (2015). “Activity Recognition From IR Images Using Fuzzy Clustering Techniques”. International Journal for Trends in Engineering & Technology, vol.5, no. 1, pp. 6-11.

TAFETA. (2011). Tafeta Smart Systems for Health [Online]. Available from: www.tafeta.ca/home2.html.

Tamura, T., Yonemitsu, S., Itoh, A., Oikawa, D., Kawakami, A., Higashi, Y & Nakajima, K. (2004). Is an entertainment robot useful in the care of older people with severe dementia?. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 59(1), pp.83-85.

Tappen, R. M., & Williams, C. L. (2008). Development and testing of the Older people with Alzheimer's and related dementias mood scale. Nursing research,57(6), p426.

Toplan, E. and Ersoy, C., (2012). RFID based indoor location determination for older people tracking. In proc. of IEEE Signal Processing and Communications Applications Conference (SIU), pp.1-4. Mugla, Turkey.

Townsend, D., Knoefel, F., & Goubran, R. (2011). Privacy versus autonomy: a tradeoff model for smart home monitoring technologies. InEngineering in Medicine and Biology Society, EMBC, 2011 Annual International Conference of the IEEE, pp. 4749-4752. IEEE.

Tunca, C., Alemdar, H., Ertan, H., Incel, O. D., & Ersoy, C. (2014). Multimodal wireless sensor network-based ambient assisted living in real homes with multiple residents. Sensors, 14(6), pp. 9692-9719.

Tzeng, H. M., & Yin, C. Y. (2009). Perspectives of recently discharged people on hospital fall-prevention programs. Journal of nursing care quality, 24(1), pp. 42-49.

Ulrich, R. S. (1999). Effects of gardens on health outcomes: Theory and research. Healing gardens: Therapeutic benefits and design recommendations, pp. 27-86.

Ulrich, R. S., Zimring, C., Zhu, X., DuBose, J., Seo, H. B., Choi, Y. S., ... & Joseph, A. (2008). A review of the research literature on evidence-based healthcare design. HERD: Health Environments Research & Design Journal,1(3), pp. 61-125.

Urdiales, C., Annicchiarico, R., & Cortés, U. (2013). The Good Assistive Robot for Elder Care. A Treatise on Good Robots: Praxiology, Volume 21, 21, p19.

United Nations(UN), Department of Economic and Social Affairs, Population Division (2012). Changing balance between age groups. New York, DESA.

United Nations (UN), Department of Economic and Social Affairs, Population Division (2013). World Population Ageing.ST/ESA/SER.A/348. New York.

Van den Broek, G., Cavallo, F., & Wehrmann, C. (2010). AALIANCE ambient assisted living roadmap (Vol. 6). IOS press.

Van der Spek, S., Van Schaick, J., De Bois, P. and De Haan, R. (2009). Sensing Human Activity: GPS tracking. Sensors, vol. 9, no. 4, pp. 3033-3055.

Van Hemel, S. B., & Pew, R. W. (Eds.). (2004). Technology for adaptive aging. National Academies Press.

Van Hoof, J., Kort, H. S. M., Duijnstee, M. S. H., Rutten, P. G. S., & Hensen, J. L. M. (2010). The indoor environment and the integrated design of homes for older people with dementia. Building and Environment, 45(5), pp.1244-1261.

Van Kasteren, T. L. M., Englebienne, G., & Kröse, B. J. (2010). An activity monitoring system for older people care using generative and discriminative models.Personal and ubiquitous computing, 14(6), pp.489-498.

Vas, C. J. and S. Rajikumar (2001). Older people with Alzheimer’s: The brain killer, WHO Regional Office for South-East Asia.

Virone, G. (2009). Assessing everyday life behavioural rhythms for the older generation. Pervasive and Mobile Computing, 5(5), pp.606-622.

Virone, G., Alwan, M., Dalal, S., Kell, S. W., Turner, B., Stankovic, J., & Felder, R. (2008). Behavioural patterns of older adults in assisted living.Information Technology in Biomedicine, IEEE Transactions on, 12(3), pp. 387-398.

Vischer, J. C. (2007). The effects of the physical environment on job performance: towards a theoretical model of workspace stress. Stress and Health, 23(3), pp.175-184.

Wang, Q., Shin, W., Liu, X., Zeng, Z., Oh, C., AlShebli, B. K., ... & Sha, L. (2006). I-Living: An open system architecture for assisted living. InSystems, Man and Cybernetics, 2006. SMC'06. IEEE International Conference on, Vol. 5, pp. 4268-4275. IEEE.

Warner, M. L. (2000). The complete guide to Alzheimer's-proofing your home. Purdue University Press.

Whitten, P., Collins, B., & Mair, F. (1998). Nurse and patient reactions to a developmental home telecare system. Journal of Telemedicine and Telecare,4(3), pp.152-160.

Wilkes, G. A. & Krebs, W. A. 1995. Collins concise dictionary, HarperCollins.

Winkler, D., Sloan, S., & Callaway, L. (2007). Younger people in residential aged care: Support needs, preferences and future directions. Summer Foundation.

World Health Organization. (2006). Neurological disorders: public health challenges. World Health Organization.

World Health Organization. (2011). Global health and ageing.

Wood, A. D., Stankovic, J., Virone, G., Selavo, L., He, Z., Cao, Q & Stoleru, R. (2008). Context-aware wireless sensor networks for assisted living and residential monitoring. Network, IEEE, 22(4), pp.26-33.

Wu, Y., & Huang, T. S. (1999). Vision-Based Gesture Recognition: A Review, Gesture-Based Communication in Human-Computer Interaction, A. Camurri, G. Volpe. Springer.

Xing, X., & Herzog, O. (2012). Towards Adaptive Decision Support for Individual Persons Suffering from Chronic Diseases. In Computer and Information Science (ICIS), 2012 IEEE/ACIS 11th International Conference on, pp. 225-229. IEEE.

Xu, L., Chen, G., Wang, J., Shen, R., & Zhao, S. (2012). A sensing cushion using simple pressure distribution sensors. In Multisensor Fusion and Integration for Intelligent Systems (MFI), 2012 IEEE Conference on, pp. 451-456. IEEE.

Xu, X., Tang, J., Zhang, X., Liu, X., Zhang, H. and Qiu, Y. (2013). “Exploring Techniques for Vision Based Human Activity Recognition: Methods, Systems, and Evaluation”. Sensors.; vol.13, no.2, pp.1635-1650.

