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Well-being and -ageing with chronical disease – The BV2 project

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Abstract – The BV2 project aims to propose a monitoring system for wellbeing but also well-ageing working on the prevention, detection and monitoring using a System of the Systems (SoS) approach. The project partner already uses the IoT technologies and the BV2 platform will combine the different developed systems. The main originality of the project consists in the development of a virtual platform by combining the existing systems.

Keywords: SoS, wellbeing, well ageing, ADL.

I. INTRODUCTION

In today's world, interactive technologies are completely changing our daily lives. They provide an increase support to our everyday needs to make our life safer and more comfortable: from devices that monitor our health (connected devices) to systems that manage assisted care [1].

Healthcare monitoring can be seen as a system of systems (SoS) that includes many operators and needs always larger networks. Research and development in this area is divided into three main levels (Figure 1). The first one is the environment and his influence on human beings. It is a very complex system to handle as security and safety have to be ensured. The second level is the technology that allows perceiving both environment and human beings. The number of sensors and the need to record continuously data (optimization of the recording or ways not to record every time) are one of the research fields. They measure different parameters, send information (either raw or processed data) through the network in order to have a real time analysis. As mentioned in [2], the health management framework is based on a causality model and so is our case of study. Finally, the third level is the human being himself. Based on modern technologies (smart devices), we can collect his health-related sensor data, such as physiological, actimetric (or body moving) and emotional data, which need complex analysis and interpretation. This evaluation helps to devise possible recommendations for people, to detect diseases at an early stage and enhance the quality of life for persons with chronical diseases.

The IoT (Internet of Things) system can be seen as a System of Systems (SoS) that is complex to manage (Figure 2). It is a

set of structures that are not necessarily dependent, but manageable together for a better performance and a better life style. We have to take into consideration the different connections levels between the persons, their environments and the connected devices. Sensors will measure data relative to human beings, their environments and the interaction between both of them. Emotions and human response are highly related to hormones and to the environment (work, friends, family, among others).

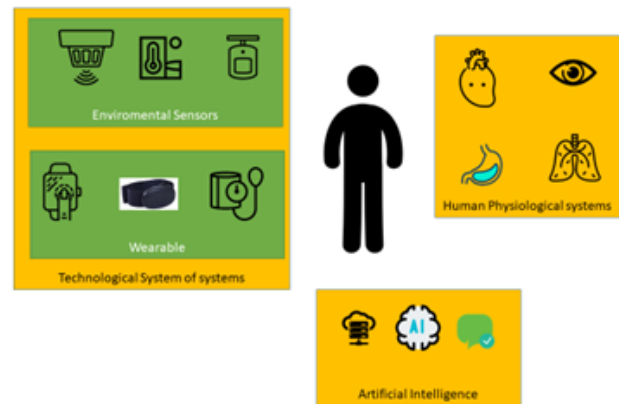


Figure 1 - SoS components

To analyze emotion, we need to take into account that feelings are personal interpretations. Some people cannot or will not identify what they are feeling. Moreover, even if they do, it still remains a personal point of view. For example, “I might feel stressed” but physiologically “I am just tired”, or “I can feel relaxed” but data shows that “I am stressed”, etc. We have to consider interactions between different levels, the complexity of data management and decision-making.

II. CONTEXT

The increase of life conditions but also advances in medical treatment has consequence that the population of adults over 60 has presented a global increase, reaching 0.96 billion in 2017, representing an increase of 252% with respect to 1980 presenting a population of 0.38 billion elderly adults. It is

expected that by the year 2050, the world population reach around 2.1 billion people over the age of 60 [3]. According to the World Health Organization (WHO), the main health problems that affect this group of persons are chronic diseases and distress situations. Among the chronic diseases, the most frequent are neurodegenerative (Parkinson, Alzheimer and other dementia) and diseases of the circulatory system (hypertension, cardiovascular diseases and metabolic disorders such as type 2 diabetes) [4-7]. These diseases also occur in younger people, lying latent for years or decades, and only materializing at later age. Diagnosis of chronic diseases is essential in the medical field as these diseases persist for long time. In Europe, chronic diseases cause at least 86% of deaths (figures of 2005 and expected to continue to grow) [8].

incorporation of new systems in order to improve the quality of life of the elderly people.

