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Embedded system applications for elderly people: State of the art

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Embedded system applications for elderly people: State of the art

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***Abstract*—Today, many researches are focusing on improving human life quality. Many technical devices are present in the market which gives solution to care of elderly person using especially wireless sensors and sensor networks which are playing an important role in research in addition to microcontrollers. Among these devices which are based on embedded systems there is devices which runs machine learning and deep learning models to give better results.**

Keywords—sensor networks; microcontrollers; embedded systems; machine learning; deep learning

I. INTRODUCTION

The aging of the world's population is an irreversible and the 'Old Continent' is aging: the European Commission predicts a 40% increase in the population aged 65-80 in the next 20 years, with a likely ratio of working people to pensioners of just 2:1 by 2050 [1].

According to a study done by the United Nations Department of Economic and Social Affairs, the number of older people (60 years and over) is expected to reach 21% of the world's population by 2050. With an average annual growth rate of 2.4%, they are expected to outnumber young people, as has been the case in some developed countries such as Japan since 1998 [2].

In Algeria, the Algerian Minister of Health has stated that the Algerian population aged 60 and over represents 8.71% of the total population, with a life expectancy of 78 years (in 2020) [3].

The European Commission encourages older people to participate more actively in the workforce and predicts that older people will live longer and more Independently, which could reduce the cost of healthcare for older people to alleviate the financial crisis this scenario could cause in most countries [4].

The main problem of older people is dependency. Dependency is defined as the total or partial inability to perform certain essential acts of daily life without the assistance of a third party. Their need for medical assistance is due to their physical (eg: walk, sight) or cognitive (eg: memory loss) impairments. According to an Indian study by the National Disability Council (NDC), more than 90% of people aged 65 years and above take at least one medicine every week, 40% take five or more and 12% take ten or more. The study also shows that most people forget to take their medication or to take it on time [5].

For this reason, older people need to be less dependent. The integration of technology and communication systems with the elderly is a solution to this problem, with several products already on the market: small devices that are provided by sensors, computing units and displays that are all embedded in a small accessory (e.g. a bracelet).

In this paper, we present the existing applications for older people and we study the different communication protocols used with Raspberry Pi as a microcontroller which can be used to develop embedded systems and make templates and try them before the real release.

II. RELATED WORK

Since the raise of the number of older people around the world the need for assistive technologies to take care of them became indispensable. Many researches have been done and many assistive devices based on embedded systems have been released.

Ageing technology, also called "gerontechnology", is a new discipline dedicated to the use of new technologies in the field of ageing. These technologies can meet most of the needs expressed by older people and have the capacity to complement and improve the productivity of caregivers.

There is many geriatric technologies, we mention:

- **Information and communication technologies:** are based on recent developments in the fields of computing, multimedia, the Internet, audiovisual and telecommunications. ICTs enable older people to maintain a link with their relatives, care staff and doctors. They provide access to knowledge and culture (Internet), and now make it possible to participate from home (Web 2.0).

- **Technologies for personal mobility and transport:** These are mainly location and navigation systems. In the outdoor environment, car or walking navigation is mainly based on GPS technology. In the indoor environment, there is no standard but a multitude of systems based on different technologies (radio frequency, optical, ultrasound, inertial sensors, etc.) [6].

- **Technologies for accessibility and disability compensation:** these help people who have trouble moving around or who have disabilities carry out

tasks on their own. To solve the problem of these people with their environment, furniture, home automation solutions that allow furniture to be adapted to the disability. As an example, motorized stairlifts (Figure 1) are good solution to people who find difficulties in climbing stairs, motorized wheelchair (Figure 1) compensate the disability of walking.



Figure 1. Motorized stairlift and wheelchair

- **Technologies for security and protection of property and people:** For property surveillance, there are generally intrusion detectors, security cameras and alarm systems. For the detection of domestic hazards, these include gas, smoke, water leakage and fall detectors. Some recent systems allow the monitoring of the health status of the person on a daily basis, with systems embedded in the environment or worn by the person that can measure vital parameters directly on the body (heart and breathing rates, temperature, etc.) or the activity of the person. Finally, assistive robotics can also be used in this category to detect a situation of danger for the person, or to confirm an alert triggered by another system (e.g. fall detector), before sending the alert to an emergency service, Vigi'Fall (Figure 2) is a good fall detector which is widely used in Europe [23].



