

# **A Survey for Chronic Diseases Management and the Related Sensors in the Ambient Assisted Living Environment**

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## **Abstract**

The technological advances which achieved during the last decades concluded to the development of a great variety of sensors applicable in the prevention, early diagnosis and management of chronic diseases. The majority of these sensors is used for remote monitoring, limiting hospitalization, aiming thus in hospitals decongestion as well as in more efficient clinical care. This paper attempts to comprehensively review the current state of the art on sensors contributing to the management of the most common chronic diseases (eg. Diabetes, Hypertension, Heart Failure, Pulmonary Diseases, Alzheimer, Parkinson's etc) in the environment of Ambient Assisted Living (AAL). The objective of this survey is to serve as a reference in order to provide guidelines for future research in sensors targeting chronic diseases management.

**Keywords:** ambient assisted living, bio-sensors, chronic diseases, comorbidities, heart failure, chronic obstructive pulmonary disease, asthma, diabetes, hypertension, alzheimer's disease, parkinson's disease

## **1 Introduction**

According World Health Organization, "Chronic diseases are diseases of long duration and generally slow progression. Chronic diseases, such as heart disease, stroke, chronic respiratory diseases and diabetes, are by far the leading cause of mortality in the world,

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representing 63% of all deaths. Out of the 36 million people who died from chronic disease in 2008, nine million were under 60 and ninety per cent of these premature deaths occurred in low- and middle-income countries”[1].

Also, according to “Estimates for Life Expectancy map” of CIA [2], the life expectancy is expected to be increased in the near future. Considering that this trend will be accompanied by a rapid growth in the number of people with physical/age related disabilities, the problem of care and assistance to these persons will become crucial both from a social and economic point of view [3]. These societal trends will bring some dramatic challenges for health and social care systems as well as open up of new opportunities for innovation for technology providers in the field of innovative Information and Communication Technologies (ICT) – Ambient Assisted Living (AAL) [4]. AAL refers to intelligent systems of assistance offering a better, healthier and safer life to patients in their preferred living environment. It also covers concepts, products and services that improve new technologies and the social environment. Identifying the needs of the elderly regardless of category (healthy, chronically ill, or dementia) they can be trained to live independently in their environment as long as possible.

Terms like “telehealth”, “telecare”, “telemedicine” and “e-health”, presuppose the existence of set of sensors. Sensors therefore are inextricably linked with the remote management of chronic diseases.

This paper presents a literature survey of the state-of-art on sensors applicable to chronic diseases management aiming the provision of a high-level view that may help and provide guidance to future developments in this field.

## **2 Chronic Diseases**

### **2.1 Chronic Diseases Overview**

Chronic conditions may cause morbidity and mortality. Such are, the cardiovascular diseases (CVDs - coronary heart disease, stroke and other cerebrovascular diseases) [5-6], respiratory system diseases (trachea/ bronchus/lung cancers, lower respiratory infections, chronic obstructive pulmonary disease, asthma, bronchiectasis, obstructive sleep apnea syndrome, pulmonary hypertension) [7-8] and arterial hypertension, which considered as the most common medical condition encounter in all medical practices among the elderly people as well as one of the major cardiovascular disease risk factor [9]. Another important chronic disease is Diabetes Mellitus for which World Health Organization (WHO) estimates that more than 180 million people worldwide suffer from it and that this number is likely to more than double by 2030 [10].

The extensive number of people suffering from Alzheimer Disease (AD) 26.6 million Worldwide as well as the increasingly rate of elderly people and consequently the estimated number of people that is expected to suffer from AD is estimated to be 40 million by 2020 and 80 million (or 1 in 85 people) by 2050 [11]. The enormous amount of money that is needed from the community to provide services to people suffering from this disease (average cost for the illness from the diagnosis to death which is 174,000\$) and its obvious impact to the national economies and social security systems [12].

## **2.2 Comorbidities**

The impact of comorbidity on use of services is poorly understood. One study of Medicare beneficiaries found a relationship between the number of comorbid chronic conditions and total costs of care, frequency of ambulatory-care-sensitive hospitalizations, and the occurrence of complications of care [13]. Another study found the salience of primary care services in the presence of several diagnoses both in children and adults by showing that the average number of primary care visits was greater than the number of visits to specialists, for the diagnosis itself as well as for comorbid conditions [14].

