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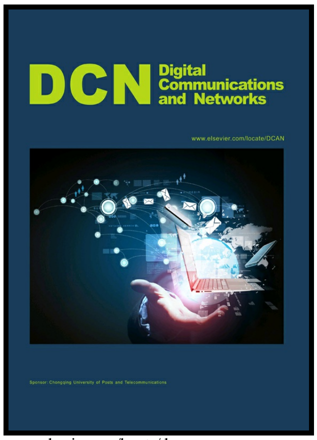

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Cognitive Assisted Living Ambient System: A Survey

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Abstract

The demographic change towards an ageing population is introducing significant impact and drastic challenge to our society. We therefore need to find ways to assist older people to stay independently and prevent social isolation of these population. Information and Communication Technologies (ICT) can provide various solutions to help older adults to improve their quality of life, stay healthier, and live independently for longer time. The term of Ambient Assist Living (AAL) becomes a field to investigate innovative technologies to provide assistance as well as healthcare and rehabilitation to senior people with impairment. The paper provides a review of research background and technologies of AAL.

Keywords: Assitive Living, ICT, Ageing, Digital Communication, Smart Home, Robotics, Sensor Network

1. Introduction

Population ageing has become a global phenomenon as a result of life longevity and declining birth rate of modern society, especially in developed regions. The trend will be more severe and cause larger impact on our society in the coming years [1]. The number of people aged 65 or older is projected to grow from an estimated 524 million

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in 2010 to nearly 1.5 billion in 2050, with most of the increase in developing countries [2]. Europe is currently holding the highest proportion of ageing population. As the demographic statistics reports [3], the amount of population over 60 years old is 24.5 % of the total of Europe. The growing number of older population will be accompanied with rapid increasing number of people with mental and physical impairments as well as various age-related chronic disease such as, cognitive decline, hyperactivity disorder, autism spectrum disorders and motor handicap etc. [4].

According to [5], up to 19 million population give primary assistance with daily activities to their older or dependent relatives. 70 % of individuals can not live independently and need activity assistance and healthcare from caregiver. In 2012, 15.4 million caregivers provided an estimated 17.5 billion hours of unpaid care, valued at more than $216 billion [6]. Costs of caring for people with Alzheimers and other dementia as will cost from estimated $203 billion from 2013 to a projected $1.2 trillion per year by 2050 in the USA. In total, dementia is estimated to cost the UK £23 billion a year. It also indicates that the global cost of dementia in 2010 at $604 billion which is 1% of global GDP and it is likely that these costs will rise sharply in proportion to the number of older people in the coming years [2]. Therefore, this phenomena of continuously increasing of older population will bring huge burden and stress to the families and society.

As consequent of the increasingly ageing population, it is significant to find solutions to improve the living condition and develop more robust, usable, safe but low cost healthcare systems to reduce the burden to society. ICT could play a remarkable role to conquer this challenge. From last decades, the research on ICT-enabled support for independent living of the older adults has been drawing great attention from the communities and governments. There are many potential areas where ICT can be significant to counteract the effects of population ageing. The term of Ambient Assist Living becomes a field to investigate innovative technologies to provide assistance as well as healthcare and rehabilitation to senior people with impairment, especially for people with some cognitive impairment living on their own. These innovative applications enable them to live independently, comfortably, stately and stay healthily throughout their lifespan, namely ageing well-being.

In the past years, the motivation for AAL research has been adopted worldwide and became a very active research area. Europe Action Plan for Ageing Well and Europe AAL Joint Program has been launched by the EU for cultivating the development of innovative ICT-based products, services and systems for the process of ageing well at home, in the community and at work, therefore improving the quality of life, the participation in social life, skills and the employability of older people and reducing the costs of health and social care. A wide variety of research projects has just delivered results or is working on AAL. The outcome of these projects aim to achieve the overarching goal of the European Innovation Partnership on Active and Healthy Ageing (EIP AHA), which by 2020 aims to increase the average healthy lifespan of Europeans by 2 years. Ubiquitous Korea Project are long term projects supported by the government to improve citizen's life especially for the ageing and disabled people [7].

The AALIANCE project presents a roadmap for Ambient Assisted Living which is a significant guidance and provides various strategies for future research and development of this area [8]. A collection of international conferences and journals have focused on ambient assisted living and ageing well, such as International Conference on Ageing, Disability and Independence(ICADI), International Conference on Intelligent Environments(ICIE), AAAI Fall Simposium on Caring Machines: AI in Elder-care, International Workshop on Ambient Assisted Living(IWAAL), Journal of Ambient Intelligence and Smart Environments(JAIS). The Handbook of Ambient Intelligence and Smart Environment [7] and the Handbook of Ambient Assisted Living [9] aggregate the scientific and engineering contributions related to ambient assisted living worldwide. Furthermore, there have been more publications investigated the study on AAL and relevant technologies [10].

This survey paper aims to provide an one-stop view and summary of the background of AAL research, especially the technologies and approaches for cognitive assisted for ageing population in home environment. We will also explore successful case studies and deployed systems. Finally, we will identify the important current and future challenges.

2. Scenarios and Applications of AAL

AAL applications are targeted to accommodate the older or the disabled to live independently and comfortably as long as possible in their living environment. Living environments are not only home, but also various environments such as neighbourhood, shopping mall and other public places. AAL applications consist of complex networks of heterogeneous information appliances and smart artefacts which can assist people with special need in several ways. In [8, 11, 12] various scenarios and prototypes of AAL services for older people are proposed. We can summarise the scenarios of AAL services into following areas, namely daily task facilitation, mobility assistance, healthcare and rehabilitation, social inclusion and communication (Fig. 1).

Fig. 1: Typical ambient assisted living environment scenarios: smart home with sensors, appliances, network and computing components, daily task assistance, heathcare, mobility assistance

Recent years the progress in ubiquitous computing, wireless technologies, sensor networks, computing processing speeds, mobile services and robotics has essentially sustained the development of AAL applications and makes some envision reality in this area. The advancement of artificial intelligence and the relevant approaches such as context-awareness, agent-based technology, computer vision, machine learning and so on have been investigated to provide more intelligent, flexible and natural services to the users. Since the last decade, there are a number of research projects which target to address technologies to support daily life of older adults. Some of them have been available for customers.

2.1. Daily Task Facilitation in Smart Home

A smart home is a concept to describe living environment with digital surroundings such as sensors, smart appliances, networks and provides natural feel interaction with human. A smart home automation is capable of delivering convenient and adaptive services to the dwellers, for instance, automatic actuator for lighting, air condition, temperature control, food/drinking preparation ect. It is therefore often used to support people with cognitive impairment living independently. In a smart home, daily life activity(DLA) monitoring is an essential component for assisted living. Various digital devices, sensors, cameras are deployed into smart environment to monitor and record the activities of dwellers continuously. Activities of daily life are recorded as a symbolic representation. A smart home system can deliver adaptive services with regard to knowledge base of users' lifestyle. Such systems record users' daily activities i.e. when to get up, when to go to sleep, if they like listening radio or news after sleep, and so on. By analysing and processing the recorded activities, the system can recognise the users' habit and produce corresponding services to them.

Service robot is envisaged to assist people with their daily task or as part of assistance to the handicapped and the older. Domestic robots or service robots are employed to provide assistance for various daily situations such as fetching and carrying objects picking up from floor, performing cleaning tasks, emergency support etc.

There have been a number of smart home projects aimed at assisted living in the world. In Asia, TRON project [13] is an open project on intelligent living environment and assistive technology. (Fig. 2) is TRON Intelligent House established in Tokyo, Japan. PAPI project and U-house project were founded in Taiwan as part of the TRON project [14]. The Ubiquitous Home [15] proposed and implemented context-aware services in a real-life smart environment. The Robotics Room and The Sensing Room by the University of Tokyo [16] is another prototype of smart home system.

Within the TECNALIA's Health Technologies Unit [17], there are many projects related to AAL. TECNALIA is the largest private Research, Development and Innovation

Fig. 2: Smart home prototype of TRON project

(RDI) group in Spain and one of the leading ones in Europe after a merging process of eight technology centres located in the Basque Country (Spain). It involves older people, people with cognitive or physical disabilities, their relatives and caregivers, clinical experts and medical professionals as potential users in the project development.

The EasyLiving project [18] at Microsoft Research developed an architecture and technologies for intelligent environments. The EasyLiving system has evolved smart user interface, dynamic device configuration, remote control, activities tracking which provides flexibly support user interaction across a wide variety of tasks and modalities.

House_n [19, 20] is a multi-disciplinary project lead by researchers at the MIT Department of Architecture. This project aimed exploring how new technologies, materials and strategies for design can make possible dynamic, evolving places that respond to the complexities of life. has focused on developing new design tools, customization and fabrication strategies, sensing, and applications related to energy, health, and communication. The project has resulted with some open source tools [2] like Portable Place-Based Research Tools, OPEN Prototype House Initiative, Portable kit within the Open Source Building Alliance.

