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Design of a Prototype Remote Medical Monitoring System for Measuring Blood Pressure and Glucose Measurement

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Abstract

Objectives: This article describes the development of two prototypes supported in the e-Health Sensor Shield V2.0 Arduino low as processing architecture, in order to manage and monitor physiological parameters related to the prevention of Chronic Noncommunicable Diseases (NCDs) is presented. **Methodology:** The introduction of Information Technology and Communications (ICT) in the health sector have fostered the creation of new approaches that encompass related to prevention, care, management and health education, offering alternatives to address traditional problems activities. **Findings:** The ultimate purpose of the system is to encourage user self-care culture and healthy lifestyles as obesity, hypertension and diabetes are now considered as a focus of health programs. **Application/Improvements:** Prototypes allow the capture, analysis, processing and remote transmission via internet biometric data (glucose and blood pressure) that can be accessed from any device.

Keywords: Arduino, Diabetes, e-Health, Hypertension, Telemedicine, NCCD

1. Introduction

The World Health Organization (WHO) have been reiterating for more than 25 years and included in its agenda and program priorities, universal coverage, promotion and prevention health as determinants in fulfilling its objectives and functions for the improvement of the health of the population of the member states (Organization World Health) factors[1].

Colombia for its part, committed to international guidelines has been taking steps to integrate ICT in the health field; Law 1419 of 2010 establishes guidelines for the development of what has been called the "Telehealth" being this "set of health-related services and methods activities, which are carried out remotely with the help of ICT and Telecommunications" and allocates a budget to finance the development of telehealth in the country. Likewise, the Law 1438 of 2011-Congress of Colombia, includes provisions to establish the universality of insurance and guarantee portability or providing health benefits anywhere in the country, all it framed in the strategy "Attention primary Health" to coordinate the State, institutions and society for the improvement of health and the creation of a healthy and healthy environment that provides services of higher quality, inclusive and equitable.

Given the above and because it has become a public health problem for the country, prevention and control of risk factors that determine the appearance of NCDs are a focus of the programs that the Ministry of Health together with MinTIC being promoted with a view to controlling

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these increasing numbers and constant improvement of health services[2,3].

Based on the above statements the following question arises: How can we contribute from telematics to the prevention of chronic non-communicable diseases NCDs? This article seeks to develop the prototype of a telematic system for the prevention of chronic non-communicable diseases applied to high blood pressure and diabetes.

2. Materials and Methods

2.1 Non-Communicable Chronic Diseases

Called non-communicable diseases (also known as chronic or degenerative) constitute the group of diseases that cause greater disability and death in the population. These diseases are called chronic for long time they need to demonstrate the individual and generate you some discomfort or death; and "non-communicable" because not transmitted from one individual to another, that is a healthy person, although in direct contact with the patient, not spread disease. Non-communicable diseases: Cardiovascular, cancer, diabetes, obesity, arthritis, chronic lung disease and chronic neurological[4].

2.1.1 Obesity

Overweight and obesity are defined as abnormal or excessive fat accumulation that can be harmful to health. This occurs when energy consumption exceeds energy expenditure over a long period of time and its origin is both genetic and environmental[4].

The Body Mass Index (BMI) is a simple indicator of the relationship between weight and height that is commonly used to identify overweight and obesity in adults. It is calculated by dividing a person's weight in kilos by the picture of your height in meters (kg/m^2). According to WHO, a BMI = or greater than 25 determines overweight, if less than 30 determines obesity, as shown in Table 1.

Table 1. WHO classification results according BMI

BMI results	Classification of Obesity
<18	Underweight
18 to 24.9	Normal weight
25 to 26.9	Overweight
27 to 29.9	Grade I obesity
30 to 39.9	Grade II obesity
> 40	Obesity grade III

2.1.2 Arterial Hypertension

Hypertension is a disease characterized by a continuous increase in blood pressures in arteries. To understand it is important to define better blood pressure. It exerts pressure on the heart arteries for this lead blood to the organs of the human body. This action is what blood pressure is known. The maximum pressure is obtained at each contraction of the heart (systolic) and minimum, each relaxation (diastolic)[5].