Yao Q, Wang, F. Y., Gao, H., Wang, K. and Zhao, H. (2007). Location estimation in ZigBee Network based on fingerprinting. In proc. of IEEE International Conference of Vehicular Electronics and Safety, Beijing, China, pp.1-6.

Yin, R. K. (2011). Applications of case study research. Sage.

Yuce, B., Rezgui, Y., & Howell, S. K. (2014). ANN-genetic algorithm-based rule generation for holistic energy management in public buildings. eWork and eBusiness in Architecture, Engineering and Construction: ECPPM 2014, p401.

Yuce, B. (2012). “Novel Computational Technique for Determining Depth Using the Bees Algorithm and Blind Image Deconvolution”. Ph.D. Thesis, Cardiff University, Cardiff, UK.

Yuce, B., Li, H., Rezgui, Y., Petri, I., Jayan, B. and Yang, C. (2014). “Utilizing artificial neural network to predict energy consumption and thermal comfort level: An indoor swimming pool case study”, Energy and Buildings, vol. 80, pp. 45-56.

Zhang, M. and Sawchuk A. A. (2012). Motion primitive-based human activity recognition using a bag-of-features approach. In Proc. of the 2nd ACM SIGHIT International Health Informatics Symposium (IHI '12). ACM, New York, NY, USA, pp. 631-640.

Zhang, S., Mcclean, S., Scotney, B., Chaurasia, P., & Nugent, C. (2010). Using duration to learn activities of daily living in a smart home environment. In Pervasive Computing Technologies for Healthcare (Pervasive Health), (2010) 4th International Conference on-NO PERMISSIONS, pp. 1-8. IEEE.

Zhang, Y., & Goza, F. W. (2006). Who will care for the older people in China?: A review of the problems caused by China's one-child policy and their potential solutions. Journal of Aging Studies, 20(2), pp.151-164.

Zhu, C., & Sheng, W. (2011). Motion-and location-based online human daily activity recognition. Pervasive and Mobile Computing, 7(2), pp. 256-269.

Ziefle, M., Röcker, C., & Holzinger, A. (2011). Medical technology in smart homes: exploring the user's perspective on privacy, intimacy and trust. In Computer Software and Applications Conference Workshops (COMPSACW), 2011 IEEE 35th Annual, pp. 410-415. IEEE.

Appendixes

Appendix A:

Common daily activity survey of patient

Towards independent living by Alzheimer's people: Investigations into the patterns of daily living

Section A: About the survey

1.	Name of the surveyor			
2.	Date of the survey	/ / 2013		
3.	Time of the survey		☐ AM	☐ PM

Section B: About the respondent
The questions in this section relate to the respondent (i.e. the person responsible for care of the Alzheimer's patient in sections B-D)

1.	Name of the respondent				
2.	Address	Line 1			
		Line2			
		City		Zip	
3.	Telephone	Area code		Number	
4.	Age	☐ 18-24	☐ 25-30	☐ 31-40	☐ 41-50
		☐ 51-60	☐ 61 and above		
6.	How long have this patient been under your care?	☐ <1 year	☐ 1-2 years	☐ 3-4 years	☐ 5-6 years
		☐ 7-8 years	☐ 9-10 years	☐ 10 years or more	
7.	Which of the following best describes your profession?	☐ Carer-Geriatric		☐ Nurse – Psychiatric	
		☐ Carer- Psychiatric		☐ Occupational therapist	
		☐ Consultant-Geriatric		☐ Physiotherapist	
		☐ Consultant – Psychiatric		☐ Specialist- Geriatric	
		☐ Doctor-Geriatric		☐ Specialist - Psychiatric	
		☐ Doctor – Psychiatric		☐ From family member	
		☐ Nurse- Geriatric		☐ Health care providers	
8.	How long have you been in your profession?	☐ <1 year	☐ 1-5 yrs	☐ 6-10 yrs	☐ 11-15 yrs
		☐ 16-20 yrs	☐ 21-25 yrs	☐ 25 yrs or more	

Section C: About the patient

Please answer the following questions about the patient being surveyed.

1.	Name				
2.	Address	Line 1			
		Line2			
		City		Zip	
3.	Telephone	Area code		Number	
4.	Age	☐ <=40	☐ 41-50	☐ 51-60	☐ 61-70
		☐ 71-80	☐ >80		
5.	What stage of Alzheimer's the patient is diagnosed with?	☐ Mild cognitive impairment		☐ Mild Older people with Alzheimer's	
		☐ Moderate Older people with Alzheimer's			
6.	When was this diagnosed?	☐ <1 year	☐ 1-2 years	☐ 3-4 years	☐ > 4 years
7.	Does the patient have any of the medical conditions listed here?	☐ Arthropathy		☐ Lung disease	
		☐ Cancer		☐ Osteoporosis	
		☐ Depression		☐ Parkinson's disease	
		☐ Diabetes mellitus		☐ Sleep disorder	
		☐ Hearing loss		☐ Vision and eye diseases	
		☐ Heart disease		☐ None	
		☐ Hypertension		☐ Other (please specify)	
8.	Where does the patient live normally?	☐ Own house		☐ Hospital (*go to Q.11*)	
		☐ Live with family *(e.g. son)*		☐ Care home (*go to Q.11*)	
9.	Does the patient have a carer?			☐ Yes	☐ No
10.	If yes, what is the arrangement of care?			☐ Full time	☐ Part time
11.	If the patient lives at hospital or care home, how often does the family visit him/her?	☐ Several times a week		☐ Once a week	
		☐ Once a month		☐ Once a year	
		☐ Once in more than a year		☐ Never	
		☐ Not applicable			

Mild cognitive impairment (the capacity to perform executive functions also becomes compromised). Commonly, for persons who are still working, job performance may decline.
Mild Older people with Alzheimer's (the most common functioning deficit in these patient is a decreased ability instrumental (complex) activities of daily life such as manage finances and preparing meals for guests etc.).
Moderate Older people with Alzheimer's (this is manifest in decrement in the ability to choose proper clothing to rear for the weather conditions and/or for the daily circumstances and occasions).