In the absence of any system to assign a main diagnosis to patients for a period of time, a more appropriate designation would be comorbidity [15-16] which is characteristic of elderly patients.

After a 14 years of longitudinal population study, Caughley and his colleagues [17], found a high prevalence of comorbidity, with almost two-thirds of the population of older people reporting two or more chronic diseases. The age of respondents was similar between the groups with differing numbers of chronic diseases, with the average age ranging from 77.9 to 78.6 years old. Similarly, the Mutasingwa's et al. study [18], presents the comorbidities addressed in a study of chronic diseases. According to this study Congestive Heart Failure, for example, often comes with Hypotension, myocardial infarction, hypertension, atrial fibrillation, diabetes, dementia, cognitive impairment, depression or the Chronic Obstructive Pulmonary Disease usually followed by Ischemic heart disease, osteopenia, osteoporosis, glaucoma, cachexia, malnutrition, cancer, peripheral muscle dysfunction, ventricular arrhythmias and so on.

Regarding comorbidities, a serious problem we have to tackle is that incidents of more than one chronic disease, happening at the same time for one patient are today insufficiently supported by the contemporary telemonitoring platforms. With rare exceptions, nowadays clinical practice guidelines focus on the management of a single disease, and do not address how to optimally integrate care for individuals whose multiple problems may make guideline-recommended management of any single disease impractical, irrelevant or even harmful. The root of this problem, however, is not narrowly confined to guideline development and application, but is inherent throughout the translational path from the generation of the evidences to the synthesis of the evidences upon which guidelines depend. It would be extremely useful if telemonitoring programs were developed with a view to cover combinations of diseases. An example of combinations could be diabetes with heart failure, or heart failure with chronic obstructive pulmonary disease (COPD) [19-20].

The continuously growing number of chronic diseases and specific issues such as comorbidities, leading to polypharmacy (multidrug) and reduction of quality of life level, due to the effects of the disease but also in an ever increasing cost of long term care and treatment (drug mainly) [21]. In addition, elderly people do not wish to remain dependent on family or other environment but to live independently. The need for as much as possible independent living and the chronic diseases are a challenge both for health systems and for caregivers of the individuals at home. Therefore actions to assist elderly people using technology are very important, both socially and economically [22].

Modern innovative technology and the application of Information and Communication Technologies (ICT) have the potential to contribute significantly to assisting and

monitoring elderly, aiming to create a comfortable, secure, independent environment that can prolong their active life.

### **2.3 Chronic Diseases Management**

The most common chronic cardiovascular disease is congestive heart failure. In 2015, according to the European Society of Cardiology (ESC), it is expected that 12 million Europeans will have a heart failure. Heart failure patients need tele-monitoring to adjust treatment with drugs or electrotherapy, to avoid hospitalization.

Tele-monitoring of patient status and self-management of chronic pathological conditions (e.g. COPD and chronic cardiovascular diseases) represents the most evident, short-term outcome of Research and Technology Development (RTD) in the domains of Ambient Assisted Healthcare, rehabilitation and long-term care [23 - 24]. Wearable sensors, advanced signal processing techniques and networking are technologies that can be applied to monitor the physiological parameters of people and control their health, but not in an invasive manner [25]. This information could be provided remotely to users, their families and clinicians in order to make known constantly the health condition of the subject, to make an exact diagnosis, to identify the correct therapies and to intervene at the right time [26].

The development of small and unobtrusive sensor systems is necessary, that can, for example, be embedded in clothes or are so small that they can be easily inserted under the skin on ambulatory medical care. Thanks to new low power wireless technologies, low bandwidth networks can be used for the exchange of data [27-29].

Context detection algorithms combined with fixed and wearable sensors can provide information that can trigger messages at an appropriate time, and a mobile device can allow a message to be presented at the appropriate place [30- 32]. For example a history of the user in terms of physical activity recorded on a mobile device should be developed to create personalized feedback based upon past experiences and current context [33-34].