The use of IoT technologies currently covers a large number of areas. Internet of Things (IoT) is a term that is more and more used in the computer field [11]. It illustrates devices communication through a wireless network, via Bluetooth or depending on pre-established protocols. The smart objects are sensors like the smartwatch, connected lock, thermostat, smart car, connected scale, etc., that are linked and connected in order to record, communicate and exchange data in real-time.

By 2020, we estimate that the number of the connected objects in the world will almost double to reach 50 billion sensors worldwide, compared to 25 billion objects in 2015 [12]. As mentioned in [13], the use of these devices in association with

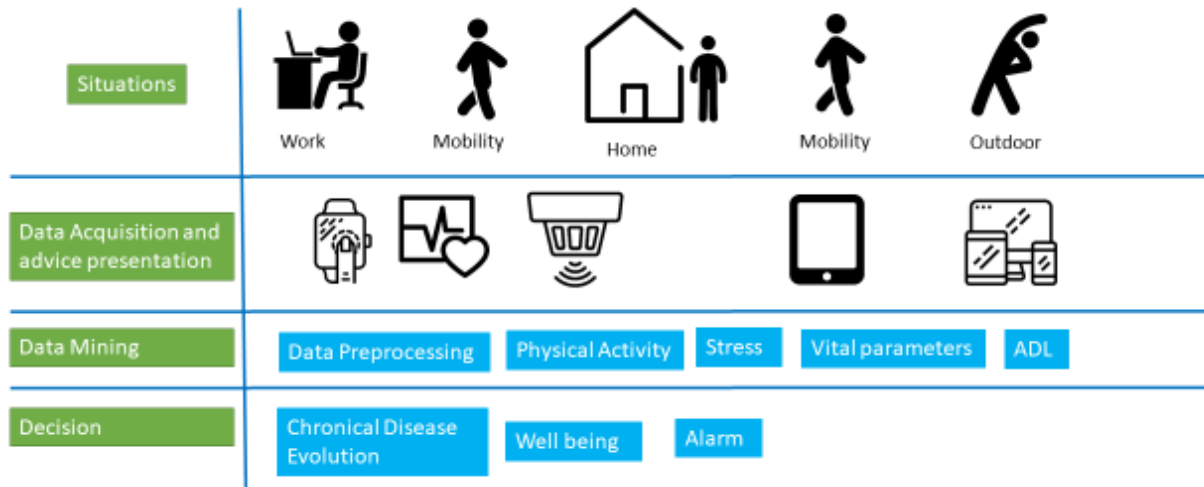


Figure 2 - SoS and IoT approach

In light of demographic change, the care system is facing unprecedented challenges. A larger proportion of older adults live alone in their homes, implying an increased likelihood of suffering distress situations related to home accidents. Falls are especially relevant to patients and health systems because approximately one third of adults older than 65 that live in a community will fall each year, while there are an estimated 3 to 5 falls per 1,000 days of stay in a hospital [9]. In practice, all the industrialized countries are affected by this phenomenon. In Chile, 15% of elderly adults live alone (330 thousand people) [10]. These distress situations have a devastating effect on the quality of life of individuals, and their consequences can result in loss of autonomy. They concern several categories of population from younger to older persons and situations can occur in everyday life at any moment, when working or dealing with home tasks. It encouraged for last decades remote monitoring solutions development for the concerned persons.

The objective of these solutions is the detection and / or prevention of chronic diseases and distress situations based on IoT technologies. However, in general, these systems are limited to the detection and / or prevention of events without having an inter-operable SoS platform allowing the rapid and efficient

Big Data tools, will contribute to French gross domestic product (GDP) by an increase of 3.6% in 2020 and 7% in 2025. Health technology companies are independently developing IoT solutions, using different platforms and frameworks, implying that devices cannot be integrated with other devices and / or platforms. Using software to enable inter-operability makes it easier for manufacturers to refine or add new features to their products without hardware redesigns. Devices in the field can also be upgraded to fix bugs or include new capabilities, helping to extend the life of IoT devices and reduce management or replacement costs. The standardization of IoT devices for eHealth (related to computer use) and mHealth (related to mobile phone use) of elderly people favors the implementation of systems that can perform their tasks either independently or being part of a system of systems (SoS).