Figure 2. Fall detection system: Vigi'Fall

In the following, we present some of the available applications based on previous researches and the existing commercialized devices.

In [7], Léonard Angelini, Nathalie Nyffeler and their team presented a design process for a smart bracelet (Figure 3) that aims to improve the lives of elderly people. The bracelet acts as a personal assistant during the user's daily life, monitoring health status and alerting to abnormal conditions, reminding of medication and facilitating daily life in many outdoor and indoor activities.



Figure 3. Sketch of the smart bracelet

The proposed smart bracelet not only offers health monitoring functionality, but also aims to facilitate daily tasks both indoors and outdoors, Following Bright and Coventry's [8] guidelines for the design of assistive technologies.

Following a user-centered approach, the design process will involve several iterations and the evaluation of prototypes with older people. Preliminary interviews will be used to refine the product design in order to create a new mock-up that will be used to perform a usability evaluation. The proposed functionality will be simulated using a Wizard of Oz technique.

By analyzing the result of this second evaluation, we will build a functional prototype that will be tested again by elderly people.

In another work, Jian Hu, Junjie Wang, and Hangqi Xie [9], presented a study on the design of wearable bracelets with variable sampling rate to measure multiple human physiological parameters.

In this paper they discuss a design method to measure multiple physiological parameters of the human body with multiple sampling frequencies. The bracelet collects three physiological parameters of oxygen saturation of blood, energy consumption during exercise and body temperature of a sporty human body. At the same time, in order to improve the endurance of a healthy wristband, a variable sampling rate scheme is designed using the BP neural network algorithm, and all physical health information can be determined based on heart rate. STM32 combined with a host computer is used to verify the design method. It can monitor human physiological parameters in real time and perform a comprehensive assessment of human health by recording changes in human health information.

Miskelly presented a study [10] on the use of electronic prisoner monitoring bracelets on elderly people with dementia.

Widely used in Europe, these bracelets are equipped with a radio transmitter which allows them to be permanently present in the security zone, to a remote control center. It can also detect access to high-risk areas. In later work [11], the author proposed a system for detecting wandering situations using a GPS-enabled phone. The phone sends the position of the phone's owner to a central station, following a request from the latter, every five minutes. The advantage of this system is that users and their families have to fill in a survey about the usual journeys made by the phone holder. This principle makes it possible to considerably minimize false

alerts. In addition, the system takes into account the timetable in the definition of the security zones (e.g. an area considered secure during the day is no longer secure at night).

Wristbands are widely used in the world due to the features delivered and the ease of use, in the following we present some of the commercialized systems

- **Vivago Care:** is a wristwatch (Figure 4) designed by the Finnish company "Vivago Pro" [12]. It is an alarm system that measures the person's activity level. Equipped with an accelerometer (movement sensor), it detects micro and macro movements of the wrist muscles, the wrist itself, and the body, in order to establish a profile of activity and non-activity (night period) of the person.
  It automatically sends the information every 20 seconds to a PC viewing station via its built-in radio transmitter module, which can be consulted by medical or monitoring staff.
  The watch is equipped with two types of alerts: automatic and manual. It can raise an alert automatically if it detects an unusual variation in the person's activity profile, such as moving outside the radio coverage area. The use of the watch has been validated in Finland on 83 elderly people living at home or in assisted living facilities [13]. During more than three months, the watch detected 1.2 to 3.5 alerts per day per user; the number of manual alerts varied between 0.3 and 1.9 alerts. From the point of view of acceptability, the watch was worn 94% of the time of the experiment.



Figure 4. Vivago Care wristwatch

- **The Columba bracelet-phone** [14] is one of the first devices against runaway, launched in France since 2007.
  It was developed by Orange in partnership with a Canadian company "Medical Intelligence Technologies".
  The bracelet (Figure 5) is equipped with GPS-assisted geolocation and a GSM/GPRS transmitter/receiver, as well as alert transmission software, enabling it to perform three main functions:
  - Trigger an alarm when leaving the area (radius of 500m around the house).
  - Define the geographical location of the wearer of the bracelet.
  - Make a call to the family or medical staff.