## **3 Chronic Diseases Management Sensors**

### **3.1 Overview**

Current application demands and technological advancements have redefined the term sensor, especially in the case of AAL environments. Thus the term sensor in an AAL environment, usually implies a smart sensor, which integrates a form of intelligence and communication functionality provided by processing power and networking interfaces that are warped around the actual sensor.. Smart sensors are progressing, in terms of costs and functionalities, and they are expected to reach rates similar to those experienced by other integrated circuits, such as microprocessors, because they use much of the same technology and they would be required at similar quantities [35]. Given these trends, there is the emerging need to standards that would define flexible standard interface that would enable any smart sensor from any manufacturer to connect to a multi-node network of smart sensors [36]. The standard defines a Standard Transducer Interface Module (STIM) that includes the sensor interface, signal conditioning and conversion, calibration, linearization, and network communication. Practically, this standard enables plug and play functionality for smart sensors that connect to smart sensor networks. Some sensor

technologies are perceived as having limited future market potential despite having a high level of technological know-how; these include fiber-optic sensors, radio-frequency sensing, eddy current and ultrasound for use in manufacturing systems and nuclear based sensors.

Sensors for safety and security in the environments [37]: Sensors will be exploited in safety and security applications for detection, identification and authentication, secure transactions, storage and communications, anti-tampering, positioning and localizing, detection of abnormal behavior, detection of hidden dangerous objects/substances, for non-cooperative, mobile individual or target recognition, detection of ill and/or infectious people and warnings associated with real-time data transmission [38 – 39]. For these applications, technological challenges exist for Smart Cards, TPD devices, electronic tagging, component and equipment's, e.g. autonomous smart sensors/smart dust, imaging devices (IR, Ultra Sound,  $\mu$ Xray, THz), NRBC sensors, biosensors, biometric scanners and sensors as well as smart clothes [40-41].

Human activity sensors: In the field of human activity [42] and status recognition, there is a clear distinction between systems that use wearable and contactless sensors to sensors mounted in the AAL environment, eg. cameras, motion sensors. The development of wearable/contactless sensors is spreading more and more due to the technological improvements in terms of miniaturization and energy consumption [43]. These sensors are really useful in an AAL context, because they permit the daily continuous monitoring of various physiological and biomechanical parameters with low invasiveness and high comfort.

Sensor networks: In order to provide monitoring and support functionality (e.g. monitor pollutants), a variety of sensors will be deployed, often as part of a wireless network. This information can then be processed and supplied to policy makers and individuals to help them make more informed policy or travel decisions based on e.g. health risks. Sensors are available and in use, but tend to be expensive and deployed in low densities. Low cost “ubiquitous” sensors should be commonly adopted in three to five years. Wearable sensors, e.g. accelerometers and pedometers, are also available for pedestrians. New data processing and storage techniques are required. The size of sensors is decreasing, and their capabilities are increasing. It is possible that they could become nano-scale technologies, whilst the range and design of personal wearable devices will undoubtedly increase [44].

Low power and sustainable sensors: Sensing applications, above all for wireless sensor network, are often limited by the reliance on battery power. Since sensors are often very small and require little power, it is expected that in future they might include embedded functionalities to efficiently manage, save, harvest and transmit energy. In the last decade many efforts have been done to design low power technologies (e.g. very low power devices) and algorithms (e.g. sleep mode) to minimize energy consumption and make free-maintenance sensor units. In future sensing technologies might include the possibility to capture energy derived from external sources, such as vibration harvesting, solar cells, electromagnetic, inductive power and piezoelectric insole, and store it in micro batteries or capacitors [45].

Internet of Things is one of the major communication advances in recent years that links the internet with everyday sensors and working devices for an all-IP based architecture, linking physical and virtual objects through the exploitation of data capture and communication capabilities. The architecture will offer specific object-identification, sensor and connection capability as the basis for the development of independent

cooperative services and applications. A wireless sensor network (WSN) is used (6LoWPAN) to connect wireless clinical sensor (glucometer) to the AAL environment gateway. The device also includes an AAL environment gateway, Web portal, and the management desktop application.