Although there is no strict threshold to define the boundary between risk and safety, according to international consensus (Table 2), a sustained systolic pressure above 120-129 mmHg or a diastolic pressure greater sustained 80-84 mmHg, are associated with a measurable increased risk of arteriosclerosis and thus is considered a clinically significant hypertension[6].

Table 2. Classification of hypertension according to WHO

Blood Pressure Level (mm Hg)		
Category	**Systolic (mm Hg)**	**Diastolic (mm Hg)**
optimal	<120	<80
Normal	120-129	80-84
Normal High	130-139	85-89
Arterial hypertension		
Hypertension grade 1	140-159	90-99
Hypertension grade 2	160-179	100-109
Grade 3 hypertension	≥ 180	≥ 110
ISH	≥ 140	<90

2.1.3 Diabetes

Diabetes mellitus is characterized by an increase in the amount of blood sugar. Normally, blood flows in a certain amount of sugar. This sugar is called glucose and by blood is sent to all body cells that transform energy. The hormone insulin is essential for glucose to enter cells. When the amount of insulin produced by the body is insufficient to the amount of glucose that are circulating in the blood (increased glycemia) then the disease called diabetes occurs[7–9]. Table 3 presents what glucose levels depending on the condition.

Table 3. Glucose levels according to the American Diabetes Association

Classification	You fasted (Unconsumed food)	postprandial (Two hours after eating)
without diabetes	70 to 100 mg/dl	Less than 140 mg/dl
pre diabetes	100 to 125 mg/dl	140-199 mg/dl
Diabetes	More than 126 mg/dl	More than 200 mg/dl

2.2 Telemedicine, Telehealth and E-Health

Telemedicine is a term that has been known since the 70s from the use of existing communication tools for the practice of medicine at a distance. Currently the World Health Organization defines telemedicine as "the provision of health care services, where distance is a critical factor for professionals who appeal to information technology and communication to exchange information make diagnoses, advocate treatments and prevent diseases and accidents, as well as continuing education of professional health care and research and evaluation in order to improve the health of people and communities in which they live"[10].

This definition expands the term to include education, further comprising the medical act transmitted for diagnosis or therapy, the transmission of this to educate both other health professionals and the population itself. With increased possibilities given technology for assistance in health the term "telehealth" which encompasses "the application of information technologies and telecommunications to transfer information from health care to provide clinical services appears, administrative and educational. "E-health is the term that refers to all forms of electronic health care made through internet and that ranges from basic information to services provided by professionals or by consumers themselves[11].

From the different concepts that have emerged with the development of telematics and its applications in health, there have been initiatives focusing on promotion and prevention of obesity, hypertension and diabetes. As indicated[12], remote monitoring of health status of medical patients is becoming an option to consider replacing in some cases hospitalization or home visits. On the other hand, it argues that advances in mobile communication technologies such as smart phone have been considerable and makes use given the characteristics of hardware and connectivity offered by these devices useful. For this reason, it is convenient to think of solutions that reduce complications for both patients and medical specialists[13].

In addition, given the large amounts of information that allow use ICT and the growing need for customization of software systems, appears what is called Personal Health Record (Personal Health Record - PHR), which is a repository used by patients represent and manage your health information in a private, secure and confidential[14].

3. Results

3.1 Prototype Development

To develop the prototype will use the Shield called e-Health Sensor Shield V2.0, which is part of the new generation of e-Health products and medical development specifically aimed at researchers, developers and manufacturers, facilitating the development of Arduino prototyping or supported on Raspberry Pi[13]. In Figure 1, the physical appearance of e-Health Sensor Shield V2.0 illustrated.

The e-Health Sensor Shield V2.0 allows users Arduino and Raspberry Pi perform biometric and medical applications capable of monitoring up to 13 different sensors: Pulse, blood oxygen, air flow, body temperature, electrocardiogram, glucometer, galvanic skin response, blood pressure, accelerometer, electromyography, snoring, spirometer and body scale (Figure 2). Additionally, the system easily allows the inclusion of the following elements during application development:

- Cloud Storage data to store historical information.
- Apps/native iOS that can be used to display information in real time and explore data Cloud.

