DEVELOPMENT OF A MECHATRONIC SYSTEM FOR BEDRIDDEN PEOPLE SUPPORT

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Abstract - This work is developed in the context of Ambient Assisted Living (AAL) and has, as main purpose, the development of a mechatronic system that allows caring of bedridden patients with ongoing medical care terminal (MCT), by a single person. This system allows higher autonomy in domiciliary care, safety, comfort and hygiene of bedridden patients. It contributes to a large increase in their quality of life as well as the ease of monitoring by providers of continuous care, which, in many cases, may be the family itself. The product includes an embedded processing interface for acquiring physiological data to support online monitoring. The development of this project was focused on improving the quality of life, autonomy, participation in social life and reducing healthcare costs in the area AAL. The developed societies currently face severe demographic changes: the world is aging at an unprecedented rate. In 2000, about 420 million people, or about 7 percent of the world population were over 65 years old. In 2050, that number will be near 1500 million people, about 16 percent of the world population. This demographic trend will be accompanied by the increase of people with physical limitations. This will impose new challenges for traditional health systems, not only for Portugal but also for all European countries. There is an urgent need to find solutions to improve the lives of people in their preferred environment by increasing their autonomy, self-confidence and mobility. Therefore, in the case of household scenarios, the provision of effective health services is of fundamental importance to the welfare and economic development of each country. This ongoing project aims to develop a mechatronic system to meet the diverse needs, namely: improving life, health care, safety, comfort, and remote monitoring of bedridden person.

Keywords*:* Ambient Assisted Living (AAL), Mechatronic Systems, Medical Care Terminal (MCT), Product Design, Healthcare.

1. Introduction

Bedridden patients are confined to live in bed due to illness or infirmity. This category of people requires additional care to avoid the formation of pressure ulcers due to the long state on the same physical posture.

The pressure applied to the skin causes a deprivation of blood on the pressed skin area. If the pressure remains too high on the same region for a couple of hours, skin tissues get damaged and may even die.

Since the discomfort of these pressure ulcers for the patients is enormous and the costs for treatment are high, the prevention of pressure ulcers is of utmost importance.

Prevention starts with the use of special materials for mattresses and sheets. In addition the patient is turned every 2 hours which requires the presence of nurses. In order to reduce nursing costs fewer nurses need to take care of more patients at the same time by noting the time of turning. In the last years a number of lawsuits have happen against mistakes in the treatment of bedridden patient.

The available commercial beds are very expensive. In Portugal the price of articulated beds is around 5,000.00 Euros [1] and have some limitations. There is not yet available commercial equipment that allows a single person to take care of bedridden patients (including sheets changing and bathing) and in parallel collect and register the biomedical data of the patient.

The target of this project is then the development of a mechatronic system to withdraw the patient from his/her bed for bathing and basic health care as well as the development of a medical care terminal (MCT) to collect physiological data of the patient [2-10].

This paper describes in particular the development of the MCT, supported in the mechatronic system, able to collect physiological data of the patient and is divided into the following sections: State of the Art, Prototype Concept, MCT, Results, Conclusion and Future Work.

2. State of the art

At the moment what exists internationally boils down to mechatronic systems that are limited to systems for handling and transportation of patients, working as a crane with a movable arm that is attached to a gurney [11].

As an example, Figure 1 presents a transport system which first lifts the patient, lowers the patient to the elevator transport, and transfers him/her to the stretcher without oscillations. These types of systems are not convenient for those who cannot suffer sudden movements and long paths [11].

Considering the remote monitoring of biomedical variables in bedridden systems, what exists in the market at the moment is expensive and unaffordable for most of families: presently, the price is around 8,610.00 Euros [12].

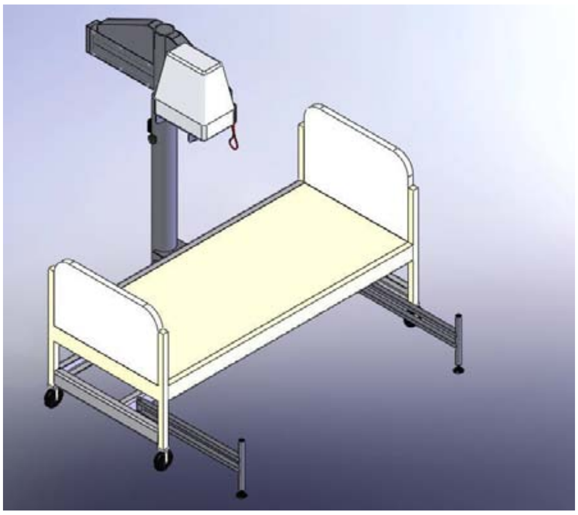

Figure 1: Patient transportation system [11]