[2]http://architecture.mit.edu/house_n/

The CASAS Smart Home [3] project is a multi-disciplinary research project at Washington State University. It focused on the creation of an intelligent home environment. In this project, the smart home environment are treated as intelligent agents, where the status of the residents and their physical surroundings are perceived using sensors and the environment is acted upon using controllers in a way that improves the comfort, safety, and/or productivity of the residents. The developed smart home is an intelligent agent that perceives its environment through sensors, and can act upon the environment through the use of actuators. The system made it simple and lightweight that the capabilities of the smart home can be deployed, evaluated, and scaled accordingly [21, 22].

The Ambient Intelligence Research (AIR) Lab at Stanford University focuses on research to develop techniques and applications of ambient intelligence in smart homes and offices. Applications such as behaviour analysis for ageing-in-place, personal recommendation systems in smart offices, and occupancy-aware smart buildings. A space in the AIR lab is set up in the form of a smart room providing natural settings of a living environment while offering an ambient interface to its user through pervasive sensing, processing, and communication. A network of sensing devices is used to monitor work habits and social interactions of the workers, and adaptive personal recommendations are provided to them to promote ergonomic health and social engagement in the smart home setting [23].

The Quality of Life Technology(QoLT) Centre [4] is founded by the US National Science Foundation (NSF) Engineering Research Center (ERC) in Pittsburgh. The Center is jointly run by Carnegie Mellon University and the University of Pittsburgh. It focuses on the development of intelligent systems and assistive technologies that enable older adults and people with disabilities to live more independently. From 2006 to present, they have carried out several projects which address the needs and activities of everyday living by prototyping personal assistive robots, cognitive and behavioural coaches, human awareness and driver assistance technologies, human-system interac-

[3] http://ailab.eecs.wsu.edu/casas/
[4] http://www.cmu.edu/qolt/

tion and observes the social and clinical factors for deployment and adoption.

The Aware Home Research Initiative (AHRI) [24] at Georgia Institute of Technology is a notable project in the area of smart home.The Aware Home is a 3-story, 5040 square foot facility designed to facilitate research, while providing an authentic home environment. The technical components involved in the home include context awareness and ubiquitous sensing, individual interaction with the home and smart floor. The project address specific application to older people in three aspects: First, social connections between older parents and their adult children promoting peace of mind for family members. Second, support " everyday cognition " by augmenting those aspects of memory that decline with age and planning capabilities of older residents. Third, crisis situations so that appropriate outside services.

Fig. 3: Smart home prototype:Aware Home Research Initiative (AHRI) at Georgia Institute of Technology

MavHome [25] is a project in Washington State University and University of Texas at Arlington in the USA. They proposed a system of smart home can record and learn from the user's behaviour and predicate corresponding response. The scenario of smart home is defined as following:

> *At 6:45am, MavHome turns up the heat because it has learned that the home needs 15 minutes to warm to optimal waking temperature. At 7:00am,*

the alarm sounds, then the bedroom light and kitchen coffee maker turn on. User steps into the bathroom and turns on the light. MavHome records this interaction, displays the morning news on the bathroom video screen, and turns on the shower. When User finishes grooming, the bathroom light turns off while the kitchen light and display turn on, and the news programme moves to the kitchen screen. During breakfast, the user requests the janitor robot to clean the house. When the user leaves for work, MavHome secures the home, and starts the lawn sprinklers despite knowing the 30% predicted chance of rain. Because the refrigerator is low on milk and cheese, MavHome places a grocery order. When the user arrives home, his/her grocery order has arrived and the hot tub is waiting for him/her.

Fig. 4: Smart home prototype of mavHome project

Under the 6th and 7th European Framework Programme during last decades, there have been a series of projects on assisted living carried out. Some notable projects include ALADIN [26], iSpace [27], RoboCare [28], SYSIASS [29], PERSONA Project [7], LsW [30]. Within Europe Ambient Assisted Living Joint Programme, there have been about one hundred project in the 5 calls so far. The list of the projects evolved in the joint programme can be found in [5].

ALADIN (Ambient Lighting Assistance for an Ageing Population) project proposed a magic lighting system for older adults. The aim of this project is to develop an adaptive lighting system with intelligent open-loop control, which can adapt to response to the users need in various situations but also provides smart eco-energy management. The dynamic lighting system can benefit to the users' eye health, sleep quality, mood, cognitive performance, even their metabolic system, especially to the people with chronic disorder and vision impairment. This system enable the citizen with mobility or other disability to operate environmental systems and devices directly without moving physically to the actuator;s location. It allows the user to control the devices by looking directly by gaze-based interaction [26].

iDorm is one of the pioneering research projects on smart home in Europe. It is established by the Intelligent Environment Group of Digital Lifestyle Centre at the University of Essex in the UK in 1999 [31]. This continuous project has been upgraded to iSpace and now becomes a excellent seed-beds for intelligent environment study. The iDorm is a multi-use(sleep, work, entertaining, study) intelligent inhabited environment equipped with different normal furniture and embedded sensors. The space contains three types of embedded computational components:

- Physically static computational component within the building: It has embedded agent to receive sensor data through the network, to learn user's behaviour, to make decision for the control actions.
- Robotic agent: A mobile service robot agent with features like adaptive navigation, communication with static embedded agents via wireless network.
- Portable computational devices: Wearable sensors and PDA for interaction with the iDorm wirelessly.

The system of iDorm is based on Incremental synchronous learning architecture and fuzzy logic controllers(FLC). Each FLC forms a behaviour, while dynamic be-

[5] http://www.aal-europe.eu

haviour learned from users amd fixed behaviours by pre-defined programmes. FLCs are suitable for complex and dynamic lifelong learning of user's behaviour. For the agents, they can communicate with each other by exchanging XML-formatted queries within the network.

RoboCare [32] by ISTC-CNR is prototype of integrated home environment named RDE(RoboCare Domestic Environment) with cognitive support to improve the every-day life of older people at home . The RDE is a distributed multiagent system in which coordinated operation of agents can provide various services:

- *A mobile service robot*. Robotic service is the key feature of RoboCare.
- *Interaction manager (IM)*. The service robot acts as a cognitive mediator in the system, which can interact with users and internal algorithms, and this interaction process is controlled by the IM. The IM has two sub modules, speech synthesis module (Lucia) and speech recognition module (Sonic). These two modules allow user to interact with the robot via speech.
- *People Localisation and Tracking (PLT) agent*. PLT service is based on a stereo vision sensor. Which consists of the following three sub modules: (1) Background modelling module, background subtraction and foreground segmentation for foreground people and objects detection. (2) Plan-view analysis of position and appearance models. (3) Tracking module for observation over time maintaining association between tracks and tracked people or objects.
- *People posture recognition (PPR) service*. PPR agent relies the person-blob obtained by PLT and defined 3D body model. It is capable of distinguishing several major postures, such as "standing", "sitting", "laying", etc.
- *Activities of Daily Living (ADL) monitor*. The purpose of ADL is to analyse and schedule tasks and behaviours may have in the system. A schedule management environment is developed for ALD, in which the schedule representation is based on a temporal constraint network (TNC).
- *Personal data assistant (PDA) agent*.

As the RoboCare system combines various distributed agents to assist user's life. It requires coordination service to manipulate the multiple agents. To deal with the coordination, ADOPTN, an extension of the ADOPT (Asynchronous Distributed Optimization) algorithm is utilized.

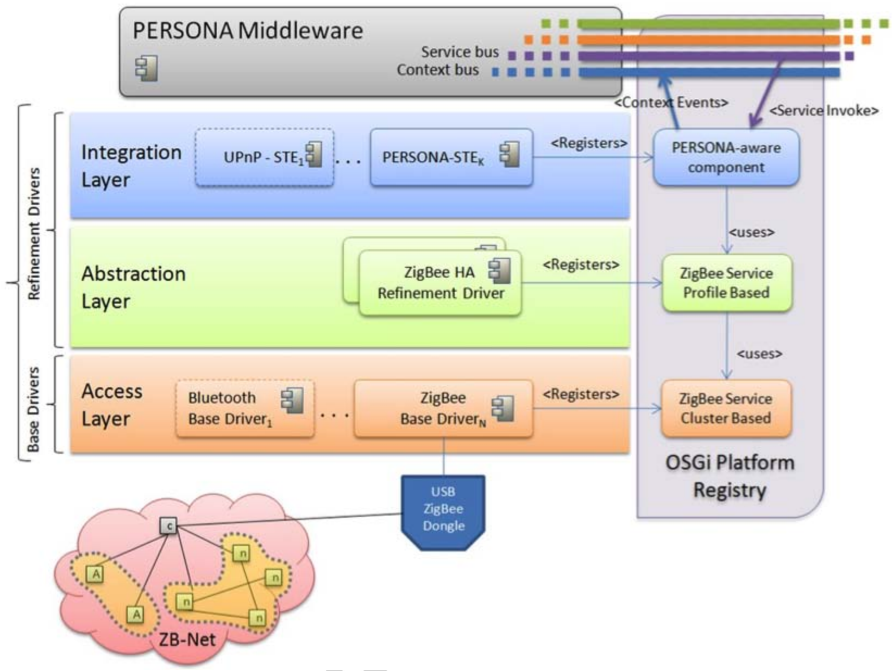

Fig. 5: Summary of PERSONA context awareness framework for AAL [33]

PERSONA [33] is a collaborative project on AAL for the ageing society founded by EU with 12 partners from Italy, Spain, Germany, Greece, Norway and Denmark. It aims to develop sustainable and affordable solution for the independent living of senior people with AAL technology. With regard to the need of older independence of life, the project is divided into four categories:

- AAL services supporting social inclusion and experience exchange,
- AAL services supporting older users in their daily life activities,
- AAL services supporting older people to feel more confident, safe, and secure, and helping their relatives to manage risky situation,
- AAL services fostering mobility and supporting older people outside their home.

