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Collaborative Smart Home Technologies for Senior Independent Living: A Review

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***Abstract*—This paper presents a review of the collaborative smart home technologies for senior independent living. It focuses on the major features that enable safe independent living for seniors. Based on the investigation of about 30 projects or systems in the area of Smart Homes for independent and assisted living, key research issues as well as underlying opportunities have been identified.**

Keywords-Smart Home, Elderly Care, Senior Independent Living, Collaborative Intelligence

I. INTRODUCTION

In most industrialized countries, demographic, structural, and social trends tend toward more and more elderly people living in single households, which have dramatic effects on public and private healthcare, emergency medical services, and the individuals themselves. For example, in Canada, the current percentage of the population over age 60 is 17 per cent; however, this is projected to increase to 28.5 per cent by the year 2031 [1]. Statistical data from the years 2000 to 2001 reveal the true impact of the aging population on the Canadian healthcare system. During this time period, the population over the age of 65 accounted for only 12.5 per cent of the overall population of Canada [2]. This 12.5 per cent of the population, however, accounted for 42.7 per cent of Canada's total healthcare expenditure [2].

For this aging population, remaining socially connected is important, and so is remaining at home. Most people with chronic conditions would prefer to be treated at home and to remain active and independent for as long as possible. In one recent study on "aging in place," nearly 90% of seniors who were not living in a nursing home or assisted living facility said that remaining in their home was very important to them.

New healthcare delivery methods will need to be adapted to meet the challenges posed by this aging population. It is generally expected that the use of technology will be required to create an efficient healthcare delivery system [3]. The "Aging at Home Strategy" announced in August 2007 by Ontario's Ministry of Health and Long-term Care marked potential solutions to this healthcare challenge [4]. The publicly managed, community based independent living services for the elderly that are provided outside the acute care hospitals or long-term care institutions is a trend all over the world so that the healthcare systems might be able to sustain in the future.

The promise is that collaborative smart home technologies will help detect signs of illness before it becomes serious, support everyday tasks, and allow continuous monitoring of a patient's condition by medical professionals while people age in the comfort of their own homes without sacrificing their health, safety, security, privacy, dignity, and freedom. The promises of a huge market, together with the challenging nature of the research area, have drawn the attention of many large research companies and universities. In this paper, we will present up-to-date findings resulting from research projects as well as commercially available solutions that help address the "quality of life" challenges facing the elderly people. The projects/systems will be addressed in the context of collaborative smart home technologies that make use of sensing and collaborative processing techniques to assist the senior households to achieve substantial standards for safety, wellness and social connectedness.

The paper is organized as follows: Section 2 presents an overview about the collaborative smart home technologies and their significance in senior independent living; Section 3 discusses major academic research projects; Section 4 reviews some major commercial projects/systems; and Section 5 draws conclusions and proposes research opportunities.

II. OVERVIEW OF SMART HOME TECHNOLOGIES

The Smart Home is most easily described as a collective term for information and communication technology in homes where components communicate through a local network [5]. The smart home technologies have been derived from the main concept of home automation, which makes use of: sensors to collect data regarding the state of the home environment and the activities of any living being inside; controllers to analyze collected data and decide on actions; actuators to produce actions, operate home devices, generate consumable services; and network communication systems to integrate devices, components and exchange information with external units/systems.

The term "Smart home" may also be referred to as other terms and forms such as: smart space, aware-house, changeable home, attentive house and collaborative ambient intelligence.

A. *Smart Home for Elderly People*

Smart homes can provide the elderly with many different types of emergency assistance systems, security features, fall prevention, automated timers, and alerts. These systems allow the individual to feel secure in their homes knowing that help is only minutes away. Moreover, smart home systems will make it possible for family members to monitor their loved ones from anywhere with an internet connection [6]. Typically, a smart home for the elderly or disabled has the capabilities of:

1) monitoring the activities of the householder and the living environment to ensure the safety of residents,
2) detecting the physiological and mental condition of the householder in order to maintain the health and wellness in addition to safety,
3) automating tasks that a householder is unable to perform,
4) alerting the householder of potentially dangerous activities and preventing such dangerous activities,
5) alerting informal caregivers (family members), formal caregivers (nurses, doctors or superintendants) or first responders if the householder is in difficulties (through a linkage with a local community service scheme),
6) facilitating in the rehabilitation of householders (by using auditory and visual prompts), and
7) linking them to their families and communities through audio-visual units (speakers, monitors, display devices, TV, etc.) .

