Smart Moving Nightstand
For Medical Assistance of Elderly People an Open Project

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Abstract: We present an open mobile platform that aims to benefit from versatile wireless sensors. This mobile assistant is a robot that can monitor different physiologic data for elderly people. Moreover it has the ability to determine the distance and potentially the position of the elderly person who use it. As an assistant it can transport some "objects" as glasses or drugs. Preliminary results show the proof of concept of our approach with a remote sensor that measures the temperature of the subject. We also present a method to assess the quality of the RSSI signal in order to determine the distance of a zigbee module attached to the arm of the subject. These results are the first steps towards a totally autonomous system that is an open platform. In this platform it will be easy to highlight the interaction or the correlation between the different physiological data and to move the robot properly in case of alert. It is possible to program different services and to integrate new sensors remotely. This platform can be convenient for developers and researchers involved in health technology.

1 INTRODUCTION

In recent years the number of elderly people isolated at home continues to grow. These people often have need for medical monitoring and have difficulty to open outward. One of the solutions is to develop connected medical sensors to remotely monitor physiological and medical data. The variety of available physiological sensors allows to consider a large number of diseases, including non-exhaustively:

Automatic blood pressure sensors are now available which send the data, either wired or wireless to a smartphone or a computer (Isais et al., 2003).

Any apparatus that measures the concentration of sugar in the blood are using the same techniques; it is imperative to remove the patient's blood on a test strip. Some of these devices can transmit data via a USB cable or wirelessly.

There are two ways to achieve the pulse measurement, with an electrocardiogram (ECG) or an oximeter. The ECG is generally composed of a transmitter unit includes a belt worn around the chest and comprising electrodes for sensing the heart beat and to transmit information to a receiver, which can be worn the wrist like a watch. Using this system can be complicated for elderly people. The alternative is pulse oximeter which measures the quantity of oxygen in the blood at the finger. The measurement of the variation of oxygen in the blood is an indirect indicator of the pulse rate.

Thermometers are classic physiological sensors widely used at home. But there is an added value to be able to record temperature regularly for monitoring the evolution of temperature. Moreover some new thermometers were recently design that can measure the temperature with no contact. The principle is simply to record the infrared radiation from the heat source and to convert it in temperature.

The main drawback of these systems is the constraint to access the data one by one. Based on this issue, some researchers proposed the project the E-Health with the purpose to connect several physiological sensors to one platform. It consists of a "Cooking Hacks" card, which is used to interface all medical sensors, associated with either a "Arduino" card or a "Raspberry Pi" card. On this platform, it is possible to connect up to nine medical sensors. Physiological data can be sent via WiFi, Bluetooth, 3G, GPRS or ZigBee. In addition to

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providing a hardware architecture, the project also provides all the software part implemented in C + +. To ensure code compatibility between the two architectures, developers have chosen to use the library "ArduPi".

The principal drawback of this project is the connection with specific sensors that are dedicated to the project. Moreover, even if the data can be processed remotely, the acquisition by sensors is done with wires. These connections not provide a convenient ergonomics and limit the number of possible sensors. Another limitation is the absence of procedure in the case the patient is experiencing a serious crisis not allowing him to call for help.

Moreover a disease can be detected earlier by the correlation of different physiological data. An automatic system allowing to one hand to centralize and process the data, and to another hand to move to the patient to observe his condition, would allow to send an alert to a health's professional or the family to alert them. Another possibility is that the patient can talk with his relatives and health's professional to reassure them in case of false alarm. This kind of task could usefully be done by a robotic assistant.

Today there are many robots that were developed to assist people.

Some robots are human's assistant, but are not natively equipped with physiological sensors. This is the case of JAZZ robot, whose main application is telepresence. It may, in some cases, allow a doctor to visually observe a patient without being physically present on the site. The robot Kompaï, for its part is designed to support the elderly in a home environment. This robot focuses on multimedia features and non-medical application. ASIMO is a robot equipped with technologies that give it a genuinely independent action. Its name is an acronym for Advanced Step in Innovative Mobility. Asimo is an autonomous robot capable of determining his behavior in unpredicted situation. Thus, it can coexist with humans. Autonomy allows him to decide to change his path to avoid a collision with another person. In some circumstances, his faculties are superior to those of men. For example, it is able to track multiple conversations simultaneously (Mutlu et al., 2005); (Sakagami et al., 2002).