Internet-connected sensors and actuators: Relatively recent advances in micro-electro mechanical systems (MEMS), in wireless communication and in digital electronics have allowed the development of low-power and low-cost sensors to communicate wirelessly within a limited range [46]. The integration of a large number of these kinds of sensor has led to the idea of developing large wireless sensor networks (WSN) able to monitor different parameters (including positions, temperature and humidity) [47]. These pervasive networks are able not only to sense important parameters of the environment but also to provide some actuators that can act based on the sensed data. The use of the Internet to supervise these networks, to gather data and to command some actuators inside the networks, greatly increases the impact and the utility that WSN can have in different applications, such as environmental monitoring, healthcare, home automation and commercial applications [48].

The sensors will be easily integrated into the networks. WSNs will become a very reliable and mature technology, popular and in widespread use in many everyday applications. For example, they will be widely used in the medical field to provide an interface for patients affected by some forms of handicap; they will be used to monitor physiological parameters. In the home-automation field, sensors will be deployed in different domestic devices such as refrigerators and central heating system, so as to provide interconnected services to the user which can interact with different devices from any location by means of the Internet [49].

The idea of inserting actuators in networks will be investigated further, considering as actuators robots that can move in the environment. Currently, robotics will probably be so mature as to be enabled to move in unstructured/partially structured environments integrated in a WSN [50]. The challenges that have to be faced are mainly issues involving the localization and navigation of the robots in an autonomous/semi-autonomous way. The robots will greatly enhance the effectiveness of WSNs because they will provide a double benefit to the networks: they will be movable sensors, enabling the network to investigate locations where no sensors are present and they will also act as movable actuators, being able to intervene in every location of the workspace. For example, robots could move to help people whenever WSN realizes they need it. In parallel to the use of moving actuators, the sensors will provide enhanced self-configuration capabilities, will present reduced dimensions/weight and will have extremely low power consumption [51].

The reduced dimensions of the sensors, the ease of their integration in the WSN and with the Internet will bring technology in every area of everyday life. WSNs will allow recognition of the user while he or she moves along roads, providing personalized services. Furthermore, sensors embedded in people's clothes will monitor the health status of the user, sending requests to an ambulance to collect the patient when some parameters vary from standard values. The large numbers of sensors immersed in the environment will provide real-time information on dangerous situations: the fast response that a human or robot could give based on this information would be essential in preventing disasters. For example, a fast intervention when a fire starts would solve the problem before it becomes out of control. Robots will be commonly present in roads and they will move around autonomously: a WSN will decide when and where the robots have to move to in

order to provide their services, considering both environmental parameters and information coming from people [52]. However, this immersion of human users into wireless networks will raise issues in terms of security and privacy. These issues have yet to be tackled and solved [53-54].

### **3.2 Heart Failure Sensors**

Despite advances in evaluation and management of heart failure, morbidity and mortality remain high, with rehospitalization rates of 20% at 1 month and nearly 50% at 6 months [55-58]. In addition, despite advances in the care of patients with heart failure, outcomes after hospitalization are not improving [59]. Certain multidisciplinary HF disease management programs have been successful at reducing all-cause hospitalization rates [60-61].

Hemodynamics is the most important parameter for heart failure management [62]. Approximately 90% of patients admitted to the hospital for heart failure have pulmonary congestion related to elevated left atrial filling pressure [63-65]. Cardiac cavities filling pressure is an index of hemodynamic status and therefore an index of heart failure management [66].

Specially designed implantable hemodynamic sensors and monitors that can measure such parameters as intracardiac pressures [67]. The RV pressure sensor system is similar to a pacemaker generator with a modified unipolar pacemaker lead (Chronicle, Medtronic, Minneapolis, Minnesota). Information includes continuous heart rate, body temperature, and hemodynamics such RV systolic and diastolic pressures and ePAD (RV pressure at maximal RV dP/dT), which correlates with pulmonary artery diastolic pressures and thus approximates left-sided filling pressures [68]. Evaluation of this device did not find a significant difference in HF events (e.g., hospitalizations, emergency or urgent care visits requiring intravenous therapy) between the intervention and control groups [69].