  Once the wearer of the bracelet has left the predefined boundaries, the 24/7 medical call center is automatically alerted and can quickly contact family or caregivers to coordinate assistance.
  A weakness of the wristband is that the safety limits must be predefined, which increases the incidence of false alarms for leaving the area [15]. The device is no longer available.



Figure 5. Bracelet-phone Columba

- **The BlueGard bracelet** [16], it which replaces the Columba, is marketed in France by the company Bluelinea. It aims to guarantee vulnerable people autonomy and security of movement in their living environment. Equipped with GPS and GSM/GPRS, this bracelet (Figure 6) can alert medical staff or the family if the wearer is located outside the predefined area (the distance can vary from 500 meters to several kilometers).
  Inside the home, the bracelet deactivates the GPS in order to reduce energy consumption, leaving only the RF (Radio Frequency) connection with a docking station that allows remote battery recharging. This method of recharging saves the family from having to remove the bracelet from their wrist.



Figure 6. BlueG bracelet

In the context of the covid-19 pandemic, continuous health surveillance becomes important, and for this purpose Aritri Debnath et al [17] have done a study and proposed a portable health care module that helps to track the health status of a patient using various parameters such as heart rate, carbon dioxide exhalation, body temperature and electrical heart recording (ECG). This monitoring can be done without the presence of a doctor. This module is useful in monitoring the health of patients who are in quarantine or under treatment in a hospital. It can also be used to monitor the health of elderly and disabled patients.

The proposed model focuses on monitoring human body parameters. It processes the data collected using the IoT based system supported by cloud platforms. It provides global respiratory health monitoring and asthma prediction using machine learning. Additional data is stored in the database. They used THINGSPEAK as a database for the IoT data.

This model (Figure 7) is capable of testing pulse rate, ECG, exhaled CO2, temperature. The hardware configuration consists of a sensor system (a CO2 sensor, a heart rate sensor, a temperature sensor and an ECG sensor) to collect the body parameters, an STM32 processor to process the input data, a module to transmit the data to mobile phones and an LCD screen to display the values. A wireless camera is also used for monitoring patients in remote locations.

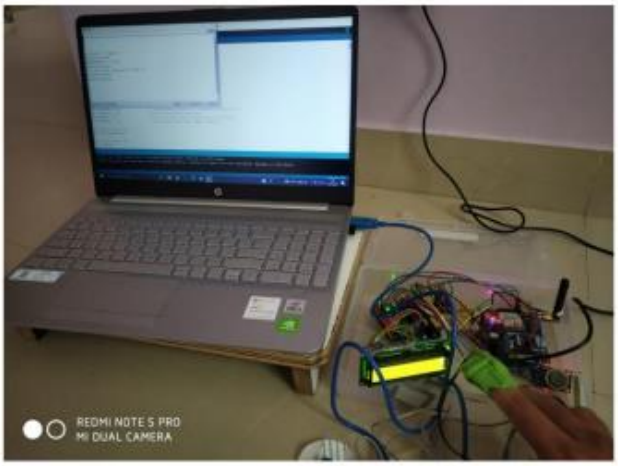


Figure 7. Materiel settings

The proposed model focuses on predicting potential heart disease in people using Machine Learning algorithms such as K Neighbors Classifier, Support Vector Machine, Decision Tree and Random Forest Classifiers.

Akash Gupta, Rohini Srivasava and their team [18] proposed a fall detection system for elderly people. A real time monitoring and fall detection is very crucial for immediate medical intervention whenever needed. In their work they propose a fall detection framework based on medical sensor for medical data acquisition and transmission module or an IoT enabled cloud-based diagnostic tool. A Raspberry Pi microcontroller is used which is a fully functioned computer. It is a system on chip (SOC) device which have an integrated Wi-Fi module which makes it easier to transmit data to the cloud server. Figure 8 illustrates the block diagram of the fall detection system.