Figure 2 presents an example of MCT from BioPlux [12]. BioPlux clinical biofeedback software GUI (Graphical User Interface) is an innovative technique for muscle rehabilitation; it takes advantage of new technologies to make the therapist's intervention more effective and users' recovery faster.

This software is a web-based app, being developed with html, css, javascript, processing as well as an android version.

Figure 2: bioplux clinical biofeedback software gui [12]

3. Prototype Concept

The proposed system is based on a MCT and a portable mechatronic system, to allow taking care of bedridden people. The system is able to collect physiological data of the patient and allows a remote medical interface, providing medical instructions to prescribe to the patient, if convenient. Environment variables can also be monitored by the system.

The system schematic is presented in Figure 3.

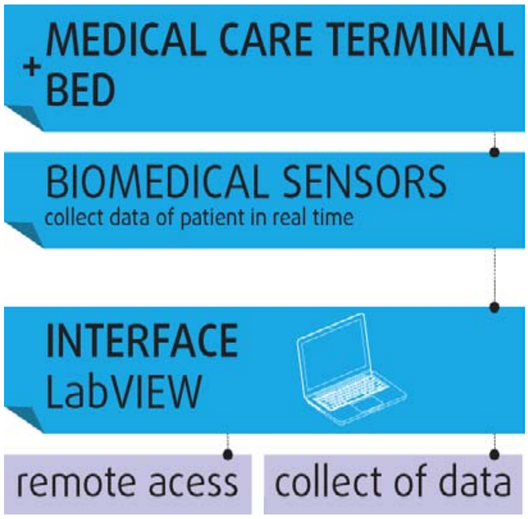

Figure 3: Schematic process of the system

In this paper special emphasis is given to the MCT. The operation of this system optimizes the healthcare of the bedridden people. The MCT has high quality biomedical sensors that perform the analyses in real time through an embedded system that enables the operation of biomedical sensors.

Figure 4 presents the MCT and the mechatronic system.

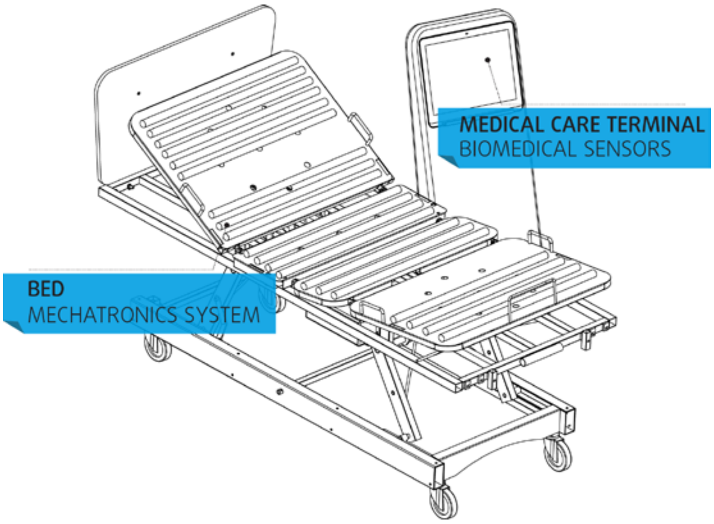

Figure 4: Bed with MCT

The Cooking Hacks biomedical-Kit has been implemented in this project and works from the interface created in LabVIEW (Laboratory Virtual Instrument Engineering Workbench) environment, being responsible for the operation and control of all sensors [13, 14]. It presents an added value in this project as the system has a high performance, safety and low cost. This MCT will also perform video conferencing increasing the advantages in healthcare. This information can be used to monitor in real time the state of a patient or to get data in order to be subsequently analysed for medical diagnosis. The biomedical information can be remotely accessed using any of the six connectivity options available: Wi-Fi, 3G, GPRS (General Packet Radio Service), Bluetooth, 802.15.4 and ZigBee, depending on the application. If real time image diagnosis is needed, a camera can be linked to the 3G module in order to send photos and videos of the patient to a medical diagnosis centre [14].