The platform will monitor in real time and remotely, the state of a patient for further analysis and medical diagnosis. The biometric information collected can be sent wirelessly for later viewing via mobile devices or laptops. It is important to mention that the selection of wireless connectivity is subject to conditions consistent Internet connectivity and geographical location of the patient.

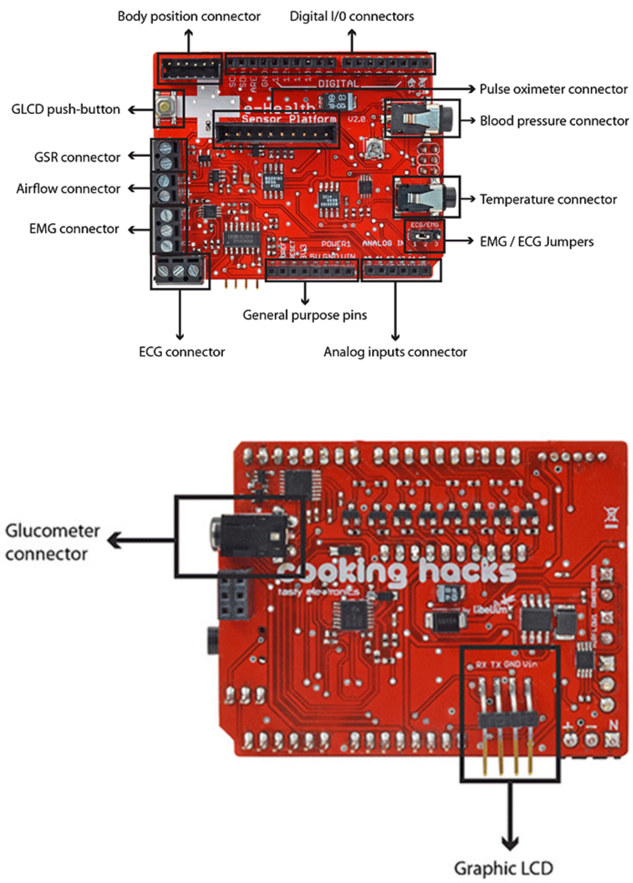

Figure 1. e-Health sensor shield V2.0.

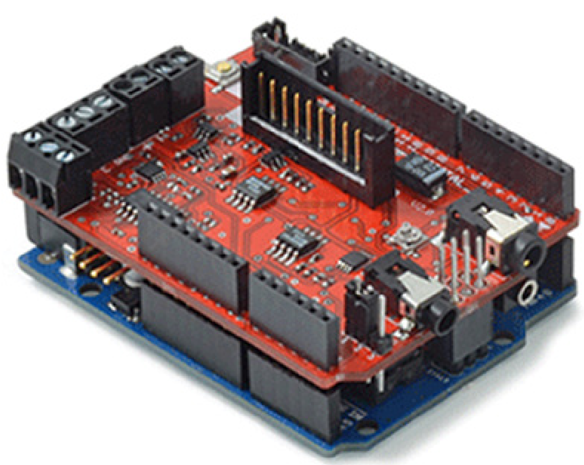

Figure 2. E-health sensor shield V2.0 under Arduino platform.

3.1.1 Prototype for Measuring Glucose Levels in Blood

The proposed equipment is a medical device for the approximate measurement of glucose in the blood and shows the level in mg/dL or mmol/L. In Figures 3-4, the kit required and the procedure for taking the blood sample and glucose measurement is illustrated by the glucometer[15]. During sampling, the meter may take a moment to calculate the reading of blood sugar, storing the result obtained in the EEPROM memory device. After this, the Arduino module extracts the information contained in the glucometer.

During the extraction process records Glucometer Arduino, it is necessary to connect between the glucometer and the shield as illustrated in Figure 5. To verify that the equipment is connected and ready to transmit the information to the cloud, the meter will display on the screen of the glucometer the message “PC”.

In order to program the Arduino, it will use eHealth.h library, developed by Engineer David Gascon Libelium Company, which has GNU license and can be adjusted according to the needs of the developer. The library has the eHealth.readGlucometer (function), which initializes the meter and through the eHealth.glucose DataVector instruction [i] glucose, it is possible to read each of the values recorded in the memory. Here is an example of coding suggested on Arduino platform for the acquisition of glucose levels is as follows (Figure 6).