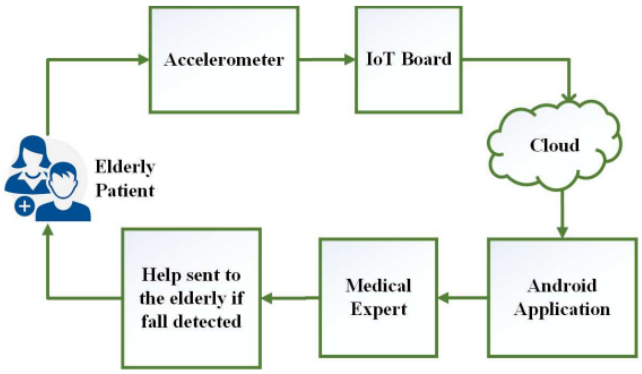


Figure 8. Block diagram of the fall detection for elderly

The system has two wearable sensors: accelerometer and gyroscope for measuring acceleration and angular velocity connected to a raspberry pi. The sensors collects the data and send it to the cloud. An android application has been developed to alert the medical staff whenever a fall is detected by the sensor systems, the data from cloud are sent to the application, the help will be sent to the elderly. Data transmission from Raspberry Pi to the cloud server (Google Cloud) is ensured by Google Sheet API (Application Program Interface).

The fall detection system is based on measuring the body net acceleration A_{net} and the angle of falling measured by two parameters: Pitch and Roll (to differentiate between a fall and a daily life activity such us lying down, setting …). Figure 9 illustrate the falling of subject.

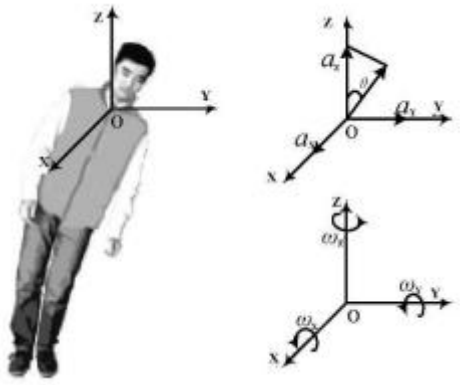


Figure 9. Falling subject illustration

In general the fall detection is based on A_{net} , Pitch and Roll parameters:

- A_{net} value will decrease when fall occurs. A fall is determined when it this value goes below a threshold (in this case, 0.8 g).
- Pitch and Roll of the elderly are compared with threshold θ (in this case, θ should be greater than 60 degrees).

The figure 10 below shows more details about the fall detection process.

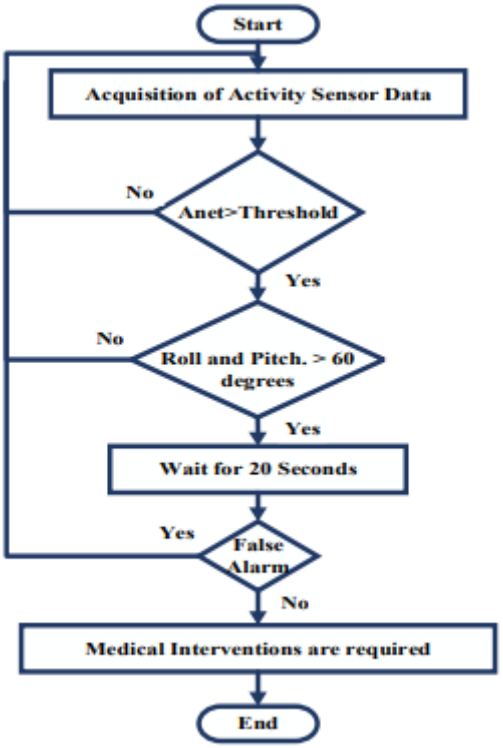


Figure 10. Fall detection flowchart

Ge Zheng, Hongtao Zhang, Keming Zhou, Huosheng Hu [19] studied using machine learning techniques to optimize fall detection algorithms in the smart bracelet. In their work they presented a machine learning approach to improve the accuracy of fall detection and reduce false alarms. Three machine learning algorithms are deployed in this research, namely K-Means, Perceptron Neural Network (PNN) and Convolutional Neural Network (CNN) algorithms.