4. Medical Care Terminal (MCT)

This section is divided in three parts, namely: Acquisition Software, System Hardware and User Interface.

Acquisition Software

The acquisition software was developed using the Arduino platform and LabVIEW. Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It is intended for artists, designers, hobbyists and anyone interested in creating interactive objects or environments [13]. LabVIEW is a system-design platform and development environment for a visual programming language from National Instruments.

System Hardware

The project's task consisted of developing a medical terminal based on a Cooking-Hacks biomedical Kit [13]. The e-Health Sensor Shield allows Arduino users to perform biometric and medical applications where body monitoring is needed by using nine different sensors: pulse, oxygen in blood (SPO2 - Saturation of Peripheral Oxygen), airflow (breathing), body temperature, electrocardiogram (ECG - Electrocardiography), glucometer, galvanic skin response (GSR - sweating), blood pressure (sphygmomanometer) and patient position (accelerometer) [13]. Figure 5 presents the biomedical toolkit system.

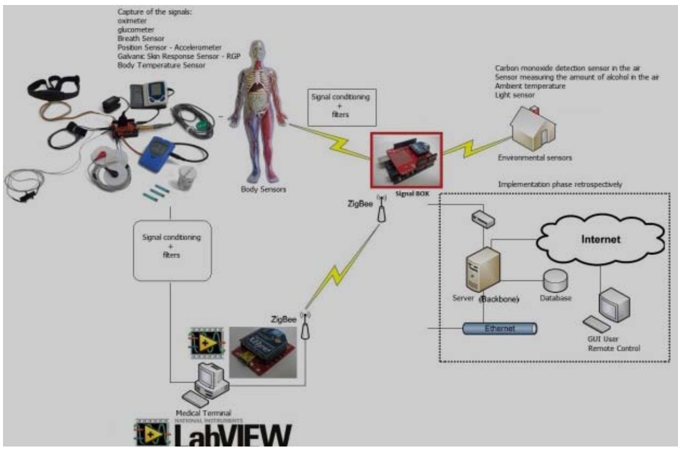

Figure 5: Biomedical Toolkit System

Regarding the equipment that makes up the terminal, one is divided into three parts: biomedical monitoring of environmental factors in the local system via wireless communication between doctor and patient terminal, a platform for handling all incoming signals for the final presentation of results on PC through LabVIEW [14] with remote communication and the environmental signals: carbon monoxide in the air, alcohol in the air, temperature and brightness of the patient room.

There is a communication between the development platform and the radio frequency module Arduino XBee [15] for transmission of signals. Wireless transmission of sensor devices is performed via a zigbee radio, specifically the MaxStream XBee pro (Figure 6).

To connect the XBee module to the Arduino are used four pins: pin 1 to power the radio with 3.3 volt, pin 2 connected to the receive pin and pin 3 connected to the transmission, pin 10 is connected to ground, as shown in Figure 6. To receive the data transmitted by the sensor devices is used a gateway. It comprises a radio XBee Pro with a USB interface connected to a computer [16], as shown in Figure 7.

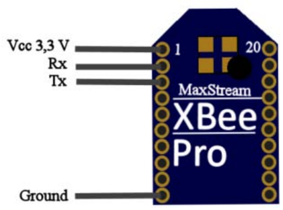

Figure 6: Xbee MaxStream [16]

Figure 7: Arduino using Zigbee protocol [9]

The data collected by the sensors is subject to review and pre-processing before being sent to the gateway.

There are two types of sensors, analog and digital. The digital sensor has an output value formatted according to the measurement unit requirements, however, the analogue sensors require the use of an ADC (Analog to Digital Converter) to convert an analog quantity into a digital one. Using the ADC analog sensors have an output value that can go from 0 to 1023[16].

Regarding the environmental variables, the system has available the following sensors [16]:

- The temperature sensor monitors the environment temperature. The sensor output values are in degrees centigrade, so there is no need for any pre-processing ;
- The light sensor comprises an LDR (light dependent resistor) which is analog and thus the output values must be pre-processed. There are considered three categories: high brightness (0 to 250), middle light (from 250 to 600) and dark (over 600)**;**
- The air quality sensor presents a value which is proportional to the air quality measured by the sensor. The measured value can be monitored in the serial monitor Arduino software or in LabVIEW Aplication;
- The carbon monoxide (CO) sensor is suitable for detecting concentrations of CO in air. The MQ-7 can detect CO concentrations anywhere from 20-2000 ppm. This sensor has a high sensitivity and fast response time.