A scalable open Distributed System (PERSONA platform) for supporting context-awareness of AAL space was developed as a result of this project. The platform provides a middleware that supports seamless connectivity and semantic interoperability for self-organisation of physical and logical architecture. It also allows re-configuration of platform components such as the Situation Reasoner, the Dialogue Manager, and the Services Orchestrator. The architecture of PERSONA platform is composed of the following components:

- Interoperable framework provides an event-based class of buses and a call-based service for communication and specification of context.
- Some of services in PERSONA platform:
    1. Dialogue Manger (DM) for handling the system-wide dialogues and hiding the complexity of utilising the application service from user.
    2. Context History Entrepot (CHE) for gathering the history of all context events and guaranteeing the essential support to reasoners.
    3. Situation Reasoner (SR) that uses the database of CHE and infer new contextual information with RDF and SPARQL.
    4. Service Orchestrator (SO) for interpreting the meta-data, describing a composite service and performing the instruction within it.
    5. Profile Component for guaranteeing the adaptability of the AAL system and managing the user profiles.
    6. Privacy-aware and Security Manager (PISM) for controlling the access to services in the middleware.
    7. AAL-Space Gateway for accessing to the hosted service with a fixed URL remotely.
- The middleware has three layers: The Abstract Connection Layer (ACL) is the lowest layer which responses to the peer-to-peer connectivity between the middleware instances. The second layer, the Sodapop layer implements the peer and listener interfaces from ACL and registers as the local peer to all connectors found. The top layer is a PERSONA-specific layer, which implements the input, output, context, and service buses with distributed strategies using an RDF

serialiser for the exchange of message among peers.

- Ontological Model provides a framework for sharing knowledge and resource handling within the distributed system. Three elementary tools based on ontology is developed in PERSONA platform: the knowledge representation technologies of Semantic Web consist of RDF and OWL; an upper ontology with appropriate programming support consisting of those concept that all users of the middleware; a general conceptual solution with a certain set of shared tools for integrating thin devices and embedded sensors, and transforming the tapped data into an appropriate ontological presentation.
- Sensors Abstraction and Integration Layer (SAIL) for sensing the environment and user is composed of stationary, portable and wearable components. Wireless Sensor Network (WSN) is applied for sensing tasks. Within PERSONA, a ZigBee based network is developed to integrate and handle the WSN and other sensing components [33].

2.2. Healthcare and Rehabilitation

Health plays a major role in the life of older people suffering from chronic diseases like diabetes, dementia and the other cognitive or physical impairments. Simplifying the treatment of those diseases not only eases their everyday life, but can also increase their personal safety by ensuring automatic alarms in case of a deteriorating health status. Living alone often causes fear of having an accident and being unable to call for help. This includes falls, accidents in the kitchen, but also general safety e.g. when leaving the home. It is therefore important to provide the older with tools, which support them regarding these issues and which, in case they cannot call for help on their own, automatically call for assistance.

With declining support from families, society will need better information and tools to ensure the well-being of the of the growing number of older citizens. It has been a burgeoning area of investigation in the wake of advances in in-home technology to enhance the health and independence of older adults without the constraints and expenses of the traditional health care system. Advances in health and communications technology come at a time of dramatic worldwide increases in life expectancy and skyrocketing health care costs. Home monitoring and assistive technologies are employed to identify changes in health and behaviour in home settings, and to facilitate successful adaptation to those changes. This section concludes some paradigms of healthcare application in AAL.

Kameas and Calemis [34] have surveyed a collection of pervasive systems in supporting activities with health significance. The @Home system can provide service to remotely monitor patient's vital parameters like ECG, blood pressure and oxygen saturation level. The HEARTFAID system is a knowledge-based platform that can improve early diagnosis and medical-clinical management of heat diseases. The system provides services such as electronic health record for easy and ubiquitous access to heterogeneous patient data; integrated services for healthcare professionals, including patient tele-monitoring, signal and image processing, alert and alarm system; clinical decision support in the heart failure domain, based on pattern recognition in historical data, knowledge discovery analysis and inferences on patient clinical data. The CHRONIC (An Information Capture and Processing Environment for Chronic Patients in the Information Society) project aimed to develop an integrated a model for the care of targeted chronic patients in Europe.

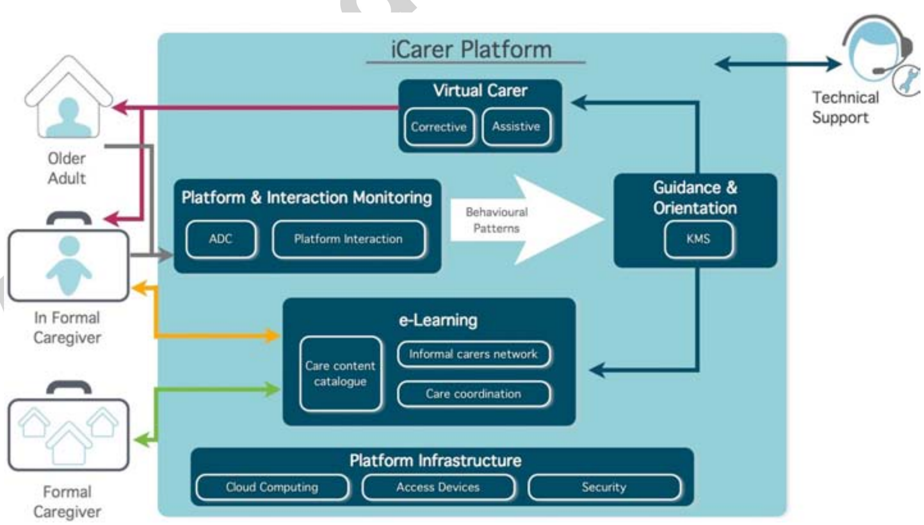

Fig. 6: Architecture of iCarer System and Services [35]

The iCarer project [35] aims at supporting the informal care of older adults to de-

Table 1: AAL for health, rehabilitation and care [8]

	Level 1	Level 2	Level 3
Self-management of chronic diseases	Intervention of the patient for powering and management of diseases	Patient part of the care team, integrated processes	No patient intervention for powering and management of diseases
Chronic disease management	Telemonitoring, remote consults using audio and low resolution video	Integration of services at care delivery organisations, link to non-healthcare services, fitness and activity management.	Cross institutional integration, supporting integrative care models
Medication management	Reminder system with monitoring of medication intake	Extended with educational and motivation for the patient and medicine interaction check	Integrated into disease management
Rehabilitation	Monitor exercises in home situation using wearable sensors	Support and monitor exercises with operational devices at home.	Support and monitor exercises with exoskeleton-like devices using advanced neuro-scientific control models
Care team support	Stand-alone services like tele-monitoring, tele-consultation, medication management, activity management	Integration of services at care delivery organisation, link to non-healthcare services like fitness and activity management.	Cross institutional integration, supporting integrative care models and non healthcare services

liver interoperable solutions providing a holistic cloud-based care support service. This includes Tunstall's lifestyle monitoring services (ADLife), enhanced to provide informal carers with the information required to support them in their care duties. Additional services include a personalised support and training programme based on e-Learning methods, assistance mechanisms for the caregiver and monitoring and assistance services for the person being cared for. These services combine in order to achieve an overall feeling of safety and a substantial stress reduction for the caregiver.

In [36], an integrated lifestyle management system is proposed to record the user's daily health status parameters and activities for health support.The system has three layers, information gathering, information processing, information presentation with the following components:

- Data Gathering Agent(DGA) can collect data from various input sources. The input source can be the devices used by the user such as mobile phone, GPS, IMU, Alive Heart Monitor [37], PC activity Platform.
- Data Transformation Agent (DTA) operate the input data available in differing format and in multiple local storages: such as data conversion, data clustering, filtering, sorting into a user database, data optimisation and Databased Model Management.
- Information Agent is responsible for processing the data collected in the central databased through the information model.
- Presentation Agent contains the role of assembling information into a story format, according to the Story Model.
- User Interface Agent is used to create various information visualizations.
- Policy Agent performs as a manager of policies related to information usage, as well as various user preferences, and will become increasingly important once other information usages involving external parties are added to the system.

This system can not only provide monitoring of health status with specific parameters, but also reflect the reason of "what happened".

Home Healthcare Monitoring System (HHMS) supports older users' daily healthcare and their quality of life by collecting relevant medical and daily routing data. The data is gathered into a Healthcare Management Information System (HMIS) for physicians in hospital to diagnose. A interoperability Mediation System was proposed in [38] which acts as a bridge between HHMS and HMIS. HHMS collects information in raw sensoray format and stores in XML format while HMIS follows standard structure of information based on its compliancy with the healthcare standard. In their system, a HARE(Human Activity Recognition Engine) is developed to monitor the activities of Alzheimer disease patients. Clinical Document Architecture (CDA) markup standard is used to specify the structure and semantics of "clinic documents" from the sensors data gathered, processed, and then filtered as part of CDA documents.