A device to directly measure left atrial pressure has also been developed (HeartPOD, St. Jude Medical, Minneapolis, Minnesota). This device has a sensor lead placed intra-atrially through a transeptal puncture, which is then linked to a coil antenna placed subpectorally [70]. Evaluation of this device found that those in the intervention group had a lower risk of acute decompensation or death.

A pulmonary artery sensor (CardioMEMS Heart Sensor, CardioMEMS, Inc., Atlanta, Georgia) has also been under development. Unlike the other models, it is a silicone, pressure-sensitive capacitor that is implanted in the pulmonary artery via right heart catheterization. It is powered externally by an antenna that is placed on the back or side of the patient when readings are conducted, and it provides accurate pulmonary artery pressure assessment when compared with both Swan-Ganz catheterization and echocardiography [71]. Advantages of this device over other implantable hemodynamic monitors include its straightforward implantation through right heart catheterization, wireless nature of the sensor, and absence of an implanted battery requiring subsequent change-out [72].

### **3.3 Pulmonary Diseases**

The sensors for the management of chronic obstructive pulmonary disease (COPD) and asthma will be mentioned in this paper. Based on international consensus, the diagnoses of COPD and asthma are based on the presence of characteristic symptoms and lung

function measurements [73-74]. Differential diagnosis of COPD and asthma is particularly important because of their distinct clinical outcomes in terms of morbidity and mortality, which require a differential therapeutic approach. However, similar clinical and physiological features can be observed in both conditions, which can hamper the clinical distinction of these diseases [75-77]. Both diseases are characterized by a combination of clinical, physiological, and pathological findings, including differential features of airways inflammation [78].

Exhaled air is known to contain thousands of volatile organic compounds (VOCs) that are derived from various metabolic and inflammatory pathways in the lung and elsewhere in the human body [79-81]. These VOCs can be used as biomarkers for diagnosing lung disease. Electronic noses (eNoses) represent an integrative measurement of VOCs, allowing high-throughput analysis of complex gas mixtures. eNose technology is based on an array of nanosensors reacting to the different fractions of the VOC mixture in breath [82]. When these sensor responses are combined, a specific fingerprint or “breathprint” for the disease is created, which is analyzed by pattern recognition algorithms [83]. Thus, this technique combines the noninvasiveness of measuring exhaled breath with real-time analysis of the complete spectrum of volatiles without individual determination of the molecular components. Therefore, eNoses may have potential as a diagnostic tool [84]. Fingerprinting of exhaled air by eNose can adequately distinguish between patients with COPD and patients with asthma [85]

The need of a continuous, unobtrusive and noninvasive measurement of vital signs in chronic disease patients triggered the design of the Wearable Sensing Infrastructure (WSI) within the CHRONIOUS architecture [86]. The respiratory monitoring is included among the several significant vital signs to be monitored. The wearability of the WSI was provided designing a vest, in form of a T-Shirt. It is comprised by an ECG sensor, a reflection sensor for the arterial oxygen saturation, a temperature sensor and two sensory wires for an inductive measurement of the abdomen and thorax volume displacement. As any of the subsystems of CHRONIOUS system, the respiratory subsystem is a low power device that is able to provide both the raw data acquired from each sensor and to extract different vital parameters from it. Therefore, from the sensors the parameters which will be extracted are: respiration rate, inspiration and expiration time, inspiration and expiration volume.

A system that uses miniaturized sensors in a wireless body sensor network is used as part of a comprehensive approach to managing asthma [87]. The system focuses on monitoring activity patterns and cumulative exposures to environmental air pollution, transmittal of this data to a health information system, and feedback of information to the user on how to manage activity, and reduce the potential for asthma exacerbation. It is based on multiple heterogeneous sensors that may be adapted to asthma care (e.g., CodeBlue [88], HealthGear [89], MobiCare [90], WWBAN [91], ALARM-NET [92], Participatory Sensing [93], and Intel MSP [94]).