In contrast, other robots are connected to physiological sensors. This is the case of the robot RP-Vita Remote Presence is a medical robot mobile telepresence designed to be used primarily in a hospital and communicate with medical instruments connected to it. It helps to have several medical officers in connection who may have access to all information on the equipped patients. This comprehensive platform is exclusively available to hospitals. It requires that the hospital has to be equipped with hardware that can communicate with the robot and the platform is not suitable for home use. In this category of robots one can quote HealthBots that is a project aiming to measure some physiologic data, but the drawback is that the robot uses some dedicated sensors (Jayawardena et al., 2010); (Jayawardena et al., 2012). Another orientation is the one taken by Robo MD which is to combine the mobility of a Nao robot with sensors networks. This approach is mainly oriented to provide an alert in case of falls situations (Van de Ven et al., 2010).

The aim of this study is to develop a medical assistant robotics for elderly people. It seems essential for such an assistant to have physiological sensors in large numbers. We decided to connect the physiological sensors with a ZigBee connection, this strategy has many advantages. Firstly it allows to be connected wirelessly with the platform, it also multiplies the number of accessible sensors, and then it can detect diseases more accurately by the correlation of physiological signals by identifying the type of sensor. An assistant must be able to both: use multimedia resources in an emergency to communicate with the older person or to observe his condition visually. Moreover, given the constraints due to the humanoid form that greatly complicates the mechanics of a system; we opted for a more rudimentary design that can be better accepted by the elderly. This is the concept of "smart moving nightstand". This platform is developed to allow an elderly person to be autonomous while being connected to the outside world (family and doctors). It would also carry essential items such as eyeglasses or medications of any user by monitoring its essential physiological variables. It is a new open platform for developers interested to compute physiological data and offers the services of wireless robotic assistant.

2 SYSTEM OVERVIEW

The system can be divided into 6 main parts (see Figure 1: Hardware block diagram of the platform.):

- The wireless communications with Zigbee and WiFi.
- Medical sensors (scalable to the needs of the user)
- The multimedia part that plays the role of user interface.
- The processor (SOC ARM 32 bit)

- The motor control to move the robot.
- The power to the battery and charging station.

In this study we focus on the first two issues.

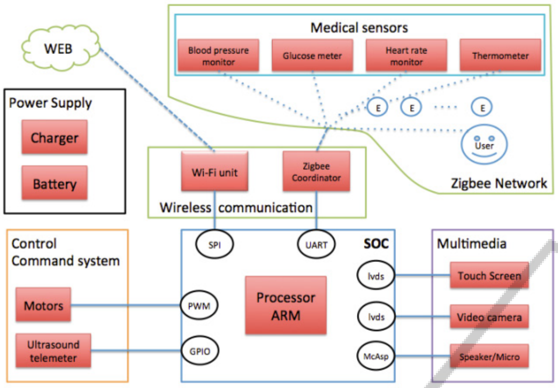

Figure 1: Hardware block diagram of the platform.

2.1 Concept

The principle behind this intelligent platform is that it can blend in with its environment. The aim is to have a "smart nightstand" that can move independently in a home environment (apartment or house). Our goal is that this assistant can navigate, locate and track the user's system when needed. This medical assistant may allow a relative or a doctor to remotely monitor the physiologic data of the user (thermometers, blood glucose meters, blood pressure, pulse oximeters, etc.). It also helps when an alert occurs to visually inspect the patient and if necessary, communicate with him. This platform should also allow the user to access a number of multimedia features such as video conferencing, play multimedia content (movies, music, etc..). The technological system choices were made with the idea that this platform must be accessible to the greatest number of elderly people.

A first prototype has been developed which embodies the concept discussed. We present here the different technologies and techniques to meet the expected functionality.

2.2 Zigbee for Localization and Sensors Communication

2.2.1 Zigbee

The Zigbee technology, based on the 802.15.4 standard and it works on the same frequency band as WiFi, 2.4GHz. This technology has the advantage of having very low power consumption, one have also the opportunity to significantly expand a mesh network (65,000 end-devices). It therefore provides parallel information from many sensors. Additionally, this technology can be used in domotic, allowing the platform to control compatible equipment. Indeed, one of the advantages of ZigBee is its interoperability. The ZigBee Alliance has created this standard to create a consistent communication between multiple devices. This standard is actually a layer (ZigBee Pro Stack 2007) which is placed on top of the 802.15.4 MAC layer handles addresses. It allows to manage the network (topology, security, communication, etc). The Zigbee standard formats the messages sent between the devices. Each device is classified into categories and sub-category (Cluster) and is able according to the categories on which it depends to send or receive specific messages. All these categories are stored in different standardized norms. For our part, we will focus especially on the “Home Automation” standard and the XBEE hardware that is constituted of many analogic channels. The standard home automation can control lights, heating, electrical outlets, smoke detectors or can provide alarms. The XBEE hardware is interesting to collect analogic data from different sensors, in our case medical sensors.