B. *Technical Overview of Smart Home Technologies*

Various projects, laboratories and industrial showcases regarding smart homes are all over the world; while some might be more advanced than others, they share many similarities. Depending on the research groups, the objectives of smart home projects can vary from proving specific technological innovations, gathering usability information, validating testing results, to demonstrating the latest commercial technologies.

In terms of the quality of life, most of the available smart home technologies can be classified into the following three main clusters:

1) Safety Enhancing Systems
   - Technologies that enable independent living, including fall detectors, personal emergency response systems (PERS) and medication management systems
   - Technologies that enable and facilitate the dispatch and delivery of services to individuals in their living setting
   - Technologies that make living environments safer

2) Health and Wellness Monitoring
   - Technologies to manage chronic diseases like cardiovascular disease, asthma, diabetes, COPD, and dementia
   - Technologies for medication management, secondary prevention, and “active” tele-health technologies that allow live interaction with the patient through conversations
   - Comprehensive and consumer-friendly Personal Health Records (PHRs) to manage care delivery across different sectors
   - Connecting and integrating different technologies through enhanced interconnectivity and the ability to exchange information between different information systems
   - The health and well-being technologies that foster a consumer-centered market

3) Social Connectedness Systems
   - Technologies helping seniors seek opportunities for social connectedness, to expand their social network
   - Measuring social interactions, through sensor and other technologies, and providing feedback may give seniors an opportunity to identify social efficiencies and take more control of their lives

III. SMART HOME PROJECTS IN ACADEMIA

A. WellAWARE

WellAware is an initiative founded in 2000 by biomedical engineers and software developers at the Medical Automation Research Center at the University of Virginia [7]. After the initial prototype designs were developed, joint research and development studies were conducted with The Volunteers of America and The Evangelical Lutheran Good Samaritan Society, two of the largest not-for-profit service providers in the United States for senior care. WellAWARE™ provides an integrated system incorporating unobtrusive sensors and a software framework, enabling professional caregivers and family members to monitor and deliver better care to the elderly household users.

The system uses a number of battery operated proximity and motion sensors operating on the Zigbee wireless protocol, deployed at several fixed objects in the house (furniture, walls, doors etc.). Major components of WellAware include a system of sensors that tracks the household movements throughout their residence; a wireless data networking infrastructure; and central control unit and management software with graphical user interfaces for comparing the activities of the elderly household to a baseline of normality, interpreting the trend analysis and alerting caregivers to changes.

A role-based web site access is provided to the caregivers, who constantly monitor the developing conditions and apply earlier intervention for more serious chronic or acute health issues.

B. AlarmNET

AlarmNet is a wireless sensor-based smart home initiative that has been developed in the University of Virginia with the goal of healthcare at home, residential monitoring and independent living [8]. The system is intended to satisfy these objectives by unifying and accommodating heterogeneous devices in a common architecture (Fig. 1) that spans wearable body networks, emplaced wireless sensors, user interfaces, "AlarmGate" gateways and back-end database and analysis programs.