III. STATE OF THE ART

Various investigations offer alternatives to the care of the elderly, focusing their results on the detection and prevention of chronic diseases or distress situations. For example, in [14-16] different approaches aiming at detecting and sending fall alerts are presented. However, they are not integrated with other systems. Likewise, in [17-19] different devices are shown for the detection of diabetes, a chronic disease that affects more than 422 million people worldwide [20]. Each of these systems does

not present a standardization of their communication protocols, making their systems closed for new platforms.

One of the main challenges facing by IoT is the high degree of heterogeneity in the communication of devices, protocols, technologies and hardware. In [21], the use of a Smart IoT Gateway has been implemented: it acts as a central element communicating with each of the IoT devices through different communication protocols (Wi-Fi, ZigBee, Bluetooth and Ethernet), sending alerts to end users and having a web server that allows internet access to data.

Another way to deal with inter-operability between different devices is based on the use of a middleware such as [22], [23] or [24]. These solutions are focused on networked homes, and are oriented towards protocols such as service discovery protocol and simple service discovery protocol. However, the use of middleware in large areas of IoT could lead to security and scalability issues.

IV. BV2 PROJECT

The BV2 (Wellbeing and aging with chronic disease) project is a Franco-Chili cooperation project which has a main objective of the mutual collaboration between the existing research platform in Valparaiso University, University of Technologies of Compiègne and "Institut Mines-Télécom". A mechanism of knowledge transfer between both countries will be created regarding the advances obtained in research related to the care of the elderly. These advances will be unified through a platform based on SoS.

The proposed system based on a SoS approach is designed to data fusion from different sources (environment, embedded sensors, context information) for information extraction about the different systems that compose human body, with the final aim to increase wellbeing of persons with chronic disease but also to well ageing in general. The acceptability criterion will be integrated in a transparent manner.

This project aims at implementing an inexpensive, preventive and effective system in order to ensure a good ambulatory monitoring. We seek to study the impact of using connected objects on chronic diseases, with a main focus on cardiovascular ones. Indeed, 33% of the main cause of death in France can be explained by high cardiovascular disease (according to INSERM- INSEE). It is prevalent among women as well as men. We seek to study the different relationships and correlations existing between the collected data sensors and their impact on cardiovascular diseases, in both prevention and treatment ways. The emotion will be treated according to the HRT [25], [26]. One of the important emotions that we will treat is stress. It can foster cardiovascular diseases, specifically in the case of a chronic stress. This physiological and psychological reaction develops both anxiety and depression. It increases blood pressure and accentuates cardiovascular disease. The stress we get will be real and not simulated [27]. Smoking, unhealthy eating habit, lack of physical activity and stress accentuate chronic diseases and make healthy people at risk.

Firstly, the systems of systems approach will be focused. This theme seeks to integrate already existing platforms developed by the applicant institutions, focused on improving the quality of life of the elderly or young adults through improving the management of healthcare centers. This integration will follow the SoS paradigm, which means a system built from independent systems that are managed separately from the larger system [28]. In this way, Labitec will integrate BV2 via the two mobile applications. The first one, "MyHospital", notifies patients to remind them to attend medical consultations at the hospital. The second platform, "Curare", can be used by the patient to schedule hours at centers for primary healthcare and receive notifications through a mobile application. In addition, the project called "Intelligent system for the management and analysis of the provision of beds in the care network of the public sector", developed by Labitec, will be added. This project consists of a web platform for the management of beds in hospitals, where the healthcare centers adhering to this system implementing inter-operability with HL7 are able to know the number of beds available in the different healthcare centers in order to improve the use of resources. The UTC will integrate the fall detection application based on sound environment analysis and the monitoring of cardiovascular patient using connected objects.

An important research and development activity is dedicated to the interoperability protocols in IoT devices for the BV2 platform, together with the application of the HL7 protocol that allows easy interconnection with healthcare centers.