Section D: Ontology of the patient's daily activities

(Time refers to how long a task needs not the time on the clock)

Task1: Sleeping or lying down in bed						
Location						
Frequency (no. of times /day)						
Does the patient need help for this activity?	☐ Yes	☐ No				
If yes, does he need help for all steps?	☐ Yes	☐ No	*If no, check the appropriate box* ↓			
Description	*Comment*	*Hr*	*Min*	*Sec*	*N/A*	*Help*
Go to bed					☐	☐
Sit down on bed					☐	☐
Lie down on bed					☐	☐
Fall asleep/ sleeping					☐	☐
Wake up					☐	☐
Remain in bed/ lie down					☐	☐
Sit up on bed					☐	☐
Leave the bed					☐	☐

Task 2: Toilet						
Location						
Frequency (no. of times /day)						
Does the patient need help for this activity?	☐ Yes	☐ No				
If yes, does he need help for all steps?	☐ Yes	☐ No	*If no, check the appropriate box* ↓			
Description	*Comment*	*Hr*	*Min*	*Sec*	*N/A*	*Help*
Open toilet door					☐	☐
Close toilet door					☐	☐
Walk up to the WC					☐	☐
Sit on the WC					☐	☐
Remain seated until finished					☐	☐
Wipe parts of the body with tissue paper					☐	☐
Fetch flexible water tap for personal hygiene					☐	☐
Open flexible water tap					☐	☐
Close flexible water tap					☐	☐
Wipe parts of the body with tissue paper					☐	☐
Stand up					☐	☐
Go next to the wash basin					☐	☐
Open the tap					☐	☐
Get soap					☐	☐
Close the tap					☐	☐
Go to/turn around to fetch towel					☐	☐

Fetch towel					☐	☐
Wipe hands dry					☐	☐
Put towel back					☐	☐
Walk to the door					☐	☐
Open toilet door					☐	☐
Come out					☐	☐
Turn around					☐	☐
Close toilet door					☐	☐

Task 3: Bathing						
Location						
Frequency (no. of times /day)						
Does the patient need help for this activity?	☐ Yes	☐ No				
If yes, does he need help for all steps?	☐ Yes	☐ No	*If no, check the appropriate box* ↓			
Description	*Comment*	*Hr*	*Min*	*Sec*	*N/A*	*Help*
Open bath room door					☐	☐
Closed the bath room door					☐	☐
Walk up to clothes rack					☐	☐
Put clothes on the clothes rack					☐	☐
Walk up to shower box					☐	☐
Standing on shower box					☐	☐
Open flexible shower water tap					☐	☐
Fetch flexible water tap for personal hygiene					☐	☐
Get shampoo from rack					☐	☐
Back the shampoo to rack					☐	☐
Fetch flexible water tap for personal hygiene					☐	☐
Closed flexible Shower water tap					☐	☐
Go to/turn around to clothes rack					☐	☐
Fetch towel					☐	☐
Wipe body dry					☐	☐
Put towel back					☐	☐
Cloth ON					☐	☐
Walk to the door					☐	☐
Open toilet door					☐	☐
Come out					☐	☐
Turn around					☐	☐
Close bath room door					☐	☐

Task 4: Dressing	
Location	

Frequency (no. of times /day)								
Does the patient need help for this activity?	☐ Yes	☐ No						
If yes, does he need help for all steps?	☐ Yes	☐ No	*If no, check the appropriate box* ↓					
Description	*Comment*			*Hr*	*Min*	*Sec*	*N/A*	*Help*
Walk up to the wardrobe door							☐	☐
Open the wardrobe door							☐	☐
Take robe from the wardrobe							☐	☐
Straighten the dress							☐	☐
Enter the right hand in the robe							☐	☐
Enter the left hand in the robe							☐	☐
Close the wardrobe door							☐	☐

Task 5: Walking/Transportation								
Location								
Frequency (no. of times /day)								
Does the patient need help for this activity?	☐ Yes	☐ No						
If yes, does he need help for all steps?	☐ Yes	☐ No	*If no, check the appropriate box* ↓					
Description	*Comment*			*Hr*	*Min*	*Sec*	*N/A*	*Help*
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐
							☐	☐

Task 6: Personal hygiene Brushing teeth			
Location			
Frequency (no. of times /day)			
Does the patient need help for	☐ Yes	☐ No	

this activity?									
If yes, does he need help for all steps?	☐ Yes	☐ No	*If no, check the appropriate box* ↓						
Description	*Comment*			*Hr*	*Min*	*Sec*	*N/A*	*Help*	
Open bath room door							☐	☐	
Closed the bath room door							☐	☐	
Walk up to the sink							☐	☐	
Take Toothbrush from rack							☐	☐	
Get the toothpaste from rack							☐	☐	
Open the toothpaste cover							☐	☐	
Put some of the toothpaste onto Toothbrush							☐	☐	
Return the toothpaste to the rack							☐	☐	
Start cleaning teeth							☐	☐	
Open flexible water tap							☐	☐	
Do the cleaning process							☐	☐	
Close flexible water tap							☐	☐	
Take Toothbrush from rack							☐	☐	
Go to/turn around to fetch towel							☐	☐	
Fetch towel							☐	☐	
Put towel back							☐	☐	
Walk to the door							☐	☐	
Open bath room door							☐	☐	
Come out							☐	☐	
Turn around							☐	☐	
Close bath room door							☐	☐	

Grooming									
Location									
Frequency (no. of times /day)									
Does the patient need help for this activity?	☐ Yes	☐ No							
If yes, does he need help for all steps?	☐ Yes	☐ No	*If no, check the appropriate box* ↓						
Description	*Comment*			*Hr*	*Min*	*Sec*	*N/A*	*Help*	
Open bath room door							☐	☐	
Closed the bath room door							☐	☐	
Walk up to the sink							☐	☐	
Take soap from rack							☐	☐	
Put some of the soap into the hands							☐	☐	
Chin rubbing with soap							☐	☐	
Take shaving brush/ electric razor from the rack							☐	☐	

Start using the shaving brush/electric razor cleaning process					☐	☐
Return shaving brush/ electric razor into the rack					☐	☐
Open flexible water tap					☐	☐
Watching face					☐	☐
Close flexible water tap					☐	☐
Go to/turn around to fetch towel					☐	☐
Fetch towel					☐	☐
Put towel back					☐	☐
Walk to the door					☐	☐
Open bath room door					☐	☐
Come out					☐	☐
Turn around					☐	☐
Close bath room door					☐	☐