2.2.2 Zigbee for Localization

The localization of the platform in its environment is achieved by Zigbee. For Zigbee network, XBee Pro module was used as a system coordinator. Then, effective way to equip an apartment with Zigbee, would be to place an electrical outlet with Zigbee on each power socket. This will allow it to have a large mesh network covering the whole apartment and allow it to achieve an effective localization. To allow a Zigbee module to be wear by the user, the Zigbee medical solution ZCare of CLEODE was chosen. This sensor allows can monitor: pulse, possible falls of the person, and includes a button to call emergency. Here we can see the interest of Zigbee with the interoperability of a system developed by third parties. This solution allows to locate the person and to perform medical monitoring at the same time.

The localization of a ZigBee module for its part can be determined based on the signal power (RSSI: Receive Signal Strength Indication) sends to other modules.

The signal strength varies with the distance (Blumenthal, et al., 2007):

With: PTX = Transmission power of sender,
PRX = Remaining power of wave at receiver,

GTX = gain of transmitter,
GRX = Gain of receiver,
λ = wave length,
d = Distance betweens sender and receiver,
PREF = power reference (Typically 1mW)
RSSI in dBm.

The RSSI values range between -45 and -100 dBm and therefore it is possible (for a signal on 100m) to trace the evolution of the theoretical RSSI function of distance (Sugano, 2006).

A number of researches have been done on the indoor localization Zigbee (Lau, et al., 2009) (Thomas & Ros, 2005). Based on triangulation algorithms it seems conceivable given the location of a Zigbee module in a room provided by Zigbee module with an error margin of 2m.

In this project, the ZigBee can be used in order to know in what room of the apartment is the user through a zigbee bracelet, and know where the platform is. It would be useful to determine how accurately our platform could determine the position of the user in the room with the RSSI signal to come and watch, and whether this accuracy is maintained in outdoor conditions.

2.2.3 Zigbee for Sensors Communication

Communication with XBee modules on our platform is done by receiving messages with UART written in hexadecimal. The X-CTU software is used to configure the XBee card. There are two possible modes, the transparent mode and API mode. The API mode is more indicated for a network or identification of multiple devices.

In this project we choose to apply the API mode that will help for the computation of different physiological signal by identifying which sensor sends the data. Moreover another type of application could be the localisation of a lost sensor which can be an interesting issue with elderly people.

3 PRELIMINARY RESULTS

Some preliminary results were obtained with our first prototype to show the potential of our approach. In this section we show the potential of our method that can either be a tool for localization and for sending data.

3.1 Distance Estimation with RSSI

It is possible to estimate the distance between two ZigBee modules with the help of the RSSI signal (Received Signal Strength Indication). A relation exist between the value of the RSSI and the distance. In the first experiment, we decided to estimate this relation with our specific hardware. We decide to estimate the distance between the ZigBee module and our robotic platform.

3.1.1 Static Determination of Distance (Indoor)

As state in the introduction, RSSI signal is perturbed by noise but the RSSI signal is more clear and discriminant at short distance (<1.5m).

We realised the following measurement at different distances: 5, 10, 20, 30, 40, 50, 70, 100, 130, 160, 200, 250 and 300 cm. These measures were repeated 10 times at each position to obtain statistically exploitable data. The mean value obtained is represented at Figure 2. This study was conducted in an office room which can be likened to a domestic environment. It can be observed that the RSSI curve is approximately bijective, meaning that the distance can be evaluated. But there is an exception at 160 cm that can be explained by occlusion and reflection of the ZigBee wave due to the objects included in the room.

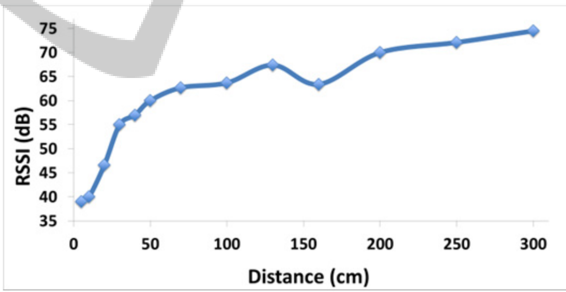

Figure 2: Static recording of RSSI (indoor).