User Interface

The interface for monitoring the system was developed in LabVIEW (Figure 8). The interface requirements were to provide instructions to the user about the correct use of the system.

The second tab in Figure 8 is dedicated to environmental sensors. Using this application the person who takes care of the patient may have a sense of what is happening at the room where the patient is. In the third tab (Figure 8) one can see the values of biomedical sensors placed on the patient.

Finally, the fourth tab (Figure 8) allows getting a remote communication with a medical specialist, as example. From this interface it is possible to record the measured data in MS Excel allowing further analyses.

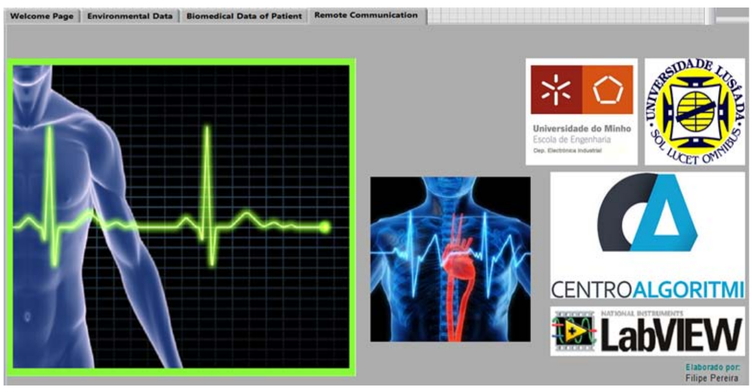

Figure 8: LabVIEW Interface (In the yellow rectangle are accessible the four system functionalities: Welcome page, Environmental Data, Biomedical Data and Remote Communication).

5. Results

In this section are presented some examples of results of the MCT described.

Biomedical Sensors

In the first example it is shown one of the biomedical sensors, in this case the Respiration sensor (Figure 9).

This menu includes the respiration sensor measured values and information regarding the desired values to be obtained in order to provide users some preliminary results and diagnosis.

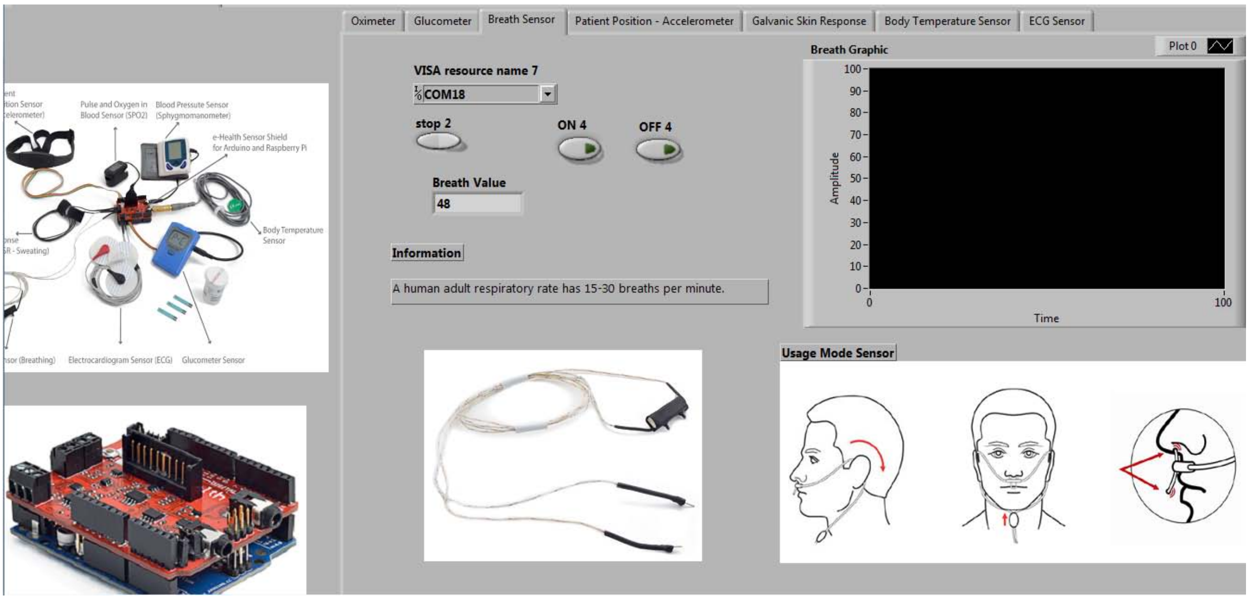

Figure 9: LabVIEW Interface for the Respiration sensor

Environmental Sensor

In Figure 10 it is shown one of the environmental sensors, in this case the light sensor. The interface includes a led light warning when there is a lack of light in the room.