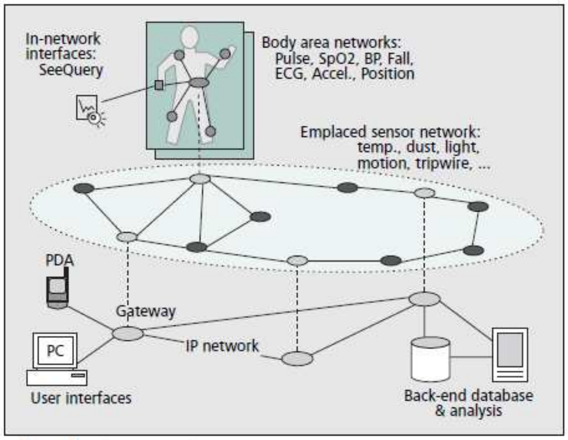

Figure 1: ALARMNET Architecture. [8]

Sensors and devices were deployed in a smart house setting. Some elements of the network are mobile, while others are stationary; some use line power, but others depend on batteries.

Mobile body networks are wireless sensor devices worn by residents that provide activity pattern classification or physiological sensing, such as an ECG, pulse oximeter, blood pressure, weight or accelerometers.

Data is collected, aggregated, pre-processed, stored, and acted upon, according to the needs and condition of the residents. The network can be tailored to the patient's own medical needs, and can provide notifications (e.g., alerts to take medicine) using an in-network wearable interface.

Emplaced sensors are deployed in the living spaces to sense environmental quality, such as temperature, dust, and light, or the residents' activities; for example, sensors on the ground that monitors footstep patterns for signs of increased fall risk and a bed sensor that monitors the heart rate, the breathing rate and four levels of movement.

The AlarmNet system is reported to support dynamically appending new devices to the network, which register their capabilities and then are initialized. This flexibility allows the system to change over time as sensors are developed or new pathologies require monitoring [9].

C. GatorTech Smart House

The Gator-Tech Smart House is an initiative developed by the Mobile and Pervasive Computing Laboratory at the University of Florida [10]. The Smart Home is a programmable pervasive space designed to assist the elderly in their daily lives to make them more comfortable and secure.

The GatorTech is based on a number of features such as: smart floors for location tracking; smart plugs with RFID readers to detect connected appliances; smart microwave ovens to detect what food is being cooked; and the plug-and-play of sensors and actuators in the sensor platform.

The overall system runs a generic Smart Space middleware built around the OSGi platform that stores service definitions for all hardware (sensors and actuators) inside the home, in essence turning the Smart Home into both a software library and a runtime environment. The Middleware implements generic reference architecture of seven layers [11].

D. Georgia Tech Aware Home

The Georgia Tech Aware Home is a complete house built by the Georgia Institute of Technology in Atlanta, GA under the Aware Home Research Initiative [12]. The Aware Home adopts a number of innovative designs on enhancing the social connectedness of the seniors with the outside world. The significant technologies developed are: the "Digital Family Box", "Cook's Collage", "Gesture Pendant" and the "Context-Aware Universal Remote". A number of multimedia technologies have been utilized to enhance the communication of the elderly residents with their families.

In addition, indoor location tracking services were developed which range from relatively simple and robust low-resolution strategies, such as RFID, to more sophisticated and higher resolution, state-of-the-art computer vision solutions. Except for engineering sensing systems to detect specific events (e.g. a fall), the research group has developed activity recognition methods to monitor the general activities of the occupants such as reading a newspaper, watching TV, preparing a meal, or using a blood glucose monitor.

E. Assisted Living Project (I-Living)

I-Living^{TM}, the Assisted-living project has been developed by the University of Illinois at Urbana-Champaign, IL [13]. The project's aim is to design, implement, and evaluate (i) an assisted-living supportive software infrastructure that allows disparate technologies, software components, and wireless devices of different protocol families to work together in a low cost, dependable, and secure fashion with predictable properties; (ii) an interface that abstracts from the software infrastructure and provides various services to assist elderly people with their independent and/or assisted living.

Already available component technologies in sensing (e.g., Ubisense/RFID techniques for tracking, presence identification, and localization), computing, and wireless networking (e.g., Bluetooth/IEEE 802.11 enabled devices and infrared-equipped remote controls), have been utilized for realizing an open environment. Open system architecture was developed for the assisted living project as detailed in [14].