Secondly, we seek to improve the habits of people to avoid suffering from chronic diseases in older age through the monitoring of biomedical signals; this means to increase the general wellbeing through two themes:

1. Chronic diseases detection and prevention is the first theme. This theme concerns the Information and Communication Technologies helping the healthcare services to offer new possibilities of treatment and follow-up but also to improve their resolution for chronic patients, particularly the cardiac and diabetic patients. The main idea is to propose automatic signal processing of biomedical signals in order to assist the health professionals even though a specialized opinion is not presented, which is the main challenge of the primary healthcare. In this context, Labitec has already developed a low-cost system that detects when an elderly person avoids the use of IoT technologies. This solution, based on the impedance method, does not need to be worn by the user to allow the detection of a micturition event and could be used for early symptom detection of chronic diseases.
2. Chronic diseases monitoring is the second theme. Labitec has developed a low-cost technological platform to monitor biometrics parameters of domiciliary patient, submitted to a cardiovascular tele-rehabilitation program, in order to ensure a better quality of life and reinsertion in the familiar and working environments. UTC has started a study on

monitoring the emotional state and physical activity of cardiovascular patients. Each patient is equipped with a smart watch able to measure the physical activity, sleep quality and R-R intervals. Each patient is also able to measure the blood pressure with a connected object. The emotions, and more specifically the stress, are estimated from HRV (Heart Rate Variability). One of the important emotions that we will treat is stress. It can foster cardiovascular diseases, specifically in the case of a chronic stress. This physiological and psychological reaction develops both anxiety and depression. It increases blood pressure and accentuates cardiovascular disease. The stress we get will be real and not provoked or simulated [27]. Smoking, unhealthy eating habit, lack of physical activity and stress accentuate chronic diseases and make healthy people at risk.

Thirdly, we seek to improve the quality of life of the elderly persons through remote monitoring; this means well ageing. Its objective is to detect distress situations within the home, as well as to recognize activities of daily life and improve behavior habits. Well ageing is studied through also two themes:

1. **Serious Game for prevention and rehabilitation.**

This theme aims at proposing and implementing various serious games for monitoring cognitive and motor abilities of the elderly at-home. These serious games will consider both actimetric and physiological monitoring of the person. The objective of the use of serious games is:

- a. to record noninvasively actimetric and physiological information of elderly in their living environment;
- b. to maintain the cognitive and motor functions of healthy older people by training, in a gamification context, using these data as input to select what training is necessary;
- c. to detect potential motor frailty and cognitive decline in the elderly at-home;
- d. to integrate rehabilitation programs, through bio-feedback integrated in these games, in order to regain (within long term training plans) cognitive and motor functions that were impaired by a disease or due to aging.

2. **Activity Daily Life (ADL) monitoring - Application to the distress situation identification.**

Through the use of environment monitoring sensors, intelligent algorithms will be implemented to process this information to obtain non-trivial behavior patterns that improve patient comfort. The sound environment is analyzed and some everyday life sounds are recognized in order to ease ADL identification. Some distress expressions are also recognized in order to detect fall or distress situations. A sound analysis system was already developed in the frame of an industrial PhD thesis for Senior@dom start-up; this system consists in a i-vectors based recognition and obtains good

recognition rate in current conditions. Another aim is to detect and avoid distress situations at home. In this way, Labitec have implemented a fall-detection system applied to very low-resolution infrared sensors. These sensors are equipped with an array of 16x2 pixels, which assures that the user's privacy is not violated while the device is being used. The system is designed to be employed in homes of older adults that live alone in controlled environments. To process the data from the sensors, recurrent neural networks (RNN) are used, in particular Bi-LSTM.

V. CONCLUSIONS AND PERSPECTIVES

The BV2 project has started at the beginning of 2019 and aims to propose a common, interoperable platform for well being and well ageing based on the System of Systems (SoS) approach. Each project partner has already developed different approach for home monitoring through different IoT and environmental sensor but the originality is the combination of these systems in a virtual common platform. This virtual platform will allow the possibility to design and test new and fully interoperable systems combination concepts even if in different country.

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