A development board with a 9-axis inertial sensor unit is used as a prototype wristband to collect data and identify falls from seven daily activities. This data is then used to train and test machine learning algorithms. Experimental results show that the CNN algorithm achieves the highest accuracy compared to K-mean, PNN and the algorithm used in existing wristbands.

III. RASPBERRY PI'S COMMUNICATION PROTOCOLS USED IN EMBEDDED SYSTEMS

Raspberry Pi (Figure 11) is a series of small single-board computers that contain a processor, graphics card and memory. All these models are combined in a small sized board.



Figure 11. Raspberry Pi board

Raspberry Pi is widely utilized in many different fields, especially in IoT and embedded systems due to the features it has. The board contain different communication protocols which are needed in developing embedded systems.

A communications protocol is a set of formal rules describing how to transmit or exchange data, particularly across a network. Communication protocols like Wi-Fi, Bluetooth, and I2C are said standard. A standardized communications protocol is one that has been codified as a standard [20].

Communication protocols in embedded systems are classified into two types:

- Inter System Protocol: They ensure communications between two devices (eg: PC and microprocessor, development board, etc.), USB, UART, USART are considered Inter communication protocols.
- Intra System protocol: They ensure communication between components (eg: sensors) on the board. They expand the network of connected components to the controller. I2C, SPI, CAN are considered to be in this type.

In the mentioned applications for elderly people, the systems are generally a network of sensors and remote control device. In the following we focus on the protocols that are used in these systems.

I2C communication protocol: It is a serial communication protocol which can connect many peripheral chips with microcontroller. It need two wires SDA (Serial Data Line) and SCL (Serial Clock Line) to ensure bidirectional communication. It is a master to slave protocol, each slave is given a distinct address.

To establish a communication, the master device transmit the target slave address along with R/W (Read/Write) flag. Other devices will remain in the off state while the targeted slave device switches to the active mode. Communication between the master and slave devices begins as soon as the slave device is prepared. If the transmitter transmits 1 byte (8 bits) of data, the receiver responds with a single bit of acknowledgment. At the conclusion of device-to-device communication, a stop condition is issued [21]. Figure 12 illustrates the protocol diagram

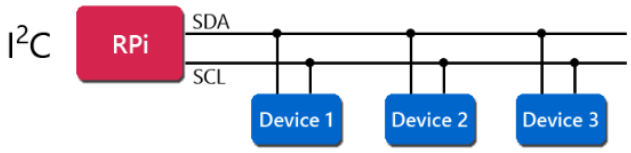


Figure 12. I2C diagram

Serial Peripheral Interface (SPI): It is a communication protocol developed by Motorola. It ensure communication through 4 wires (MOSI: Master Out Slave In, MISO: Maser In Slave Out, SS: Slave Select, SLCK: Serial Clock).

It is also a master to slave protocol, the master unit sets the clock at a particular frequency and SS is used for appropriate slave selection by pulling SS low where it is normally held high. Once a slave is selected the communication is established. Figure 13 shows how devices are connected

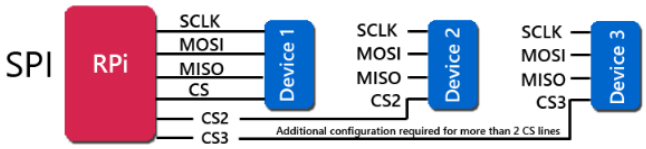


Figure 13.SPI diagram

Constrained Application protocol (CoAP): CoAP is a transfer protocol specifically designed for use with the web, constrained nodes, and constrained networks [22].
The protocol is excellent for use inside the IoT systems and was created for Machine-to-Machine (M2M) applications.

The protocol's low power consumption and minimal network overhead enable reliability in conditions of limited bandwidth and high congestion. CoAP can continue to function in networks with high congestion or poor connectivity when TCP-based protocols like MQTT are unable to effectively exchange data and communication effectively. The fundamental network protocol for COAP is UDP. In general, COAP is a client-server IoT protocol where the client sends a request and the server responds, similar to how HTTP works [23].

IV. Conclusion

In this paper we have presented the different embedded systems used for the care of elderly people.

Smart wristbands have shown good features and proved that they are effective in assisting older people.

We have also presented the Raspberry Pi board and some of the important communication protocols used in embedded systems designed for elderly people.

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