F. Assisted Cognition Environment

The Assisted Cognition project [15] was developed by the University of Washington which specializes in exploring the use of Artificial Intelligence systems to support and enhance the independence and quality of life of people suffering from Alzheimer's Disease and similar cognitive disorders. The system involves the abilities to sense location and the surrounding environment, interpret behavioral patterns, offer help via verbal and physical interventions and alert caregivers during emergencies. Two concrete examples of the Assisted Cognition systems are: an *Activity Compass* that helps reduce spatial disorientation both inside and outside the home, and an *Adaptive Prompter* that helps patients carry out multi-step everyday tasks [15].

G. CodeBlue – Wireless Sensors for Medical Care

The CodeBlue project [16], carried out by Harvard University researchers, explores applications of wireless sensor network technology to a range of medical applications, including pre-hospital and in-hospital emergency care, disaster response, and stroke patient rehabilitation. A WSN consists of small, battery-powered "motes" with limited computation and radio communication capabilities. WSN technology has the potential to allow for vital medical signs being automatically collected, relayed, processed and fully integrated into the patient pre-hospital care record system. A wide range of wireless medical sensors (e.g. pulse oximeter, two-lead EKG, accelerometer, gyroscope, and EMG sensor), were developed based on the popular TinyOS operating platform [17].

The integrated Harvard "Pluto" Mote (as in Fig. 2) is designed to be small and wearable. A scalable software infrastructure (as in Fig. 3) for wireless medical devices was designed to provide routing, naming, discovery, and security for wireless medical sensors, PDAs, PCs, and other devices that may be used to monitor and treat patients in a range of medical settings.

The Harvard "Pluto" mote, designed to be small and wearable. *Pluto mote with case and wriststrap.* *Pluto mote in case.*

Figure 2. The Harvard "Pluto" mote.

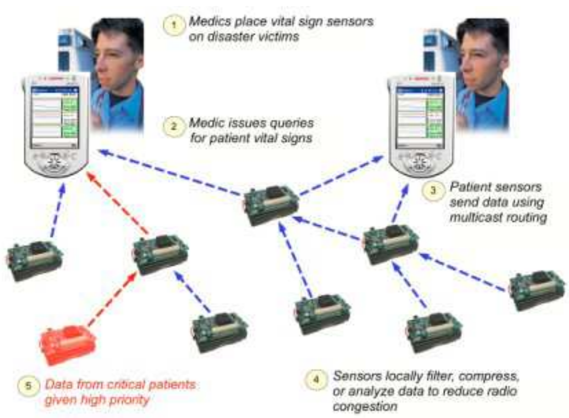

Figure 3. CodeBlue software architecture for emergency response.

H. ORCATECH

ORCATECH is an initiative by the Oregon Health and Science University [18]. It is also known as the Oregon Center for Aging & Technology.

The project is dedicated to the development of key independent living technologies with a wide variety of studies for health and elderly home care. Some significant technology studies related to senior independent living are as follows:

- Intelligent bed that tracks sleeping patterns; preventing falls by turning on lights when getting up
- Enabling the use of home-based technology for independent living
- Home monitoring and cognition of Congestive Heart Failure (CHF)
- Monitoring the seniors outside the home
- Remote controlled tele-presence in seniors' homes
- Monitoring and information needs of the elderly
- Technologies for monitoring health in the home
- Social health monitoring and support

I. MIT House_n Project

House_n Project research at the Massachusetts Institute of Technology is focused on how the design of the home and its related technologies, products, and services should evolve to better serve future living for all ages, for example proactive healthcare, biometric monitoring, activities of daily living, indoor air quality, new construction solutions, privacy and trust [19].

A living laboratory facility called PlaceLab, has been constructed near MIT in order to facilitate experiments related to the project. The PlaceLab is a 93 square meters single-bedroom condominium, equipped with hundreds of sensors that can be used to develop innovative user interface applications that help people easily control their environment, save resources, remain mentally and physically active, and stay healthy. The sensors are also being used to monitor activity in the environment so that researchers can carefully study how people react to new devices, systems, and architectural design strategies in the complex context.