In [39] Corchado et. al. developed the GerAmi (Geriatric Ambient Intelligence), an intelligent environment that integrates multiagent systems, mobile devices, RFID, and Wi-Fi technologies to facilitate management and control of geriatric residences. The system was evaluated to reduce task time with Nurse agent and Doctor agent,provide patient care by enhancing the communication between patients and hospital staff, facilitate security monitoring patients and guaranteeing that each is in the right place, storing information more securely.

Quality of sleep is an important attribute of a senior person's health state. The sleep pattern is a significant aspect to evaluate the quality of sleep. An automatic sleep monitoring system for home healthcare is presented by [40]. In this system, the sleep data can be collected by sensor board and transmitted to data centre in real-time and continuous mode. A web-based application is used to visualize sleep data. It also provides algorithms to produce a user's sleep qualities and health patterns by analysing the sleep data.

Safety risks are the most often-cited reason for people having to leave their homes for supported living environments. According to the caregivers, wheelchair users tend to fall down from their beds or their wheelchairs when they transfer between bed and wheelchair or between wheelchair and toilet seat. It is also likely that old people who suffer from senile dementia tumble from their beds when they try to sneak out of the bed. Pivato et. al. proposed a low-cost wearable WSN node for body detection [41]. Their project was resulted with an ultra-light and easily wearable device for both fall detection and coarse-grained RSS-based localisation, while keeping lifetime as long as possible.

Diabetes Support Systems usually record blood glucose measurements, timestamps as well as information related to administering insulin. A diabetes support system in AAL is described in [42]. The service value network (SVN) approach is applied to automatically match medical practice recommendations based on patient sensor data in a home care monitoring context to health services provided by a network of service providers. The system is demonstrated with an SVN composition based on an initial set 493 patient profiles in the context of Type 2 Diabetes management.

Memory decline is a highly debilitating condition for many seniors, especially for those with dementia. There have been many applications within the area of AAL are likely to be relevant to older adults with cognitive impairments [7, 43, 44, 9]. Automated Memory Support for Social Interaction (AMSSI), a system proposed by Bellodi et. al [45] that helps memory impaired people with their social interaction. This system provides active support that may help reducing stress level of patients. It can recognize visitors, determine the purpose of the visit, monitor the dialogue, determine whether the patient needs support, and provide feedback. AMSSI is tailored to patient needs, it has fast computation, full automation, and can be handled by the patient without supervision. The assistive system can be beneficial for improving the quality of life of patients with mild to moderate cognitive impairments.

Paper-based Early Warning Scorecards (EWS) are widespread in hospital for clinical decision support. They are designed to help clinicians identify the patients who are most at risk of suffering an adverse event in advance. A scorecard is a reference table which associates individual vital signs parameters (e.g. heart rate, respiratory rate, etc.) with a score (0, 1, 2, or 3), which is representative of the physiological derangement from a normal range. But somtetimes hospitals and caregivers experience delayed recognition of the deterioration and lead to late referral to critical care, even some cases death. An Electronic-Early Warning Scorecard proposed in [46] has demonstrated its significant efficiency and usability over paper-based EWS with sensor network based health monitoring and context awareness.

2.3. Mobility Assistance

Mobility is significant component to quality of life as it allows a person to independently move about when and where he or she intends to. Many people with motor disabilities and cognitive impairments often encounter various barriers existing in their daily life. They invalidate the ability to perform movement to a desired destination and certain tasks. This can limit the capacity of operating devices, manipulating objects and mobility. As a result, considerable part of the population with motor impairment must rely on assistance from others to get from place to place. Mobility support ranges from assistance with planning routes and navigation from one location to another as safely without human intervention.

The research of smart wheelchairs emerged since the early 1980s over the world

(a) NavChair

(b) Wheelesley

(c) VAHM

(d) PerMMA-wheelchair

Fig. 7: Examples of intelligent wheelchair prototypes.

to accommodate these people [47]. Assistive robotics technologies have been applied to develop smart wheelchairs that can provide navigation assistance. Such wheelchair typically consists of electric powered wheelchair or scooter attached with computer, sensors and actuators. Since 1990s, several long-term projects were established to develop appropriate wheelchairs for motor disabled people. VAHM [48] is a EU project from 1989 to 2002, an agent based smart wheelchair was developed in the project. The NavChair [49] is a advanced intelligent wheelchair developed in a project from 1990 to 1999. The collaborative shared control architecture prototype was proposed in NavChair and this significant architecture was employed widely in many intelligent wheelchairs [47]. SENARIO [50] wheelchair is developed in a EU founded project. It can provide shared-control navigation (obstacle avoidance) and autonomous navigation based on a pre-built map. Neural networks is used for localization, and distributed control architecture in SENARIO. Wheelesley [51] project (1995-2002) at MIT employed machine vision for obstacle detection, which allows wheelchair to travel safely outdoors as well. PerMMA [52] is composed of a robotic powered wheelchair and two arms to provide enhanced mobility and bi-manual manipulation for people with lower and upper extremity impairment.

However, hitherto there are few intelligent wheelchair are widely resealed commercially, most of them are still in laboratory for research use since it is too expensive and seldom citizen can afford. Many ongoing research projects [53, 54, 55, 56, 57] aim to reduce the cost of intelligent wheelchairs and enhance the capabilities of the wheelchairs with higher "Intelligence".

(a) Segway wheelchair

(b) Omni(mecanum) wheelchair

(c) HAL

(d) Smart scooter

(e) Mobility aids walker

(f) Toyota-i-real

Fig. 8: Mobility assistance equipment prototypes.

Besides wheelchairs, some other innovative personal mobility devices such as Nosegay vehicles [58], mecanum wheel vehicles [59], hybrid assistive limb (HAL) [60], intelligent mobility scooter [61], smart tricycle [62] and smart vehicle are investigated by the research communities. These robotic products will be significant to accommodate the population with mobility barriers.

2.4. Social Inclusion and Communication

Another important mission of AAL service is to prevent social isolation. Social interaction and communication are factors that have remarkable influence on the quality of life. As an individual, interacting with other and taking apart in social activities and entertainments are essential elements of enjoyable life. Traditionally, people can get communicate with their families and friends via phone, email, internet based communications etc. Television, newspaper and the internet are typically the main media to access social information and entertainment. However, many older people with cognitive/physical impairments have obstacle to access the social media and participate social activities. Whence AAL technology aims to engage the older people to stay happy in their living environment, remain active in their community, get contact with their community [63].

GENIO [64] is an AAL application in home automation. It is endowed with functions such as reading e-mails, programming washing machine, checking the goods in fridge, creating the shopping list, doing shopping with a PDA in the supermarket, activating the dishwasher, being guided on how to prepare a recipe for the oven and checking if there are the needed goods to do it, listening some music stored at home, watching some photos, watching some selected video and so on. The users can dialogue with the system through microphone attached in their pocket.

The aim of Building Bridge Project [66] is to applied communication technology to enhance social connection for the older with their peers, family and friends. The device can provide older people with the opportunity to connect with their family and friends through the shared experience of a video or radio broadcast (such as documentaries, news, health bulletins). Following each broadcast, listeners have the option to take part in a group chat. Further functionality includes individual or group calls, a (textual)

Fig. 9: Social Inclusion Services for assisted living [35].

messaging service, and most recently a tea room which represents a chat forum.

A domestic communication designed within NETCARITY (EU FP6) project aimed to provide service that foster social contact and strength social ties within the social network of older people living alone [67]. The project proposed a prototype of e-inclusion: a user interface that exploits touch-screen technology, whereby interaction is based on the direct manipulation of the digital objects, using natural gestures recalling real world motor patterns.

The HOST project [65], a smart technologies for self-service to seniors in social housing, is a part of The EU AAL Joint Programme. It aims to provide solutions to the needs of the today Social Housing requirements, in order to enrich the life of the older people living in the current social house park with a comfortable and friendly context to enable the integration of older population into the self-serve society. These competences of social hosing allow a better quality of communication and a better access to