### **3.4 Diabetes**

Diabetes Mellitus is estimated as one of the major chronic diseases and growing public health problems in the world. Intensive treatment of glucose in diabetes patients reduces the risk of complications, in particular the microvascular complications of retinopathy, nephropathy and neuropathy [95]. Factors such as the illness that patient suffers, treatments received, physical and psychological stress, physical activity, drugs,



intravenous fluids and diet can cause unpredictable, potentially dangerous fluctuations in blood glucose levels, resulting in hypoglycemia and hyperglycemia episodes [96-97].

Self-management systems may help to control the blood glucose levels [98-99]. Many technologies are being pursued for monitoring and modelling of blood glucose. According to Oliver et.al (2009) [100], glucose sensors are divided to Continuous and Point Sample sensors. Point Sample sensors could be either finger-pric glucometer or urine dipstick. The Continuous sensors are divided into invasive and non-invasive glucose sensors: In non-invasive sensors included the optical transducers and the transdermal sensors. The Subcutaneous needle-type sensors included in invasive sensors. NIR spectroscopy, optical coherence tomography, photoacoustic spectroscopy and fluorecence are cosidered as the most promising sensing modalities for an ideal glucose sensor.

The device Movital [101] for personal diabetes management is also been developed, based on Internet of Things, in order to provide a new generation of mobile assistance services and consider more of the mentioned factors for insulin therapy. It can also reduce the number of the patient hyperglycemia and hypoglycemia episodes and consequently their risks.

### 3.5 Hypertension

Hypertension is a major public health problem in many parts of the world [102]. It is known as “The silent killer”, it may exist for prolonged periods without symptoms and may manifest only after causing serious complications. It has been identified as the most common, most potent and most universal contributor to cardiovascular mortality, which accounts for 20-50% of all deaths [103]. It is the first sign of a chronic progressive process that may end in serious and potentially fatal complications such as stroke or renal failure and it is a major risk factor of coronary artery disease [104]. Hypertension per se is not a condition that can be regarded in isolation [105]. All major hypertension management guidelines recommend the use of risk stratification, in the context of a patient’s total cardiovascular risk.

State-of-the-art blood pressure devices are mainly based on a sphygmomanometric occlusive arm-cuff, which is clumsy, uncomfortable and allows only for intermittent measurements at intervals of several minutes. A wearable ear photoplethysmographic (PPG) sensor with continuous cuff-less blood pressure monitoring is used for hypertension management [106] Continuous cuff-less blood pressure monitoring is used for improved hypertension diagnosis and treatment, as well as cardio-vascular event detection and stress monitoring. A Pulse Wave Velocity (PWV) sensor is used to infer the arterial blood pressure [107-108]. A wireless Body Sensor Network (BSN) enables continuous cuff-less blood pressure measurements, at beat level. The unit is fixed at the upper arm and supports wireless data transmission via IEEE 802.15.4. The wireless sensors' clocks must be synchronized in such a way in order to align their data for correct blood pressure estimation.

Another approach [109] is based on body area network (BAN) with advanced sensors and a mobile base unit as the central communication hub from the one side, and the clinical environment from the other side [110]. The mobile base unit (MBU) in hospital coordinates the sensor network and notifies the medical personnel with respect to the monitoring outcome. The subsystem located at the patient site consists of a BAN incorporating biosensors, such as blood pressure (BP) and heart rate (HR) sensors [111], which are all controlled by an MBU, i.e., a smartphone or personal digital assistant (PDA)

that is capable of configuring the operation of each sensor at run time, while coordinating the monitoring scheme and receiving its outcome by exchanging appropriate messages.

### **3.6 Alzheimer's Disease**

Alzheimer disease (AD) is a progressive dementia with unknown etiology that affects a growing number of the aging population. Worldwide, almost 25 million people have dementia, 50–75% of who have alzheimer disease [112]. In addition (AD) is one of the most common neurodegenerative disorders of the aging human brain, is clinically characterized by early memory deficit and by progressive cognitive and functional disorientation [113]. AD is a devastating illness that results in a progressive decline in cognitive ability and functional capacity, causes immense distress to patients and their families, and has an enormous effect on society [114].