Sensors are embedded in various locations in the lab. For example: cabinets in the lab contain sensor modules for measuring environmental quantities, infrared transmitters and microphones. Video cameras and biometric sensors capture data about the users and their movements. Data visualization and user interfacing to the system has been established through PDAs.

J. Smart Medical Home

Designed as a "living laboratory," the "Smart Medical Home" is a cross-disciplinary research effort at the University of Rochester to develop interactive technology for home healthcare [20]. The home-like setting is packed with technology designed to improve early detection and prevention of health and medical problems.

An interactive medical advising system called "Chester the Pill" is one of the live systems demonstrated in the Smart Medical Home. Using advanced artificial intelligence and speech-recognition software (combined with detailed medical data), the interactive medical advising system is designed to converse with residents in real time to deduce possible illness by listening to questions and statements. The system also dispenses information about medications, side effects, and other health issues and assists patients to understand the physician's instructions.

K. MavHome

The MavHome is a smart home project at the University of Texas at Arlington [21]. The name of MavHome comes from "Managing and Adaptive Versatile Home", and the focus is to maximize the comfort of its users and minimize operating costs. In order to achieve this, the house must recognize and predict the actions of its users and adapt to their routines. For this purpose MavHome uses several prediction algorithms.

The MavHome attempts to view the smart home as an intelligent agent that uses sensors and actuators to achieve its purposes. The agent architecture consists of four layers: a decision layer, for executing actions based on information obtained from other layers; an information layer that gathers, generates and saves information that could be beneficial later; a communication layer that manages information exchange between layers; and a physical layer, which consists of physical devices in the smart home space.

L. TAFETA Project

The TAFETA project (Technology Assisted Friendly Environment for the Third Age) has been developed by the Department of Systems and Computer Engineering, Carleton University, Canada [22].

The primary technology laboratory (testing facility), called The TAFETA Smart Apartment at the Elisabeth Bruyère Health Centre, was built in 2002 and was equipped with various sensors and actuators to detect and control the environment such as: magnetic switches, smart thermostats, accelerometers, RFID tags, infrared motion sensors, microphone arrays, smart grab bars, etc.

The TAFETA project uses pressure-sensitive mat technology, which uses sensors placed under a bed or seat to monitor movement activity in the smart home. The mat technology can also be utilized for monitoring breathing rates and sleep quality.

The electronic nose, or "e-nose", is another significant feature of the project. The e-nose is a wireless sensor placed in the apartment to identify food spoilage and provide warnings of potential health issues based on the home occupant's status.

M. Gerontological Smart Home Environment

The Gerontological Smart Home Environment (GERHOME, Fig. 4) project has been started by a network of research partners, led by the CTSB (Centre Scientifique et Technique du Bâtiment) Research Centre for Construction Techniques in France [23]. The overall system has been designed to enhance the independence of the people with a loss of autonomy or at risk.

GERHOME utilizes software solutions for automatic recognition and interpretation of human behaviors using real-time video images and real-time sensor data. The research initiative aims to design a communication platform, allowing the easy integration of sensors of various natures, coupled or not with existing equipment, within a total system, based on the existing standards, and on a software architecture utilizing intelligent agents.

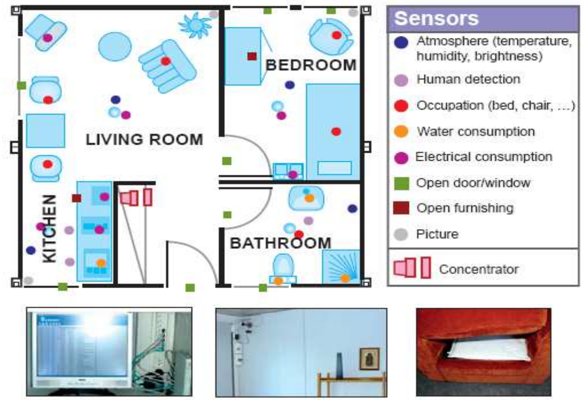

Figure 4. GERHOME Layout. [23]

GERHOME involves wired and wireless sensors embedded in furniture and appliances to collect data regarding the activities of the elderly (detection of illnesses or symptomatic behaviors, monitoring the drug use, etc) and the characteristics of the home environment (temperature, lighting, etc.). The collected data are then analyzed in a learning procedure in order to identify and describe the daily tasks of an elderly person at home, to detect any unusual behavior or changing trends in behavior, and to predict a decline in the person's physical or mental condition.