Task 7: Make food						
Location						
Frequency (no. of times /day)						
Does the patient need help for this activity?	☐ Yes	☐ No				
If yes, does he need help for all steps?	☐ Yes	☐ No	If no, check the appropriate box ↓			
Description	*Comment*	*Hr*	*Min*	*Sec*	*N/A*	*Help*
Open kitchen door					☐	☐
Walk up to the fridge					☐	☐
Open the fridge door					☐	☐
Take food plate					☐	☐
Close the fridge door					☐	☐
Open oven door					☐	☐
Put the food plate inside the oven for worming					☐	☐
Close oven door					☐	☐
Open back the oven door					☐	☐
Take the food plate from oven					☐	☐
Close the oven door					☐	☐
Close the dishwasher door					☐	☐
Walk to the door					☐	☐
Come out					☐	☐
Close kitchen door					☐	☐

Task 8: Make drink	
Location	
Frequency (no. of times /day)	

Does the patient need help for this activity?	☐ Yes	☐ No					
If yes, does he need help for all steps?	☐ Yes	☐ No	If no, check the appropriate box ↓				
Description	*Comment*		*Hr*	*Min*	*Sec*	*N/A*	*Help*
Open kitchen door						☐	☐
Walk up to the Kitchen cupboard						☐	☐
Get a cup, tea bag milk and sugar						☐	☐
Go to the work surface						☐	☐
Have a cup with a tea bag (TB) in it on work surface (WS)						☐	☐
switch on the kettle						☐	☐
Have boiling water and tea bag in the cup (kettle boil cup)						☐	☐
Have sugar in cup (sugar cup)						☐	☐
Have milk in cup (milk cup)						☐	☐
Have cup of tea						☐	☐
Walk to the door						☐	☐
Come out						☐	☐
Close kitchen door						☐	☐

Task 9: Using applicable in kitchen (Using Washing Machine)							
Location							
Frequency (no. of times /day)							
Does the patient need help for this activity?	☐ Yes	☐ No					
If yes, does he need help for all steps?	☐ Yes	☐ No	If no, check the appropriate box ↓				
Description	*Comment*		*Hr*	*Min*	*Sec*	*N/A*	*Help*
Open kitchen door						☐	☐
Walk up to the washing machine door						☐	☐
Open washing machine door						☐	☐
Put the clothes in the washing machine						☐	☐
Get a piece of laundry soap from rack						☐	☐
Back the laundry soap box into the rack						☐	☐
Calibrations of washing machine control switch to the appropriate temperature						☐	☐
Close the washing machine door						☐	☐
Turn on the washing machine						☐	☐
Open the washing machine door after the rinse cycle						☐	☐
Take dry clothing to the storage cupboard						☐	☐
Close the washing machine door						☐	☐
Walk to the door						☐	☐

Come out					☐	☐
Close kitchen door					☐	☐

Section E: Patterns of daily living

Dear Sir/Madam,

I would like to express my sincere thanks and gratitude for your participation in this research consultation. As a person responsible for the care of an Alzheimer's patient, your observation of their behaviour is an important source of knowledge for the development of care pathways of people.

Instructions:

In this section the respondent will be required to observe the patient during his care service time on a normal activity day hoping to collect full days 24 hours observations from all care shifts and put all the observations of patient in a one day observation sheet.

The aim is to document what the patient was doing as an activity for a period of 20 minutes covering the whole activity day.

For example, the activities below can be used as descriptive categories.

Getting to bed for sleeping	Going to toilet	Watching dishes	Using phone	Making drink
Using appliances	Bathing	Changing clothes	Doing laundry	Care of pets
Managing medication	Make food	Personal hygiene	Watching TV	Sweeping
Ironing	Feeding	Walking	Praying	Shopping
Fasting	Reading	Writing		

1.	Date of the survey	….. September 2013		
2.	Day of the survey	………	Note: should be during weekdays not holidays	
3.	Is the patient's routine different for different day?		☐ Yes	☐ No
4.	Do you think that the symptoms can be part of the behaviour and must be added to the questionnaire?		☐ Yes	☐ No

1.	Name of the respondent	1- 2-			
2.	Address	Line 1			
		Line2			
		City		Zip	
3.	Telephone	Area code		Number	
4.	1) Age	☐ 18-24	☐ 25-30	☐ 31-40	☐ 41-50
		☐ 51-60	☐ 61 and above		
	2) Age	☐ 18-24	☐ 25-30		☐ 31-40
		☐ 51-60	☐ 61 and above		
6.	How long have this patient been under your care?	☐ <1 year	☐ 1-2 years	☐ 3-4 years	☐ 5-6 years
		☐ 7-8 years	☐ 9-10 years	☐ 10 years or more	
7.	Which of the following best describes your profession?	☐ Carer-Geriatric		☐ Nurse – Psychiatric	
		☐ Carer- Psychiatric		☐ Occupational therapist	
		☐ Consultant-Geriatric		☐ Physiotherapist	
		☐ Consultant – Psychiatric		☐ Specialist- Geriatric	
		☐ Doctor-Geriatric		☐ Specialist - Psychiatric	
		☐ Doctor – Psychiatric		☐ Family member	
		☐ Nurse-= Geriatric		☐ Other (please specify)	
8.	How long have you been in your profession?	☐ <1 year	☐ 1-5 yrs	☐ 6-10 yrs	☐ 11-15 yrs
		☐ 16-20 yrs	☐ 21-25 yrs	☐ 25 yrs or more	

Section E: Daily activities diary

Time	Task	Time	Task
00:00-00:20 AM	Write down the name of the task	12:00-12:20 PM	
00:21-00:40 AM		12:21-12:40 PM	
00:41-01:00 AM		12:41-13:00 PM	
01:00-01:20 AM		13:00-13:20 PM	
01:21-01:40 AM		13:21-13:40 PM	
01:41-02:00 AM		13:41-14:00 AM	
02:00-02:20 AM		14:00-14:20 PM	
02:21-02:40 AM		14:21-14:40 PM	
02:41-03:00 AM		14:41-15:00 PM	
03:00-03:20 AM		15:00-15:20 PM	
03:21-03:40 AM		15:21-15:40 PM	
03:41-04:00 AM		15:41-16:00 PM	
04:00-04:20 AM		16:00-16:20 PM	
04:21-04:40 AM		16:21-16:40 PM	
04:41-05:00 AM		16:41-17:00 PM	
05:00-05:20 AM		17:00-17:20 PM	
05:21-05:40 AM		17:21-17:40 PM	
05:41-06:00 AM		17:41-17:00 AM	
06:00-06:20 AM		18:00-18:20 PM	
06:21-06:40 AM		18:21-18:40 PM	
06:41-07:00 AM		18:41-19:00 AM	
07:00-07:20 AM		19:00-19:20 PM	
07:21-07:40 AM		19:21-19:40 PM	
07:41-08:00 AM		19:41-20:00 PM	
08:00-08:20 AM		20:00-20:20 PM	
08:21-08:40 AM		20:21-20:40 PM	
08:41-09:00 AM		20:41-21:00 PM	
09:00-09:20 AM		21:00-21:20 PM	
09:21-09:40 AM		21:21-21:40 PM	
09:41-10:00 AM		21:41-22:00 PM	
10:00-10:20 AM		22:00-22:20 PM	
10:21-10:40 AM		22:21-22:40 PM	
10:41-11:00 AM		22:41-23:00 PM	
11:00-11:20 AM		23:00-23:20 PM	