3.1.2 Dynamic Determination of Distance (Outdoor)

In this section we tested with two repetitions the RSSI value in indoor condition when the mobile platform was moving to the target (i.e. Zigbee module) to find whether the motion can lower the accuracy of RSSI signal. We propose a new manner to assess the quality of the obtained points by computing the coefficient of determination (R^2) between these points and a logarithmic curve that fits the points. If the points follow a bijective and logarithmic function as expected ideally, the R^2 will be close to 1. If the R^2 is further to 1 it means that the quality is low and certainly the RSSI signal is perturbed by occlusion, reflection or low intensity signal. In this experiment the R^2 is equal to 0.92 (see

Figure 3) that is compared to 0.96 in the static condition.

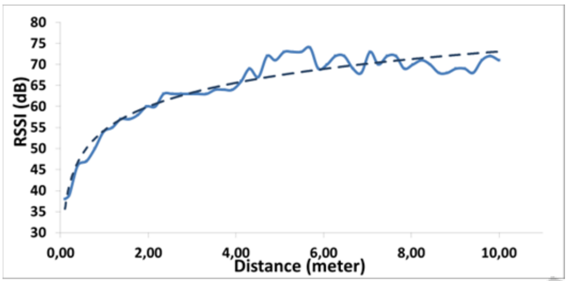

Figure 3: Dynamic recording of RSSI (outdoor).

This result has to be compared to the RSSI data obtained in indoor in dynamic condition. We obtained a R^2 of 0.87 (see Figure 4). We can observed that in this case the curve is much noisy compared to outdoor condition and also compared to static condition where 10 samples were recorded.

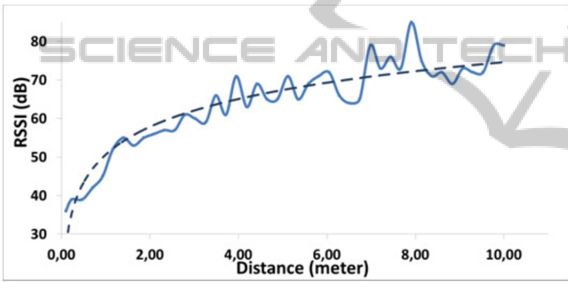

Figure 4: Dynamic recording of RSSI (indoor).

3.2 Send Data from a Sensor

The XBEE technology can be connected to a shield that sends data to a UART port. We developed a software that reads the data from this UART and record it on our platform. As explained before the user holds a sensor using the home automation protocol. Moreover we send wirelessly the data of temperature during a moment when the user grasps the thermometer. This thermometer is a device that we developed for the experiment (see Figure 5).

The temperature of the body where captured (hand temperature) and sent remotely to the robot (see Figure 6). One can notice the ambient temperature around 24° C, the progressive increase around 27°C, the temperature of the hand during the grasping and a progressive return to the former value of ambient temperature.

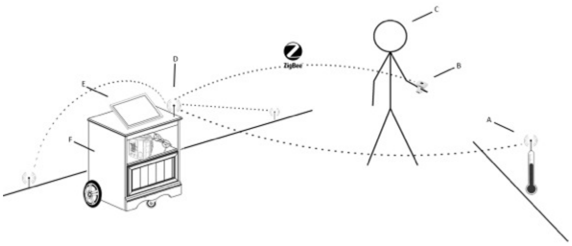

Figure 5: Communication between our robot and the user. A: Zigbee Thermometer, B: ZCare device, C: User, D: Zigbee Coordinator, E: Touch screen and F: Robot.

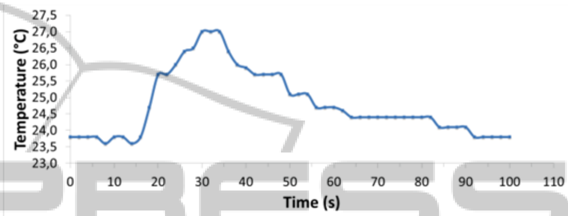

Figure 6: Temperature measurement with ZigBee transmission.

4 DISCUSSION AND FUTURE WORK

We propose an open platform allowing to access the robot at low level. We demonstrated a first proof of concept by sending remotely temperature data. We also presented a method to assess the quality of the RSSI signal. And we showed that outdoor dynamic measurement is more reliable than indoor measurement, probably due to occlusion and reflection of the wave signal. The determination of the distance between the robot and a wireless sensor is essential because this can lead to the localization of the user that wearing the sensor. Another important issue is the localization of a lost sensor which can be solved with the same method. Our ongoing researches are focused on different type of sensors. The development of specific algorithms based on the different sensors is the challenge that we want to promote with the help of the community of developers and researchers involved in health technology.

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