N. BioMOBIUS Research Platform

The BioMOBIUS has been developed by the Technology Research for Independent Living at University College Dublin, Ireland [24]. The project is an Open, Shareable Software and Hardware System that supports the rapid creation of technology solutions for biomedical research. The BioMOBIUS research platform is built on the EyesWeb XMI software platform, an open software platform developed by InfoMus Lab at the University of Genoa for research on multi-modal interfaces, non-verbal expressive gestures and movement analysis and recognition.

The BioMOBIUS platform includes hardware-based sensing capabilities which monitor particular physiological parameters, physical characteristics or personal behaviors, examples of which include gait stability, blood pressure, alertness or social activity. Collected data is then processed using a variety of in-built techniques which convert the sensor data into meaningful information for the clinician or therapist. The system supports a variety of hardware, via wired and wireless interfaces. Default blocks are supplied to support a wide range of generic hardware devices (e.g., TCP/IP, Serial, and WDM camera devices).

O. Casattenta Project Intelligent House

The Casattenta project was initiated by the Laboratory for ICT Technology Transfer in Bologna, Italy to demonstrate a research project on Ambient Intelligence, Sensor Fusion and Wireless Sensor Networks. The system is composed of fixed smart sensors distributed in the living environment and wearable sensor nodes monitoring the inhabitants' health and activity, providing elderly people living alone in their house with adequate and non-intrusive monitoring in order to improve the quality of life [25].

The interaction between fixed and mobile sensor nodes, based on the ZigBee wireless protocol, allows for the tracking and recognition of critical events (e.g., falls, immobility).

P. SISARL - Taiwan

The SISARL (Sensor Information Systems/Services for Active Retirees and Assisted Living has been developed by three collaborating institutions in Taiwan: National Taiwan University, National Tsing-Hua University, and National Chao-Tung University [26]. The initiative refers broadly to consumer electronic and assistive appliances, as well as services, designed to enrich the quality of life of the elderly and to help them live actively and independently. The project involves several applications such as: *object locators* that help us to find household and personal items; *medicine dispensers* that help to ensure correctness and enforce compliance of medication schedules; *monitoring systems* that record and process vital sign signals, detect irregularities of the elderly, and send appropriate notifications; and *robotic helpers* that enhance dexterity and accessibility and minimize the effects of functional limitations. Several off-the-shelf technologies have been adopted; for example RFID tags, interrogators (smart phone or PDA), agents (RFID reader or transponder) and Wireless Sensor Networks.

IV. SMART HOME PROJECTS IN INDUSTRY

A. IST Vivago® WristCare

The VTT Technical Research Centre of Finland has been working on the Pervasive Health Technologies Research for healthcare and independent living since 1993. The research centre focuses the application of pervasive computing technologies for healthcare, and wellness management on two main themes: (i) technologies for healthcare professionals in the hospitals; (ii) technologies for individuals outside the hospitals such as personal wellness and disease management (e.g. diabetes, fitness) and independent living.

The WristCare system developed by the Finnish company IST International Security Technology is the first security device, which monitors the bearer’s well being 24 hours a day [27]. It is a wrist-worn smart security device with basic functionality of a panic alarm system. The wrist continuously measures physiological signals: movements, body temperature, pulses, and skin conductivity. The system facilitates automatic alarms for immobility or exceptionally low or high activity and allows unobtrusive monitoring of the activity for an extremely long-term. ZigBee based Wireless RF communication has been used in the range of 30-60 meters with a battery life of around 6 months [28].