Appendix B:
Professionals questionnaire

Towards independent living by Alzheimer's patients: Patterns of daily

Introduction to the questionnaire

Dear expert,

First, I would like to express my sincere thanks and gratitude for your participation in this questionnaire. Your contribution is essential for the success of this research consultation.
Elderly patients with early or mild stage Alzheimer's face many challenges to live independently. There are significant concerns about their safety and wellbeing when they live alone. The cost of care in nursing/care homes or hospitals is usually high and increases if care in mobilised in their own homes for long term care.
Smart houses, where occupant behaviour is constantly monitored by an intelligent system to assess his/her conditions and take appropriate actions (e.g. alert healthcare staff and families), have been suggested as a potential enabling technology for independent living. This questionnaire aims to identify the potential characteristics or features a smart home for Alzheimer's patients. The objectives are to:
a) Identify common activities performed by Alzheimer's patients to define patterns of daily living;
b) Identify the characteristics of home environment that enables independent living by the elderly; and
c) Identify personal and environmental sensing and monitoring needs for independent living.
By completing this questionnaire you will contribute to the development of smart solution for independent living, therefore enhancing the quality of life of Alzheimer's patient.

Data protection:

Information supplied as part of this questionnaire will be held by Cardiff School of Engineering, Cardiff University and will remain secure and confidential. Your details will only be used for academic research purposes and will not be passed on to any third parties or used for marketing purposes in accordance with the Data Protection Act 1998.

Eligibility:

To participate in this questionnaire you need to be:
• At least 18 years of age.
• You need to be professionally involved in the care of Alzheimer's patient in the kingdom of Saudi Arabia.

By clicking the "Proceed" button you agree that you meet the eligibility criteria.

Contact information:

Should you wish to contact us please send an email to Mr. Riyad Alshaqi at Sear6@cardiff.ac.uk. Alternatively you can send a letter to:

Mr. Riyad Alshaqi
Cardiff school of Engineering
Queens Buildings
The Parade
Cardiff CF24 3AA
Wales UK
Tel +44(0)292087 75918

Section A: About you

Page 1

Towards independent living by Alzheimer's patients: Patterns of daily

***1. Respondent details**

Name:

Company:

Address line 1:

Address line 2:

City/Town:

ZIP/Postal Code:

Email Address:

Phone Number:

***2. What is your gender?**

○ Male ○ Female

***3. What is your job title?**

***4. How long have you been involved professionally in the care of Alzheimer's patients?**

Section B: General questions about your patients

***1. What was the range of average age of the Alzheimer`s patients you have dealt with as a professional?**

○ Less than 40 ○ 40-50 ○ 51-60 ○ 61-70 ○ 71-80 ○ Over 80

***2. What was the gender of the majority of patients?**

○ Male ○ Female ○ Don`t know/ not sure

***3. Where were the majority of the patients based at?**

○ In their own homes

○ In a specialized care home

○ In a hospital

Other (please specify)

Section C: Common behaviour of early and mild stage Alzheimer patients

Page 2

Towards independent living by Alzheimer's patients: Patterns of daily

These questions aim to explore the common behaviour of early and mild stages Alzheimer patients while they are living in their own homes. Please answer the following question based on your professional experience.

***1. To what extent do you agree with the following behavioural traits as common among the Alzheimer's patients?**

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. Getting lost (wandering)	○	○	○	○	○
2. Difficulty managing money	○	○	○	○	○
3. Repetitive questions and conversations	○	○	○	○	○
4. Taking longer than usual to finish routine daily tasks	○	○	○	○	○
5. Poor judgment	○	○	○	○	○
6. Apathy	○	○	○	○	○
7. Losing things.	○	○	○	○	○
8. Noticeable changes in personality or mood.	○	○	○	○	○
9. Falling	○	○	○	○	○

***2. Patient behaviour: To what extent do you agree to the following statements?**

	Strongly disagree	Disagree	Neither agrees nor disagrees	Agree	Strongly agree
1. Early and mild stage Alzheimer's patients may present danger to others	○	○	○	○	○
2. The behaviour of Alzheimer's patients in hot climate (e.g. in KSA) is different to patients from colder climates	○	○	○	○	○
3. Symptoms demonstrated by male and female Alzheimer's patients are same at a given stage	○	○	○	○	○
4. The behaviour of Alzheimer's patients changes if she/he suffers from other aging-associated diseases	○	○	○	○	○
5. Alzheimer's patients in early and mild stages can live independently in his/her own home	○	○	○	○	○
6. It is necessary to have a family member living with Alzheimer's patients permanently	○	○	○	○	○

Towards independent living by Alzheimer's patients: Patterns of daily

***3. Religious practices of fasting and prayer: To what extent do you agree to the following statements?**

	Strongly disagree	Disagree	Neither agrees nor disagrees	Agree	Strongly agree
1. Early and mild stage Alzheimer's patients engage normally with their religious practices, including prayer	○	○	○	○	○
2. Daily religious practices may impact positively on Alzheimer patient's condition	○	○	○	○	○
3. Early and mild stage Alzheimer's patients may forget to pray or forget to perform ablution	○	○	○	○	○
4. During Ramadan, early and mild stage Alzheimer's patients can fast as normal	○	○	○	○	○
5. Fasting during Ramadan may have positive impact on Alzheimer's patients' condition	○	○	○	○	○
6. Fasting may amplify patients' Alzheimer's symptoms, including memory loss and panic attack	○	○	○	○	○
7. Early and mild stage Alzheimer's patients can keep proper timing of the start and end of the fasting	○	○	○	○	○

Section D: Home Design

The purpose of this section is to identify features of home environment, suitable for living by Alzheimer's patients.