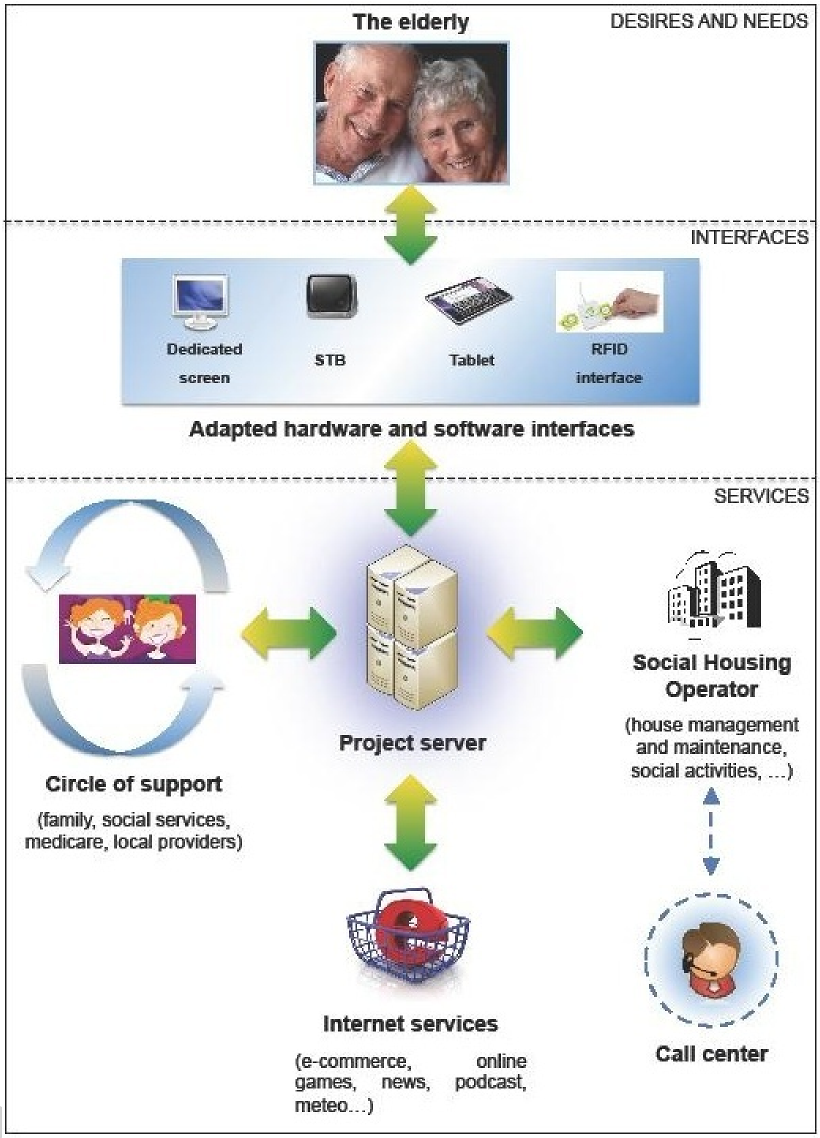

Fig. 10: Scenario of Social Inclusion Services for HOST assisted living [65].

package services from the older; enable easier relations with, family, service providers and housing operators, through enriched supports (images, text, voice, documents).

3. Instrumentation and Platforms

3.1. Appliances and Sensors for AAL

A smart home is a daily living space with various type of sensors and actuators installed, in order to monitor activities and control appliances in the space. Sensors and actuators are the main components that cannot be absent in a smart home. The sensors can be used to measure the temperature, light intensity in the environment or sample the biological signals from users. These actively obtained information are used as the inputs of a smart home system, that a user do not need to manually input them. The actuators are used to perform user's repeatedly or predictively actions, like turning on/off appliances, opening/shutting a door, etc., which adds autonomous features to the system.

In a typical smart home, the devices/ appliances can be summarised below [68]:

- **Sensors:** RFID tag, physical presence sensor, positioning sensor, health monitoring detector (body sensor), accident detector, video camera (CCTV or private camera);
- **Household appliances:** Refrigerator, wash machine, light, bed, door, TV, computer, cleaner, air conditioner, kitchen appliances etc.;
- **Actuators:** Door open/closing actuator, window open/clouing actuator, air-conditioning actuator, light actuator, home appliances switches;
- **Security:** Password lock,voice pattern lock, Biometric verifier (fingerprint reader, iris scanner);
- **Communicate:** Network, smart-phone (watch, camera), human machine interfaces.

There are various wearable health monitoring devices currently on the market such as 9Solutions IPCS, Health Buddy (Bosch), Telestation (Phillips), Genesis DM (Honeywell), Health Guide (Intel), LifeView (American TeleCare), Ideal LIFE Pod (Ideal Life), Healthanywhere (Healthanywhere Inc.), Respiratory Rate Detector [69] and Smart cloth [70, 71, 72]. These systems are able to take physiological readings (e.g. blood pressure, heart rate, temperature, glucose levels, calories etc.) using conventional measurement devices (e.g. blood pressure cuff, thermometer, blood glucose meter, location etc.) and share them remotely with clinicians [73].

In many smart home prototypes, the typically appliances (bed, lights, bathroom, TV, fridge, cook stove etc.) are designed particularly for the older or disabled to access conveniently and safely. For some cognitive impaired people, it may lead to fire risk if they forget to switch off the stove and leave a pan on it. A stove guard kitchen monitor is presented in [74]. The monitor is mounted on stove to avoid fire risk. Another smart kitchen system for AAL is described in [75], which integrates a wide variety of home technology (household appliances, sensors, user interfaces, etc.) and associated communication standards and media (power line, radio frequency, infrared and cables). The system is based on the Open Services Gateway initiative (OSGi), which allows building a complex system composed of small modules, each one providing the specific functionalities required, and can be easily scaled to meet our needs.

The Robotic Bed [76] is sleeping system equipped with a controlling system. It enables the user to steer easily and to change between the wheelchair and the bed mode. In the wheel chair mode the robot is able to recognise people and obstacles in order to avoid collisions and to navigate safely. In bed mode, it supports the posture by adjustment and optimization of the mattress form. Intelligence Toilet [76] in Daiwa House & Cyberdyne is a toilet system, which is able to measure the sugar level in the urine, and also the blood pressure, body fat and weight. These features should facilitate the user to avoid forthcoming illnesses by early diagnosis and reduce medical inspections at a doctor's office.

Many of these devices allow the person being monitored to interact with clinicians over video screens, enabling more personal communication. Some also have access to online, multimedia educational materials, caregiver networks, and other resources that can help people to manage conditions. These tools can be valuable for caregivers and clinicians who are managing the health of older adults with dementia living at home. With the help of these sensors and actuators, a smart home is then able to analyse the requirements of people that having cognitive impairment, and support them living better on their own.

With further processes, additional information could be acquired beyond the sensor is originally designed for. For example, WLAN (wireless local area network) is a common basic communication framework in a modern building. Besides of its normal communication usage, a location tracking application is possible to be implemented by calculating the distances of mobile devices to each network access point. In this design, the advantages are no additional localisation devices are needed and can work indoors. The difficulties usually are caused by the complexity of environment (walls, passengers and other obstacles). In order to solve this problem, [77] uses a back-propagation neural network to calibrate the interferences from the obstacles. By combining various type of sensors, even more information could be obtained. Explicitly, cameras, temperature, light and other sensors are used to learn a user's behaviour in a smart environment in [27].

Based on the current development trend, we noticed that the basic sensor types are limited, smart home (environment) appliances are required to have various sensors collaborate together to provide the most information, and have standard information sharing interfaces to interact with other smart appliances.

3.2. Robotic Service Platforms

The next revolution in the smart home is expected to come from the world of robotics [78]. Service and assistive robotic technologies have high relevance to AAL. Robotic assistive technologies cover a range of applications helping people with physical, social, and/or cognitive disorders from daily tasks to cognitive rehabilitation. For different purposes, the robotic service platforms are vary from each other in mobility, size and appearance design. [8] lists a rich collection of platforms for personal daily care. The most major of those recognized today include mobility, self-maintenance activities assistance, such as cooking, feeding, dressing, grooming, bathing etc. [79] presents a serial of approaches to enhance the cognitive capabilities of ubiquitous robots, in order to supply users with assistive services and execute complex tasks in dynamic real world domains.

Mobility assistance is an essential service for disabled persons. Intelligent wheelchairs, guide-canes, assistive limbs and interactive walkers are developed to support mobility to the older and disabled as we mentioned in previous section.

Fig. 11: Some domestic assistant robots for commercial and research.

Many older persons may have difficult activities of the daily living such as feeding, dressing, meals preparation, taking medicines and so on. Service robots can provide the user with a functional assistance for them to deal with the difficulties encountered in daily life. As an example, Pearl robot [80] from the Carnegie Mellon University is one of the most-cited and studied robots which provides routine activities reminder (eating, drinking, taking medicine) as well as some walking guidance. The interaction is realized through speech synthesis, visual display onto a touch screen, and motions of an actuated head unit. Other relevant systems are the Care-o-Bot[78], the Cero [81] robot, PR2 robot and the ROBOCARE [28].

Besides, as health of a person is closely related to the quality of life. With the age growing, older people are more likely to rely on nutrition supplements or drugs for senile diseases. A medicine service robots should be capable to remind the user and monitor the drug taken information. Some robots are designed to proper diet, exercises, health monitoring and check up or monitor health parameters. MINAmI was a project working on interacting the tiny AmI environmental sensors with mobile phone. One of their target is to provide supplement safety and health services for older people. As a part of this research, a similar drug service platform is described in [82].

A robot exercise coach presented in [83] is able to train physical exercise for the older population. Its built in workout game, the sequence game, the imitation game, and the memory game can help the users with cognitive impairment and engage them participate to social activities.

A robot might be employed for security and emergency intervention. Such robot is able to monitor home and upload sensing data to the server and identify risks. In case of an emergency situation such as detected fall, a mobile robot has the advantage that it is able to move towards a person. The robot can talk to the person first, and than take a picture, send it to caregivers and initiate an alarm. Furthermore, the fallen person could call the robot for help. The robot can directly contact the user and initiate a call to family members or caregivers [84].