There are two target user groups that Vivago solutions aim for: elderly persons living at home and institutional users in hospitals or healthcare institutions. The home system model of Vivago is shown in Fig. 5.

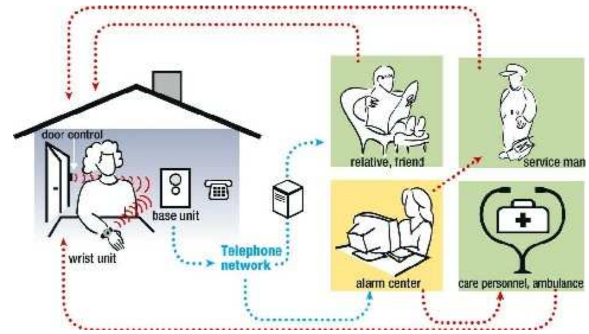

Figure 5. VIVAGO Home System. [27]

B. Intel Proactive Health Lab

Intel established their Proactive Health Lab in 2002, to explore ubiquitous computing technologies that will help people to proactively manage their health and wellness in their home and daily lives, to prevent or delay the onset of disease. In particular, the researchers focused on technologies that will help tomorrow's elderly population to age “in place” at wherever they and their families choose [29].

The Digital Home Technology is the core to achieve Intel’s ageing in place strategy, which involves multitudes of consumer electronics (e.g. TV, clock, telephone, PC, PDA) to link together in a wireless sensor network. Prototypes of smart homes were built and equipped with a network of sensors (e.g. motion sensors, RFID, motes) that track and monitor everything from cooking habits to purchasing activities to the level and quality of physical movement. By monitoring changes in activity patterns or levels, it is possible to detect the early onset of dementia or provide appropriate levels of assistance to support and enhance people's abilities to conduct normal daily activities. Ambient displays are provided for distance family members and healthcare professionals to check the condition of the patient.

Typical examples of applications of Intel Health products are: 1) Analyzing sensor data to determine if medication is taken delivers timely reminders via cell phone, TV or any preferred device. 2) Wearable wireless sensor networks to detect falls.

C. Shimmer Platform

Shimmer (Sensing Health with Intelligence, Modularity, Mobility, and Experimental Reusability; is a small wireless sensor platform that can record and transmit physiological and kinematic data in real-time. Originally designed by Intel, Shimmer Research has commercially marketed the Shimmer platform since 2008 and the platform has been utilized in different areas of research such as assisted living, gait analysis, Parkinson’s, and epilepsy in world class research institutes such as Harvard and TRIL [30].

Based on an open, flexible architecture, Shimmer incorporates wireless, tiny and wearable ECG, EMG, GSR, Accelerometer, Gyro, PIR, Tilt and Vibration sensors. Each device in the ad hoc network collects data, relays the collected data to its neighboring devices and then to a specified destination where it is processed. This sensory input, when gathered from all the locations and analyzed by more traditional computers, paints a comprehensive, high-resolution picture of the surroundings in real time.

The sensor platform overcomes issues of size, weight, and low power-based communication capabilities which, to date, have constrained wireless sensing technologies. Shimmer provides an extremely extensible platform which enables researchers to move past any hardware challenges and allows them to focus on higher value added research into the analysis and interpretation of the actual data that can be attained.

D. ExperienceLab - Philips

Philips research group in Eindhoven, Netherlands, has built a research lab for testing Ambient Intelligence solutions [31]. The HomeLab facility built in 2002 is a fully equipped home, used for testing prototypes in a realistic scenario with the latest technologies. The lab facilities of Philips are now called ExperienceLab.

The laboratory features speech recognition and user positioning along with several screens for displaying information in order to study how users deal with new technologies in a home setting. Microphones and cameras are mounted in every room. Tests were conducted with family members, who were able to share digital media and discover new ways of interaction. Equipment can be controlled in new ways using gestures and speech commands leaving the user free for other activities at the same time.