***1. To what extent the following factors affect the behaviour of Alzheimer's patients?**

	Strongly disagree	Disagree	Neither agrees nor disagrees	Agree	Strongly agree
1. The presence of stairs inside the house	○	○	○	○	○
2. The presence of doors separating different rooms	○	○	○	○	○
3. The presence of elevator or stair lift	○	○	○	○	○
4. Changes in level (floor) inside the house	○	○	○	○	○
5. Bright interior lighting (e.g. high illumination)	○	○	○	○	○
6. Bright natural light (e.g. through bigger windows)	○	○	○	○	○
7. Bright coloured walls and surfaces	○	○	○	○	○
8. Spaciousness of rooms or the lack of it	○	○	○	○	○
9. Opening and closing of windows	○	○	○	○	○
10.Ventilation system in the house	○	○	○	○	○
11. Furniture size	○	○	○	○	○
12. Furniture shape	○	○	○	○	○

Appropriate home layout for Alzehimer patients

Page 4

Towards independent living by Alzheimer's patients: Patterns of daily

***1. Which of the following bathroom options is ideal for a bedoom? Please state "why" in the space provided below.**

- ◯ Bedroom with ensuite bathroom
- ◯ Bedroom without ensuite bathroom

Comment: Please specify why you have selected the above option.

***2. Which is the following relationships between a bedroom and the kitchen is ideal? Please state "why" in the space provided below.**

- ◯ Bedroom adjacent to the kitchen
- ◯ Bedroom integrated with the kitchen (e.g. Studio)
- ◯ Bedroom far away from the kitchen

Comment: Please specify why you have selected the above option.

***3. Which of the following relationships between the bathroom and sitting room is ideal? Please state "why" in the space provided below.**

- ◯ Bathroom adjacent the Sitting room
- ◯ Bathroom far from the Sitting room

Comment: Please specify why you have selected the above option.

***4. Which of the following relationships between the kitchen and sitting room is ideal? Please state "why" in the space provided below.**

- ◯ Sitting room adjacent the kitchen
- ◯ Sitting room integrated with the kitchen
- ◯ Sitting room far from the kitchen

Comment: Please specify why you have selected the above option.

Section E: Sensors

A smart, responsive home for Alzheimer's patient needs to incorporate several sensing and environmental monitoring technologies. Their distribution around the home is important to monitor the patient's condition and provide rapid

Towards independent living by Alzheimer's patients: Patterns of daily

intervention in emergency situations. Please answer the following questions based on your professional experience.

***1. To what extent do you think the following monitoring technologies need to be integrated in a smart home?**

	Strongly disagree	Disagree	Neither agrees nor disagrees	Agree	Strongly agree
1. Pressure sensor/pads in the bed is a convenient method to monitor cases of falls	○	○	○	○	○
2. Motion sensor (infrared) in the room is useful to monitor patient's movement and location	○	○	○	○	○
3. Smoke detectors to monitor the occurrence of fire	○	○	○	○	○
4. Carbon monoxide detectors to monitor the risk of poor air quality and its impact on heart conditions	○	○	○	○	○
5. Water flow sensors on taps and water outlets to identify water leakage inside the house	○	○	○	○	○
6. Loop sensors on the patient to monitor vital signs (temperature, blood pressure, heart rate)	○	○	○	○	○
7. Cooker sensors for monitoring the operation of oven and hobs	○	○	○	○	○
8. Sensors for monitoring the opening/closing of refrigerator	○	○	○	○	○
9. Door sensors to detect movement from/to spaces, houses or escapes	○	○	○	○	○
10. Coded main door lock to prevent the patient from leaving home	○	○	○	○	○
11. Using Maze chain lock at the main door to prevent the patient from leaving home	○	○	○	○	○

***2. What other spaces in a house should be monitored? Please select as many as you consider relevant.**

- ☐ Bedrooms
- ☐ Sitting room
- ☐ Study/ home office
- ☐ Bathroom/ toilets
- ☐ Kitchen
- ☐ Laundry room
- ☐ Corridors
- ☐ Lobby/ foyer
- ☐ Stairs

Page 6

Towards independent living by Alzheimer's patients: Patterns of daily

***3. Which of the following interior spaces should be monitored using a video surveillance system, e.g. CCTV? Please select as many as you consider relevant.**

- [ ] Bedrooms
- [ ] Kitchen
- [ ] Bathroom/Toilets
- [ ] Sitting room
- [ ] Corridors
- [ ] Lobby
- [ ] Laundry room
- [ ] Stairs

***4. Which of the following interior spaces should be equipped with monitoring sound level equipment?**

- ◯ Bedrooms
- ◯ Kitchen
- ◯ Bathroom/Toilets
- ◯ Sitting room
- ◯ Corridors
- ◯ Lobby
- ◯ Laundry room
- ◯ Stairs

***5. Should exterior spaces be monitored using CCTV?**

- ◯ Yes all spaces including balcony and backyard
- ◯ Yes but only the balconies that are on the first floor
- ◯ There is no need to monitor exterior spaces
- ◯ Not sure/ don't know

***6. Would you be willing to participate in a follow up interview?**

- ◯ Yes
- ◯ No

***7. Please choose the preferred method for contacting you.**

- ◯ Email
- ◯ Telephone
- ◯ Post

Page 7

Towards independent living by Alzheimer's patients: Patterns of daily

8. Please provide your contact details.

Email	
Telephone:	
Post:	

Page 8

Appendix C: Ethical Approvals

Cardiff School of Engineering
Director of School Professor P J Bowen BSc PhD CEng MIMechE FInstP
Research Office
Deputy Director of School-Research Professor A Porch MA PhD CPhys MInstP MIET
Ysgol Beirianneg Caerdydd
Cyfarwyddwr yr Ysgol Yr Athro P J Bowen BSc PhD CEng MIMechE FInstP
Swyddfa Ymchwil
Dirprwy Gyfarwyddwr yr Ysgol-Ymchwil Yr Athro A Porch MA PhD CPhys MInstP MIET

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Cardiff University
Queen's Buildings
The Parade
Cardiff CF24 3AA
Wales UK
Tel *Ffôn* +44(0)29 2087 0076
Fax *Ffacs* +44(0)29 2087 4939
Email *Ebost*
ENGINResearch@cardiff.ac.uk
www.cardiff.ac.uk/engin/
Prifysgol Caerdydd
Adeiladau'r Frenhines
The Parade
Caerdydd CF24 3AA
Cymru DU

Ethical Approval

Title of Project: Home Centred Healthcare Management in an Assisted Living Context

Researcher: Mr Riyad Al-shaqi

Supervisor: Prof. Y Rezgui

The above application was considered by the members of the Cardiff School of Engineering Ethical Review Committee and was recommended for the School's Research Committee approval.