To help and easy the living of the cognitive impairment older people, companion robots are being investigated by various institutions. A robotic baby seal (Paro) is being developed at AIST (the national institute of Advanced Industrial Science and Technology, Japan). From their experiment results in [85], it is proved that Paro can actually bring happiness to the older people with different levels of cognitive impairment (evaluated by counting the smiling/laughing times during the experiments). More theoretically, the interaction mechanism between companions (animal or robotic companion) and human is being investigated at the MIT Media Lab. To test the corresponding theory framework, a robotic Teddy-bear is constructed. Based on how animal or human skin is designed, [86] investigated the usages of various types of sensor (including temperature, pressure, etc.) to construct the “sensitive skin ”.

Instead of discussing the technical details, [87] studies the potential psychology theory between human and robots. It points out that the recent robots can be classified into two major categories according to their applications: assisting robots and interactive simulation robots. Assisting robots aim at increasing the working productivity or finishing the jobs that are impossible for human. In contrast, the interactive simulation robots focuses on providing social, educational or entertainment services with immersive and realistic using experience. The later category is the major object of the human-robot psychology research. In this research, the interaction between human and robots is organised in a Complex Interactive System (CIS) and multiple dimensions of communication effects are discussed and analysed. Particularly, a robot cat (NeCoRo, Omron Corp. [88]) is used as the research object while Person-Robot Complex Interaction Scale (PRCIS) [89] is used as an assessment tool.

The research in domestic service robotics concerns Self organizing brains, Human-Robot-Interaction and Cooperation, Navigation and Simultaneous Localization and Mapping (SLAM) in dynamic environments, Computer Vision and Object Recognition under natural light conditions, and Object Manipulation. All these challenges involve vast of research subjects and disciplines.

3.3. Human Machine Interfaces

(a) GUI (b) Voice Control (c) EPOC Emotiv(EEG)

(d) Computer vision based Control (e) Myo gesture control(EMG+IMU) (f) Leap motion gesture control

Fig. 12: Examples of human machine interface

Various smart devices technologies are steadily penetrating in our daily lives. We are surrounded by these products and interact with them in many ways. Particularly, such devices may potentially improve the quality of life of older people and patients with impairments. Applications of assist daily living require robust interfaces that allow for natural control. These interfaces may rely on diverse modalities information that can be related with the intention, preparation and generation of voluntary movement, either at mechanical or neural level. To have the smart environment work more pervasive and easier to access by old people which usually do not have much knowledge on operating complex computer systems, the human machine interfaces (HMIs) largely determines whether the smart homes are acceptable by older users.

Instead of using traditional keyboards and mouses, natural interaction approaches between human and machines (robots) are investigated in both academia and industry. Some relatively mature techniques include using joystick, touch pad/screen. Comparing with the keyboard/mouse commands, these methods provides more intuitive interacting experiences.

In order to provide immersive using experience, voice and vision controllers are widely employed. Since these using experience is more close to the interaction between humans, it is more nature and effective. In the voice controlling research, voice recognition is well researched and the difficulties remains in the natural language processing (NLP). The target of NLP is finding the approaches to have machines understand human languages. Vision interaction is a relatively wider research field, it contains various topics and each of them has the great potential in different scenarios. For instance, an eye-blink monitoring system is proposed in [90], a vision 3D automatic microassembly system is presented in [91], and a thermal-based human tracking system that can localise users is reported in [92]. Except for the traditional camera based methods, more powerful cameras with depth information are being developed and used for research in recent years, such as Kinect [93], and Leap Motion [94, 95]. Due to the depth information obtained, more control strategies are able to be developed with better accuracy. Specially, biological signals is one of the solutions for receiving commands from human pervasively. Widely investigated biological electro signals include EMG (Electromyography), EEG (Electroencephalography) and EOG (Electrooculography) [96].

4. Monitoring and Communication Infrastructure

Typically, AAL environments are composed by different kinds of devices such as mobile phones, embedded devices, and wired or wireless sensors. Although nowadays are raising some efforts based on communication standards for telemedicine devices, its adoption is going slow. In addition, both biomedical and users devices often runs on different network protocols which obstruct a real integration between devices. Smart sensors have been a breakthrough in the applications of monitoring mobile objects or individuals. On this basis, smart sensors are becoming a main "role " on AAL environments. Thanks to the protocols and standards of sensor network technology, the heterogeneous devices are able to communicate and process the information within a smart home and users.

4.1. Some Standards of Communication for AAL

WSNs are an important technological support for smart environments and ambient assisted applications. A WSN consists of hundreds or thousands of sensor motes that have the ability to communicate either with each other or directly with the base-station. A base-station is a fixed node or mobile node that is capable of connecting the sensor network to an existing communications infrastructure or to the Internet. At a higher level, WSNs can be modelled as a distributed database where every mote is a database. The attributes of database are the types of sensors mounted on the mote. A user can query the database (mote) to retrieve the values of attributes of interest, such as pressure, humidity, temperature, longitude, latitude, etc. Due to the embedded, distributed, pervasive and other features that commonly required in AAL projects, a series of suitable communication standards are usually chosen as the guide for developing smart environments. Some of the important ones are organised below [97]:

CORBA: Common Object Requester Broker Architecture (CORBA) is a standard for enabling software modules, written in multiple languages and ran on different computers, to work together. Additionally, CORBA provides strong data-type between different languages to reduce human errors, encapsulates data-transfer and other low level technical details to enhance the robustness, and makes the system development more convenient. Therefore, this standard could be considered as the foundation of developing distributed systems.

UPnP: UPnP (Universal Plug and Play) is a group of protocols or a much-extended architecture suggested by Microsoft (Olleros 2007) and promulgated by the UPnP Forum, which ensures that some network devices can autoconfigure. The aims of UPnP are making sure that the devices can connect perfectly and simplifying the implementation of networks at home (exchange of data, communications and entertainment) and in corporate environments. It is an open and distributed architecture based on already existing protocols and specifications, such as UDP, SSDP, SOAP or XML. In order to simplify the installation and connection between any two devices in a distributed network, the UPnP is promoted as a set of networking protocols. This protocol set allows the peer-to-peer connection between devices, which is a distributed architecture based on various established protocols such as TCP/IP, UDP/IP, HTTP, etc. As a instance, ALL applications in [98, 99] employed UPnP to integrate robot and sensors to the digital home.

Jini: Jini is an architecture similar to UPnP. By using which, a device can announce its presence to the network together with its services as soon as its connected to a network. Comparing with UPnP, both of them are designed for the "plug and play" feature, but UPnP focuses more on managing devices in the network while Jini concentrates on discovering and providing services [100].

WS (Web Service): WS is usually used as a supplementary technique to the previously mentioned standards. The main highlight of this standard is that the standard text-based HTTP is used and it can compatibly run on different platforms. However, due to the over-complexed package header (requires fragmentation frequently), the text-based function calling approach cost higher run-time resources. Additionally, WS can easily penetrate the firewall, which provides convenience on communication but also introduces security problems. To solve these problems, [101] proposes the embedded web services.

4.2. Communication Techniques in Current AAL Projects

Internet of things (IoT) provides connectivity and intelligence to convert small devices and common things into smart objects. The IoT describes a world where machines and physical objects are seamlessly integrated into the information network, and communicate together to exchange and process information.

The smart objects present high capabilities to integrate and transfer enriched data from embedded sensors, activities, behaviours and clinical devices from mobile health and smart environments. AAL with IoT technology can facilitate people with disabilities the assistance and support they need to achieve a good quality of life and allows them to participate in the social and economic life. Assistive IoT technologies are powerful tools to increase independence and improve participation. Smart environment projects presented in [102, 103, 104, 105] provide some instances of IoT for AAL.

For example, in [102], communications among devices are categorised into two groups: LTE-based indoor communication and short-distance wireless communication. The LTE is also known as the 4G mobile network which provides better data capacity. While using 20MHz channel, its downlink and uplink can reach to 100 Mbps and 50 Mbps. This makes the data bandwidth sufficient for connecting mass number of devices simultaneously. The short distance wireless communication techniques include Bluetooth, RFID, WiFi, Zigbee, etc. From the analysis in the paper, it has been found that Bluetooth is suffering from too short communication distance and peer-to-peer communication mode, and RFID encounters poor reliability with networking inconvenience. Therefore, the usage of these two techniques are relatively limited in a smart environment. In contrast, WiFi is developing fast in the sense of its coverage area and data transmitting speed capability. Zigbee is a new type of technique with low power consuming and high reliability. Hence they are predicted to play significant roles in the future smart environments.

Comparing with the traditional network communication techniques, the ones used in AAL require additional configurations with larger address space and lower power consumption. In order to achieve this goal, [106] provides a gateway solution that can interact with IPv6 devices over 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks). To be compatible with IPv4, WiFi and Ethernet interfaces are also provided. Additionally, UPnP is enabled on IPv6 to make the system easier to be configured and used.

[107] provides an example of intrusion detection system, using WiFi/internet with mobile SMS (short message service). In this project, the camera information is collected from each of the cameras in different rooms through WiFi and past to the cloud service over internet. If any intrusion occurs, the cloud will send a message to the user together with the corresponding camera streaming video. Then the user is able to make the decision, e.g. call the local police or ring the alarm.