E. Philips Lifeline

As part of Philips Independent Living solutions, Philips lifeline medical Alert services provide a simple and reliable one-button triggered a bi-directional hand free communication channel to a group of well-trained Response Centre Associates who will promptly arrange for assistance and follow up to ensure proper care to Lifeline subscribers. Lifeline program is available in various countries [32]. An AutoAlert option was recently added into the Lifeline product so that its embedded fall detection unit can automatically send a help signal when a person is unable to push the help button in case of an emergency.

F. HomMed

The Honeywell HomMed is a health monitoring framework that is designed to assess people's health, in the environments where they live and work [33].The system uses a set of software interfaces supported by a real-time health data collection suite. The main products in the system are as follows;

Genesis ™ DM Remote Patient Care Monitor: a Web-based monitor, which provides web-enabled, on-demand access to disease-specific symptom management (DSSM), customizable by diagnosis and symptoms. Various peripherals can be accommodated (plug-and-play) to measure the patient's vital signs.

LifeStream View gives physicians, clinicians, patients and family members, remote access to patient health information from PCs and handheld devices.

TeleHealth peripheral devices to measure the physical health related parameters of the patients such as weight, temperature, heart rate, oxygen saturation, blood pressure, blood glucose level, ECG, spO..

G. Personal Care Connect solution (PCC)

Healthcare is one of the case studies chosen by IBM to show the architecture of an "enterprise strength" pervasive computing. A vision of "Smart Hospitals" is plotted in detail in [34], and a conceptual architecture for enterprise pervasive computing is proposed based on IBM's up-to-date, web-based, multi-tier application and development environment.

The PCC is a standards-based open infrastructure platform for remote monitoring headquartered by IBM. PCC consists of a data collection component designed to capture biomedical information at the point of generation (typically, in the patient's home); a server that normalizes and stores the data collected; and an application programming interface that presents the normalized data.

The significant technology provided is an in-home hub that links medical devices to the PCC server. Bluetooth-empowered cell phones have been typically employed to act as these hubs. IBM's PCC solution is featured with an open-system application programming interface which allows a broad variety of biomedical device vendors and healthcare application vendors to integrate their technologies into the PCC system platform.

H. Home Assurance

The Home Assurance project is run by General Electric. The aim of the project is to provide an unobtrusive "watchdog" in a home that will automatically identify and alert caregivers to irregular behavior of the person living in the home [35]. Wireless security sensors placed strategically in a home electronically capture and report routine movements and activities - the opening and closing of doors and motion through rooms like bedrooms and kitchens. Sophisticated algorithms organize that data into models of "normal" routines for that specific household. Current activity is constantly compared to the normal model.

The system generates summary reports of activities that a caregiver can monitor via the Web, and can also alert them via phone, e-mail or pager that something out of the ordinary has occurred. Long-term trends can be viewed to see if the behavior is changing over a period of time that would indicate a higher level of care is needed.

V. Conclusions

The increased interest in sensing and ubiquitous computing can adapt to a wide spectrum of novel easy-to-use technologies. Smart devices, medical sensors, actuators and other technologies that are made to be proactive for elderly people have become much more readily available and affordable. With the recent developments in Smart Home technologies, it becomes possible to observe and deliver care or ensure the safety and wellness of the elderly living in their own homes. This paper presents an overview of the available Smart Home projects and systems, from both academia and commercial perspectives, focusing on the major features that enable safe independent living for the seniors.

Based on our investigation on about 30 projects in the area of Smart Home for independent and/or assisted living, the following key issues and underlying opportunities have been identified:

- Affordability with low cost technologies.
- Usability of advanced technologies for a broad spectrum of users with varied levels of capabilities, competence and comfort with the technologies.
- Feasible business models for quick and wide deployments.
- Re-configurability and plug-&-play functionality of the commercial smart home hardware and software technologies.
- Fully automated, robust and wearable sensors / devices in term of a body area network system for long-term monitoring of human health condition, location, and position.
- Information, security and privacy issues.

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