After due consideration, the Chair of the Research Committee agreed with advice of the Ethical Approval Committee and officially approved the project, under Chair's action, on 21st June 2012.

If you have any queries regarding this approval please do not hesitate to contact Mrs Aderyn Reid, Research Support Administrator, on ext. 74930 or e-mail reida@cf.ac.uk.

A. Reid

PP Professor A Porch
Director of Research,

Chair – ENGIN Research Committee

Cardiff School of Engineering

The Institute of Medical Engineering
And Medical Physics

Cardiff University

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Cardiff University
Queen's Buildings
The parade
Newport Road
CF143AA

INFORMATION SHEET

(Home-centred Healthcare Management in an Assisted Living context)

PhD Research

We would like to invite you to consider whether you would like to take part in a research study that is related to designing an ambient intelligent system to assist patient with Alzheimer disease to live independently within their home environment. The system with the help of distributed sensory devices will be able to recognize the patients' behaviour to assess his/her condition and decide the proper interference required.

Before deciding whether you will participate in this study or not, you need to understand why the research is being conducted and what it would reflect on the society. So, the following g information will help you to build clear vision about the study. Please read through carefully and discuss with others if you wish to do so.

The following paragraph in Questions and Answers format will help you to understand the main points related to this research.

Q1: Who is the main subject of this study?

A1: A person he/she who suffer from early or mid-stage Alzheimer disease is the main subject this study is conducted to monitor his/her general everyday behaviour.

Q2: What is the reason of this study?

A2: Ageing population is one of the crucial issues in Saudi Arabia. Recent studies showed increased percent of Alzheimer disease patients amongst those elderly people, while a lot of them tend to like to live in their own homes and avoid care centres. This raises the problem of uncontrolled behaviour especially, when the person is living alone, that maybe life threatening to the person himself or people around him. The Saudi Arabian current elder people housing is insufficient in meeting the needs of the ageing population of this category. There are various challenges that Alzheimer patients have to face, including: (a) Spending a great deal of time at home alone, (b) Reduced mobility, (c) Reduced social integration, (d) Difficulties with basic and trivial needs, (e) Experiencing a gradual loss of personal memory, and (f) Facing increased risks related to the activities of daily living (cooking, bathing, etc.). This increases the care cost and burden to relatives of the patient. The home, therefore, is a crucial focal point to ensure independent, healthy, and socially inclusive living environment, and should be designed and equipped with the right infrastructure to support and host a variety of services that Alzheimer patients may require to meet their needs and guarantee their safety. The main aim of the study is to determine the common everyday life behaviours that may need to be recognized by ambient intelligent system and the required intervention or support method that is proper in each situation. The study aims to extract common behaviour patterns that can form the core database for the monitoring system. The study also aims to design the main elements of the system based on the expert, family relatives, and even patients themselves perception of the system elements.

Q3: Why I have been approached to take part in this study?

A3: You have been approached for this study as we are interviewing expert staffs who are involved with such category of patients in Saudi Arabia. Your experience will support the information gathering related to the raised questions in the study.

Q4: Do I have to participate in the study?

A4: No, you don't have to, while we appreciate your participation to collect as many expert perceptions for the study and system elements as possible, which will enrich the results and financing outcomes of the research. Even if you decided to participate and then changed your mind during the process, you are completely free to do so.

Q5: What will happen if I decided to take part in this study?

A5: Ok, if you decided to take part in the study, we will ask you to fill-in a web-based questionnaire. We will ask you as will to forward the questionnaire link and this information sheet to anyone you think he have enough experience to participate in this study and fill-in the questionnaire. The aim of this step is to expand the research audience like a falling snow ball to increase the diversity of points of view and expert perception. The second phase will be an oral interview with yourself and any other person who agrees to conduct the questionnaire. The interview will be conducted in your convenient time and location, preferable in the domain of work that is related to the research subject. The interview will last for around thirty minutes.

2 11/06/2013 15:50:15

Q6: What are the possible benefits from participating in the study?

A6: We don't expect any specific benefits for the individuals taking part in the study, however, the information we gather from the study will help to improve the assessment of such category of patients in the Kingdom of Saudi Arabia, which if taken into account may help to improve the service in care centres and reduce the number of patients in case of system implementation in homes.

Q7: Is there any risk or obligations associated with participating in the study?

A7: No, there are no risks or any obligations and participations are completely volunteering.

Q8: What if this is a problem?

A8: We don't expect any problem to happen, while in case any complaint about the way you have been approached or dealt with during the study will be addressed professionally and eliminated promptly.

Q9: What happens when the research study stops?

A9: As soon as the interview has been completed, your participation in the study will finish. After that moment, you will be free to contact the researcher with any questions or quires that you may have regarding the study.

Q10: What will happen if I decided to stop conducting the study?

A10: If you withdraw from the study, we will destroy all your identifiable information, but we would like to use the data collected up to your withdrawal for the benefit of the study. You are free to withdraw from the study at any time.

Q11: Will participation in the study be kept confidential?

A11: Yes, we will follow the ethical and legal practice and all information about you will be handled confidentially.

Q12: Who is organizing the study?

A12: The study is being conducted by the Institute of Medical Engineering, Cardiff School of Engineering, Cardiff University. The study will be conducted by the main researcher Riyad Al-shaqi in collaboration with Prof. Yacine Rezgui and Dr. Monjur Mourshed.

Q13: Who has reviewed and approved this study?

A13: This study has been reviewed and approved by Cardiff School of Engineering Ethical Review Committee, Cardiff University (Approved on 10/06/2013).

Q14: What is the contact information?

A14: If you would like to discuss any part of the project in greater detail then please do not hastate to contact Mr.Riyad Al-Shaqi at:

The Institute of Medical Engineering
And Medical Physics
Cardiff School of Engineering
Cardiff University
Cardiff, Wales UK
CF243AA
Tel +44(0)29208 Ext 75918
Email: Al-shaqiR@cardiff.ac.uk

Thank you for your time and consideration

Riyad Al-Shaqi
PhD candidate Cardiff School of Engineering

4 11/06/2013 15:50:15

Kingdom of Saudi Arabia
Ministry of Health
King Fahad Medical City
(162)

المملكة العربية السعودية
وزارة الصحة
مدينه الملك فهد الطبية
(١٦٢)

IRB Registration Number with KACST, KSA: H-01-R-012
IRB Registration Number with OHRP/NIH, USA: IRB00008644
Approval Number Federal Wide Assurance NIH, USA: FWA00018774

September 30, 2013
IRB Log Number: 13-206E
Department: EXTERNAL
Category of Approval: EXEMPT

Dear Mr. Riyad A. Alshaqi:

I am pleased to inform you that your submission dated September 26, 2013 for the study titled '**Towards independent living by Alzheimer's patients: investigations into the patterns of daily living**' was reviewed and was approved.