As a conclusion, most of the existing communication techniques can find their own positions in AAL projects, depending on several criteria: installation/maintaining costs, power consumption, security level, communicating speed, etc. A balance among all these factors is the key of producing a better smart environment.

5. Theories and Approaches for AAL System

5.1. Multi-agent System

Autonomous agents and multi-agent systems represent a way of analysing, designing, and implementing complex software systems. The agent-based approach offers a collection of powerful tools, techniques, and metaphors that have the potential to significantly improve the way in which people conceptualise and implement different types of complex software. Agents and multi-agent systems are being applied in an increasingly wide variety of applications [108]. Of course, multi-agent systems approach is widely used in support of Ambient Assisted Living in various aspects. AAL environment by using a multi-agent system consists of agents that represent inhabitants (humans, animals, plants, and objects) of the environment and physical devices (sensors and actuators) that control and monitor the environment. The issues involving multiple parameter optimization and constraint satisfaction while maintaining the well being and physical structure of the inhabitants of environment as well as the comfort of multiple human inhabitants sharing the same environment and its resources Inhabitants. An ambient agent is assumed to maintain knowledge about certain aspects of human functioning, and information about the current state and history of the world and other agents. Such paradigms of agent-based AAL systems can be found from [109, 110, 111, 112, 113]. Here we briefly describe some instances of AAL systems which utilise agent-based approaches.

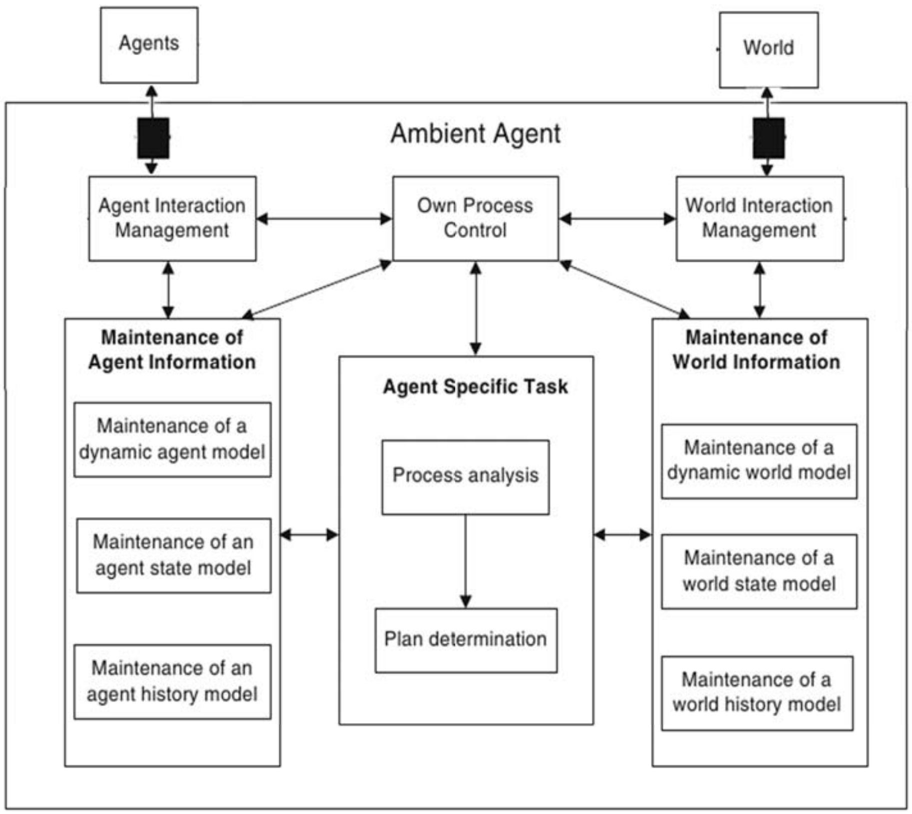

Fig. 13: A example of multiagent system for AAL [114].

The MavHome smart home project [25] focuses on the creation of an environment that acts as an intelligent agent, perceiving the state of the home through sensors and acting upon the environment through device controllers. The MavHome agent can be decomposed into multiple lower-level agents responsible for subtasks within the home, including robot and sensor agents, and MavHome can dynamically reorganize the hierarchy to maximize performance. Within the system, agents are separated into four cooperating layers. 1) The Decision layer selects actions for the agent to execute based on information supplied from the other layers through the Information layer.

2) The Information layer gathers, stores, and generates knowledge useful for decision making. 3) The Communication layer facilitates the communication of information, requests, and queries between agents. 4) The Physical layer contains the hardware within the house including individual devices, transducers, and network hardware.

In [115] an ambient agent architecture exploiting automated cognitive analysis an agent-based ambient agent architecture is presented based on monitoring human's interaction with his or her environment and performing cognitive analysis of the causes of observed or predicted behaviours. Within the agent architecture, a cognitive model for the human is taken as a point of departure. From the cognitive model it is automatically derived how internal cognitive states affect human's performance aspects. Furthermore, for these cognitive states representation relations are derived from the cognitive model, expressed by temporal specifications involving events that will be monitored. The representation relations are verified on the monitoring information automatically, resulting in the identification of cognitive states, which affect the performance aspects. In such a way the ambient agent model is able to provide a more in depth cognitive analysis of causes of (un)satisfactory performance and based on this analysis to generate interventions in a knowledgeable manner. The multi-agents architecture and ontology defined permits real time process of environment and user data collected through non invasive market sensors, installed in the home, to allow early detection and notification of potentially dangerous situation like the older fall episode.

As computers become ubiquitous, settings in which they make decisions with people over time are becoming increasingly prevalent. Many of these settings require computer agents to generate advice to their human users about which decisions to take in a way that guides their behaviour. Such settings arise in a variety of application domains such as hospital care-delivery systems, negotiation training or route-navigation systems. Although computers and people in these domains share some goals, such as completing the use's tasks, their goals may also conflict. An intelligent agents reasoning platform to support smart home telecare presented in [116] offers advice provision strategies for computer agents that interact with people in repeated settings. The model of these interactions are defined as a family of repeated games of incomplete information called choice selection processes comprising a human and computer player. Both of the participants in a choice selection process are self-interested.

5.2. Context Modelling and Context Awareness

Context awareness (i.e. heart rate monitoring, medication prompting, generation of agenda reminders,temperature changing, weather alerts, emergency notifications, human emotions etc.) is a significant feature in smart environments designed for helping old people living alone and independently in their homes. Activity monitoring and recognition may be useful in generating health or emergency alerts in both short and long term, possibly requiring immediate intervention, performing fluid interaction, and providing associated actions or services with regard to the dwellers behaviours etc. This is very meaningful for helping people with cognitive and mobility impairments to promote Active Ageing activities related to communication, stimulation and environmental control [116]. In order to achieve this, a system must have a thorough knowledge of environments- we may say “ understanding ” of the environments, devices and people exist in it; “knowing” of the interests of user, the capabilities system, the events happening, the tasks and activities are being undertaken etc. [117].

The issues context awareness include [118]:

- How to acquire, categorize and model contextual information;
- how to exploit contexts to answer a user’s data request;
- how to effectively communicate answers to the users on small hand-held devices;
- context-aware query language for users;
- what context-aware strategies are needed, both for finding useful answers to queries and for presenting the answers to the users.

To understand the behaviour of human in AAL environment, activity monitoring and recognition problems have to be considered, which uses data collected from environmental sensors installed in the home and wearable biomedical sensors to build a profile of the dweller’s typical pattern of living and health status, such as when s person gets up and goes to bed, level and location of movement, etc. Any variation from the typical pattern of activity may be a source of concern, for example a reduced level of activity during the day may be indicative of a decline in health status. Activity recognition algorithms can be divided in three categories: machine learning techniques [119, 120], grammar based techniques [121] and ontological reasoning [122]. Many types of machine algorithms for activity recognition were developed, including Hidden Markov Models, Bayesian Networks or Support Vector Machine techniques [123, 124]. Among them Hidden Markov Models and Bayesian Networks are the most commonly used methods in activity recognition. Standard Hidden Markov Models (HMM) are employed for simple activity recognition [125, 126, 127]. Moreover, Hybrid model of Bayesian networks and support vector machines is used for more accurate and faster activity recognition [128].

To express real world states is related with information expression and knowledge expression. Bikakis [129] and Hiristova [130] presented various solutions that have been proposed to represent context for AAL environment by invoking semantics-based approaches. By semantic approach, we mean ontology language and model which is widely used for the representation of context. An ontology is understood as a formal, explicit specification of a common conceptualization. The use of ontology languages is becoming common in AAL applications mainly because they offer enough representational capabilities to develop a formal context model that can be shared, reused, extended for the needs of specific domains, but also combined with data originating from other sources. Moreover, most of them have relatively low computational complexity, allowing them to deal well with situations of rapidly changing context. These technologies simplify the reaction to various and rapidly changing needs of assisted living [131]. In accordance to the general understanding of information sciences, ontologies are composed of a vocabulary and the coherent explicit assumptions regarding the meaning of the vocabulary. For the description of the vocabulary, logic-based languages can be used with their most prominent representative, the Web Ontology Language (OWL).