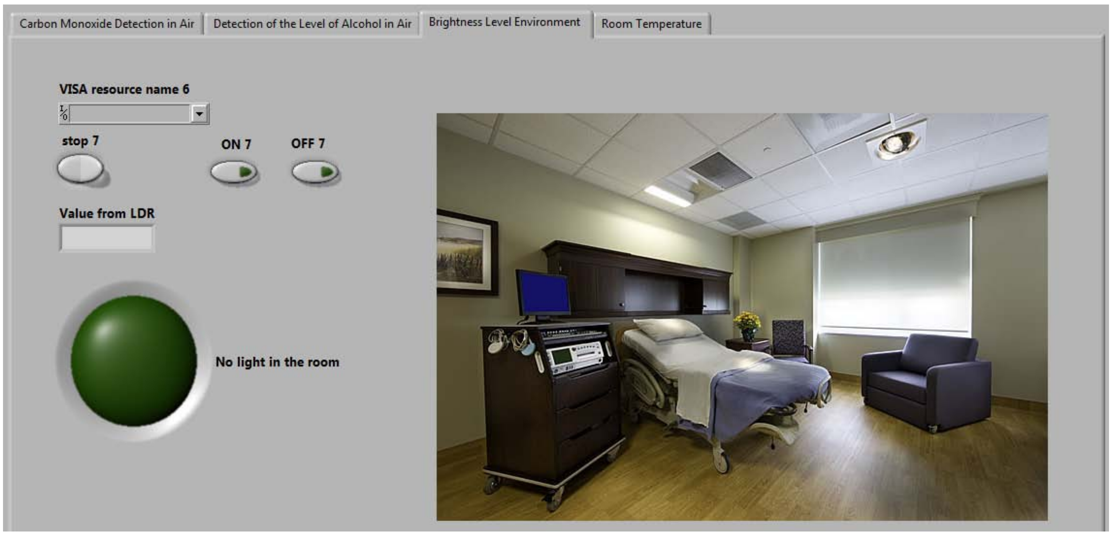

Figure 10: LabVIEW Interface for environmental Sensors

Remote Communication

For this function it was developed an application that allows the person who cares for the patient to communicate remotely with a doctor or specialist; even the patient himself is able to obtain information or basic healthcare practitioner via a webcam installed on the MCT (Figure 11).

Figure 11: LabVIEW Interface for Remote Communication

6. Conclusions and Future Work

This paper describes the development of a system based on a medical care terminal (MCT), for support of a mechatronic system, able to allow monitoring bedridden patients; video conferencing is also provided. This system can be used to monitor in real time the state of a patient or to get sensitive data in order to be subsequently analysed for medical diagnosis.

The MCT promotes the Ambient Assisted Living (AAL) [17] for patients, a concept that is based on a set of technologies which aims to provide an enhanced support to people's daily life, namely to offer new solutions for healthcare to improve the quality of life of the population and reduce costs associated with healthcare [18, 19].

The added value of this project lies in the fact that the caregiver can control in real time the state of the patient through the collection of biomedical data and remotely receive medical help.

This system of data collection is integrated in the biomedical module of the mechatronic system and presents several advantages, such as:

- Allows a user-friendly interface;
- Facilitates the communication with the central medical unit, allowing better control of the patient;
- Tight integration between hardware and software for fast response;
- Uses only one application for the integration of multiple sensors;
- Allows collecting the patient's biomedical data and environmental data providing better control of the patient comfort.

The major goal of this project is the development of a mechatronic system that in conjunction with the MCT offers to the bedridden people the ability to monitor in real time physiological and environmental data allowing remote monitoring and storage information in a database.

As future work, the whole system will be assembled and tested in healthcare facilities for validation.

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