We wish you well as you proceed with the study and request you to keep the IRB informed of the progress on a regular basis, using the IRB log number shown above.

If you have any further questions feel free to contact me.

Sincerely Yours,

Prof. Omar H. Kasule
Chairman Institutional Review Board--IRB.
King Fahd Medical City, Riyadh, KSA
Tel: + 966 1 288 9999 Ext. 7540
E-mail: okasule@kfmc.med.sa

KFMC
Approved
30 SEP 2013
IRB

المملكة العربية السعودية
وزارة الدفاع
رئاسة هيئة الأركان العامة
الإدارة العامة للخدمات الطبية للقوات المسلحة
إدارة الأبحاث والتطوير
(قسم الدراسات والبحوث)

الرقم : ٩/٤/٤/١٢٨٠٠
التاريخ : ٢٩/١٢/١٤٣٤هـ
المرفقات : (٨)

الموضوع : بشأن موافقة على توزيع استبانه

سعادة مدير إدارة مستشفيات القوات المسلحة بالمنطقة الجنوبية

السلام عليكم ورحمة الله وبركاته

الإشارة:

الخطاب رقم ٩/٤/ ١٩٩٣١ بتاريخ ١٤٣٤/١٢/١هـ الموجه من المقدم/رياض بن عبده محمد الشاقي ، ضابط بالإدارة العامة بالخدمات الطبية والمبتعث حالياً في بريطانيا للحصول على درجة الدكتوراه في مجال الهندسة الطبية بشان الموافقة على توزيع استبانه في (مدينة الأمير سلطان الطبية العسكرية بالرياض ، مستشفى القوات المسلحة بالجنوب ، مجمع الملك فهد الطبي بالظهران ، مستشفى الأمير سلمان للقوات المسلحة بتبوك) كجزء من متطلبات الحصول على درجة الدكتوراه.

الإفادة:

نفيدكم أنه لا يوجد ما يمنع من توزيع الإستبانه وذلك وفق الشروط التالية:

١. إلزام الباحث بإيداع نسخه من الإستبانه في مكتب المساعد لشئون التعليم والتدريب والأبحاث .
٢. يجب المحافظة على توزيع نسخة الإستبانه المكونه من عدد (٨) صفحات وتكون بشكل مقنن بعيداً عن العشوائية في التوزيع.
٣. يجب عدم تصوير الإستبانه بعد التعبئة وعدم تسليمها لغير المعنيين .
٤. يجب على الباحث أن يتعهد بعدم استخدام الإستبانه ونتائجها لغير أغراض البحث وعدم نشرها بأي وسيله إلا بإذن مكتوب من إدارة استخبارات وأمن الخدمات الطبية .
٥. يجب أن يتم إتلاف الإستبانه في حال الانتهاء من الدراسة وفقاً لإجراءات إتلاف الوثائق الرسمية .

المطلوب:

آمل بعد الإطلاع تسهيل مهمة الباحث متمنين له التوفيق .

والسلام عليكم ،،،

اللواء/ الركن

عبيد بن منصور العدواني

مساعد مدير عام الإدارة العامة للخدمات الطبية

لشئون التعليم والتدريب والأبحاث

نسخه إلى :

- مدير مدينة الأمير سلطان الطبية العسكرية بالرياض .
- مدير مستشفى الأمير سلمان للقوات المسلحة بالشمالية الغربية.
- مدير مجمع الملك فهد الطبي العسكري بالظهران.
- إدارة الأبحاث و التطوير / ملف الاستبانات.

المملكـــة العــربيـــة السعــوديـــة
وزارة الدفاع
رئاسة هيئة الأركان العامّة
الإدارة العامة للخدَمات الطبيّة للقوات المسلحة
مدينة الأمير سلطان الطبيّة العسكرية
إدارة الشؤون الأكاديمية والتدريب

الرقم: Acdm. & T.A. HA.. (666)
التاريخ: 04 Muharram 1435H
07 November 2013G
☎ (Ex.) 88522 (F) 473-0214
المرفقات:
الموضُوع : (إتمام فترة الإشراف على دراسة ميدانية)

مركز الأمير سلطان لمعالجة أمراض وجراحة القلب للقوات المسلحة
PRINCE SULTAN CARDIAC CENTER

سعادة/ الملحق الثقافي السعودي بالمملكة المتحدة وإيرلندا

الاسم	المسمى الوظيفي	الإدارة	الرقم الوظيفي
المقدم/ المهندس رياض بن عبده الشاقي	مدير إدارة الهندسة الطبية	الهندسة الطبية	٩١٣٩٣٠٤

السلام عليكم ورحمة الله وبركاته ،،،

نفيدكم أنه قد تمّ الإشراف على الضابط المحررة هويته بعاليه خلال قيامه بالدراسة الميدانية وكان ذلك اعتباراً من تاريخ: ١٤٣٤/١١/٠٢هـ الموافق: ٢٠١٣/٠٩/٠٨م حتى تاريخ: ١٤٣٥/٠١/٠٦هـ الموافق: ٢٠١٣/١١/٠٩م وكانت لغرض إتمام متطلبات حصوله على درجة الدكتوراة.

مع خالص التحية والتقدير ،،،

الدكتور
عبدالرحمن بن عيسى الرضيان
استشاري أمراض القلب لدى الأطفال
مدير إدارة الشؤون الأكاديمية والتدريب
في مركز الأمير سلطان لمعالجة أمراض
وجراحة القلب للقوات المسلحة في الرياض

مركز الأمير سلطان لمعالجة أمراض وجراحة القلب
الإدارة
إدارة الشؤون الأكاديمية والتدريب

هـ/ع/ع ر

Tel : 4791000 Fax: 4760895 P.O.Box 99911 Riyadh 11625
تليفون: ٤٧٩١٠٠٠ فاكس: ٤٧٦٠٨٩٥ ص.ب ٩٩٩١١ الرياض ١١٦٢٥
PSCC Stock No.: 77-00089