The management of severe Alzheimer disease often presents difficult choices for clinicians and families. The disease is characterized by a need for full-time care and assistance with basic activities of daily living. We outline an evidence-based approach for these choices based on recommendations from the Third Canadian Consensus Conference on the Diagnosis and Treatment of Dementia [115].

An application for alzheimers management [116] uses Pervasive computing (PerC), which is very environment-centric, provides such seamless computing and transparent interaction among small handheld PDAs, wearable devices and sensors, so that comprehensive patient monitoring can be achieved .

Wireless sensor networks (WSNs) [117], enable non-invasive and nonintrusive patient monitoring. The development of a system [118] to monitor the brain activity of an AD subject by capturing Electroencephalogram (EEG) / Rapid Eye Movement (REM) and his/her movements unobtrusively (made possible by miniature sensors built into a small device worn by the patient). Wireless Sensors Networks nodes which equipped with tri-axial accelerometers can record and classify movements, to monitor the patients' functional status and to detect anomalous patterns preceding a crisis. The captured signals are compared to find relationships between the brain activity and the body movement schemes. From test results, the body movements will be classified as those prone to fall or not.

Another approach for alzheimer management is related with a system [119] of continuous telesurveillance with the help of eight passive infrared sensors and installed it in an experimental hospital bedroom to analyse patients' motor activity. Patients were continuously monitored by the system from 21:00 until 6:00 the next morning. Patients' motor activity is monitored and correlated it with his or her illness as well as patient management.

### **3.7 Parkinson's Disease**

Parkinson's disease (PD) affects about 3% of the population over the age of 65 years and is the most common movement disorder besides essential tremor and the second most common neurodegenerative disease [120]. The main motor features of PD are tremor, bradykinesia, rigidity, and impairment of postural balance [121]. Drug therapies are successful for some time, but most patients eventually develop motor complications [122]. Complications include wearing-off, the abrupt loss of efficacy at the end of each dosing interval, and dyskinesias, involuntary and, at times, violent writhing movements.

Wearing-off and dyskinesias produce substantial disability, and frequently interfere with medical therapies [123-124].

As good practice examples in PD, the following could be mentioned:

An accelerometer sensor and a platform [125] are used to analyze the sensor's data to reliably estimate clinical scores capturing the severity of tremor, bradykinesia, and dyskinesia. After that, wearable sensors are placed in specific points on the body and are used to gather the accelerometer data.

Another approach for Parkinson's management is a device [126] developed on a Web based system to provide remote access to data collected. Wearable sensors (accelerometers) also used to allow one to carefully manage resources such as battery life and processing power to achieve monitoring over several days.

Mercury [127] is a wearable, wireless sensor-platform for motion analysis of patients being treated for neuromotor disorders, such as PD. Mercury is designed to support long-term, longitudinal data collection on patients in hospital and home settings. Patients wear up to 8 wireless nodes equipped with sensors (one on each limb segment) equipped with MEMS accelerometers and gyroscopes, for monitoring movement and physiological conditions. Individual nodes compute high-level features from the raw signals, and a base station performs data collection and tunes sensor node parameters based on energy availability, radio link quality and application specific policies.

## **4 Conclusions**

The chronic diseases management intends to meet the needs of practicing clinicians that they struggle with the uncertainty of applying disease-specific guidelines to older adults with multiple conditions of diseases, by engaging patients in collecting more frequent information on the symptoms of their diseases and the related treatments. This new approach in caring comorbidities will imply secondary prevention and treatments of the pathologies that sees the patients more involved in the health care decision making process and that allow General Practitioners (GP) and health care Specialists interacting on the bases on innovative organizational models that could imply a more outcome oriented reimbursement schemas. As it was evident from the previous sessions, the use of the emerging technology regarding the bio-sensors, can contribute in the effective management of chronic diseases which in turn can result to the: improvement of mortality rates; increase of quality of life; increase of self-efficacy regarding patients with comorbidity; reduction of number and costs of visits into outpatient consultation, treatments and hospitalization/re-hospitalization at the emergency departments; benefits for the private and public economy.

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