In an ontology based information system, semantic-web based languages, like RDF (Resource Description Framework) and OWL (Web Ontology Language) are commonly employed to describe taxonomies and logic for context data. RDF is used to represent resources in the form of SubjectPredicateObject triples; RDF Schema (RDFS) created together with its formal semantic within RDF, is used to describe classes, properties and their relationships and we use them both to create a lightweight ontology. OWL is a language derived from description logic, and offers more constructs over RDFS. OWL is used to create a more expressive ontology [132, 133].

Ontologies are used to derive data structures, schemas and interfaces which provide access to the data saved in the format of a given schema. During the development of such an ontology the following characteristics have to be taken into account according to [134]:

- The ontology has to be designed in a formal way so that it can be processed by machines.
- The ontology has to be reasonable for the task at hand. It should describe the problem domain reasonably well without containing too much information.
- The ontology represents the common understanding all of its users have about a problem domain.

Accordingly, ontology representation of context can be applied in various scenarios of AAL applications. [135] presents Ontology-based state representations of long-term activities of human for intention recognition in a smart environments. Blodow et. al. [136], Galindo [137] and Lorenz [138] proposed approach that use ontology based semantic mapping for robots performing everyday manipulation tasks in kitchen environments. The projects in [139, 140, 141] use ontology to produce semantic modelling of space which can enhance human-robot interaction and navigation. Ambient home care systems (AHCS) in [130] are specially design for healthcare which can collect heath status from ambient sensor and process the information with ontology. An ontology and rule based intelligent information system to detect and predict myocardial diseases is proposed by [142]. In [143], a formal representation of RAALI integration profiles is described by ontology based framework- AALOnto. Others instances of ontology-based context-awareness for AAL can seen in [144, 145, 146].

5.3. Reasoning and Planning

Reasoning and planning are intersective and conjunctive issues in the study of AAL system. The role of reasoning in context aware system is to deduce and derive from the basic context information (includes information unknown, ambiguous, imprecise, and erroneous) to generate meaningful information and support system decision making. Planning concerns the problem of how to achieve a goal state starting from a known initial state. To achieve a goal, the system needs to deduce the existing knowledge based on the available context data. A entire process of planing produces a sequence or partially ordered collection of actions that if executed starting from the initial state, is expected to achieve the goal state. There are several ways that planning can be used in AAL scenarios, for example in an AAL system, planning can be used to coordinate the capabilities of the available resources to provide a solution or perform a task; planning for AAL may have to deal with multiple agency; Planners can be used, for example, to schedule task for specific status. Research in the area of AI planning has made notable progress over the last decade. There are many state-of-art reasoning and planning algorithms have impacted different application areas for AAL according to the surveys by [147, 148, 149].

Temporal-logic based approach concerns contextual information over time [150]. Temporal plan is a sequence of actions over the events that maintained by temporal constraints. In such plan logical preconditions describe under which circumstances an event may occur, its effects (or postconditions) describe the changes to the current world state after its occurance [151, 152]. In [153], the authors present a remarkable paradigm of AAL system planning with temporal plan. They employ concepts drawn from constraint-based planning and execution frameworks in conjunction with efficient temporal reasoning techniques for human support. The planning framework uses a uniform formalism based on Allen's interval algebra to represent both the criteria for context recognition and a planning domain for AAL services. Ullberg [154] proposed a prototype of AAL system which utilises temporal constraints for continuous activity monitoring.

Case-based reasoning is capable of handling imperfect data and uncertain data as input for context aware. It is made and each new case is evaluated refer to previously acquired cases. In general, case-based reasoning is suitable for carrying out online analysis, as efficient algorithms are already available for this task [155]. this method has been employed as a method for identifying situations in a dynamic environment.

In [156], Case-based Reasoning and Case-based Planning is integrated as reasoning mechanisms into deliberative agents within a dynamic AAL environment. The AAL applications in [157, 158] also demonstrate the use of Case-based reasoning.

Rule-based Reasoning is a typical reasoning approach which provides a formal model for context reasoning. It gives no inherent support for reasoning of incomplete data or the handling of uncertain information (probabilistic information). Besides, rule-based reasoning is easy to understand and widespread used, and there are many systems that integrate them with the other model. Rule-based reasoning is well suited to online analysis and is also scalable to handle large amounts of data. However, it cannot handle the highly changeable, ambiguous and imperfect context information. In AAL application, rules are mainly used to represent policies, constraints and preferences etc. [159]. Bikakis et. al. [129] presented FOL rules to reason about context in To resolve possible conflicts, they have defined sets of rules on the classification and quality information of the context data. They suggest that different types of context have different levels of confidence and reliability. For example, defined context is more reliable compared to sensed and deduced context.

To reason and process the ontology based representation of contextual environment, semantic reasoning associated methods are required. Description-logic (DL)-based reasoning, Meta-logical (ML)- based reasoning is suitable for reasoning of OWL ontology [160, 161, 162]. Several semantic reasoning engines are develop to support the reason of ontology and among which Jena framework, Pellet, RacerPro [163, 164, 165] are primarily employed in the AAL community.

As many smart environment systems are agent-based, the reasoning and planing methods relevant to agent and multi-agent systems are considered to support AAL applications. BDI (Belief, Desire, Intention) is a essential reasoning model for multi-agent system. It is based on a philosophical model of human practical reasoning[166]. Beliefs are the information an agent has about its environment. Desires are goals assigned to the agent.Intentions are commitments by an agent to achieve particular goals. In other words, they are plans that are choices available to the agent at any moment of time to achieve its goals [167, 168].

Plans are central to BDI model of agency. For instance, [156] presents a deliberative architecture model where the agents' internal structure and capabilities are based on mental aptitudes, using beliefs, desires and intentions. In the system, Case-Based Reasoning systems is integrated within deliberative BDI agents, facilitates learning and adaptation, and provides a greater degree of autonomy than pure BDI architecture. In [169], a Context-Aware Multi-Agent Planning (CAMAP) framework is proposed for intelligent environments. CAMAP is applied to a real-world application of AAL in the field of health-care with BDI method. Game theory has strong relation to multi-agent systems. In game theory agents act to maximize what is called there the utility. The term utility is used in a very broad sense and refers to the amount of welfare an agent derives from an object or an event. Game theory can provide an explanatory account of strategic reasoning in AAL system [8].

Besides, other approaches such as Fuzzy-logic Based Reasoning, Evidential Reasoning, Dempster-Shafer theory, Finite State Machineor, Decision trees are commonly utilised in different level of AAL application. Since AAL systems are heterogeneous and distributed, these approaches are integrated and hierarchised in different components and scenarios [17].

6. Conclusion and Perspectives

In this work, we have explored many aspects of the research on AAL for older adults. The literatures and studies show the motivation and solutions of ALL to well-being of old adults and deal with the problems of ageing society. Cognitive aspects of AAL is essential to achieve the better facilitation to users. AAL technology covers a broad range of research from ambient intelligence, assistive robotics, sensor networks, wearable sensors, internet of things, big data etc. The emerging and tremendous progress of these technologies have made it possible to improve the older adults' daily life with AAL such as wearable devices, health monitors, smart walkers etc. However, there are still growing challenges that need to be addressed in the future.

Though the dramatic growth of IoT, wearable devices, cloud computing, advanced robotics, sensor networks etc. have made various kinds of products available for assistive living. There is seldom of integration of these services to unleash the full power of AAL for for healthcare, rehabilitation and assistive living. Integration of separate devices and services in larger systems can benefit from collecting and processing large volumes of data, evaluating more complex situations and scenarios, collaborative tasking, precise identification of potentially dangerous situations and finding solutions. The integration of AAL services relate to interoperability, dynamic configuration, communication, context awareness (cognitive architectures) security and privacy. A mixture of these would probably be required to achieve the following outcome.

- The new generation of sensors should provide robust, high-precision perception of context and components related to assistive living. Besides, mobile and wearable be more comfortable to wear and less obtrusive.
- Assistive devices and robots can be designed to enhance not only physical but also cognitive skills of human users through mobility experiences. They should be able to adapt to their gradual physical and cognitive decline, as well as to their sudden changes such as a hip fracture. Researchers and developers should pay attention to the combination of biological, physiological, medical aspects and robotics to develop intelligent cognitive robots for assistive service.
- Development of empirical models of social behaviour in a smart space, to enable context awareness of participants and environment.
- Proper framework for system coordination, components integration, service allocation, and knowledge sharing to support the operation of heterogeneous groups of AAL components.
- A set of global standards for a AAL service architecture enabling individual application development for a networked ecology of of sensors, robots, mobile devices and data resources etc.

On the other side there are still gaps and obstacles between innovative AAL systems and different aspects of participants within the system. In the future, more user studies should be performed regarding the acceptance of AAL services and devices by the users, usability as well as the users' expectations of such assistive services. It is also essential to bring together all the stakeholders and enable the very important networking between policy makers, developers, producers, service providers, end user organisations, designers, health professionals (medical doctors, psychologists, rehabilitation nurse etc.), sociologists, home carers, older adults and other potential end user groups.

In addition the technological aspect of AAL, security and privacy problems have to be concerned. Within a complex networked system, multitude of personal data will be collected. The future AAL systems should employ a variety of security methods based on biometric and physiological features to safeguard user privacy. Different levels of security should be granted to different users in such complex systems.

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