In Figure 7, the result is illustrated for making three samples under the use of the prototype developed.

Figure 3. Kit for measuring blood glucose compatible with e-Health Sensor Shield.

Figure 4. Procedure for taking blood sample.

Figure 5. Connecting the glucometer to e-Health sensor shield V2.0.

Figure 6. Example of coding suggested on Arduino platform.

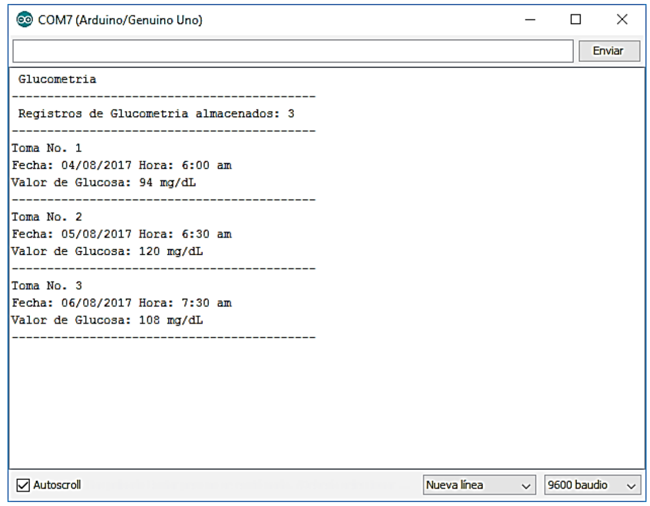

Figure 7. Results obtained under use glucose meter developed.

3.1.2 Prototype for Measuring Blood Pressure

Blood pressure refers to the force exerted by the blood against the walls of the arteries. When the heart beats, it contracts and pushes the blood through the arteries to the rest of the body, generating pressure on the arteries. Blood pressure consists of two values: systolic and diastolic pressure (Table 4).

Monitoring of blood pressure at home is important for many people, especially if you have high blood pressure. Blood pressure is influenced by several factors, including body position, breathing or emotional state, exercise, sleep and status can change throughout the day. An important aspect when it comes to measurement of blood pressure is done when the patient is relaxed and sitting or lying[16].

High blood pressure (hypertension) can lead to serious problems such as heart attack, stroke or kidney disease. High blood pressure usually has no symptoms, so it is recommended that the patient perform control and continuous monitoring of blood pressure. The main features of the sphygmomanometer for measuring blood pressure can be mentioned[16]:

- Measurement Method: Oscillometric System.
- Display Type: digital LCD 97 mm [L] x 87 mm [W].
- Measuring range: 0-300 mm Hg pressure.
- Pulse 30 ~ 200 w/min.
- Measurement accuracy: ≤ 3 mm Hg Pressure.
- Pulse ≤ 5%.

- Operating environment: Temperature 10-40.
- Relativa ≤80% humidity.
- Power supply: 4 AA batteries.
- Dimension: 150 mm [L] x 110 mm [W] x 65 mm [H].
- Weight: Approximately 370 g.
- Cuff size: 520 mm [L] x 135 mm [W].
- Cuffs range: 220 mm [L] – 320 mm [W].

In Figure 8, the way in which the cuff should be used for blood pressure measurements, which may take a moment to perform reading and then proceeds to record the pressure values obtained in the memory of the instrument illustrated. Figure 9 shows the connection diagram of the sphygmomanometer to Arduino occurs.

In order to make programming Arduino, will use again the eHealth.h library. The library has the eHealth. readBloodPressureSensor () function, which initializes the sphygmomanometer and through the instructions eHealth.getSystolicPressure (i) and eHealth.getDiastolicPressure (i), reading the register i corresponding to the systolic pressure is carried out and diastolic respectively recorded in the memory.

Next, an example of suitable form is illustrated for the process of reading the systolic and diastolic pressure measured by sphygmomanometer, which are stored in class variables private e-Health. An c for acquiring blood pressure levels is presented (Figure 10):

In Figure 11, the result obtained when taking three samples under the use of the prototype developed illustrated.

Table 4. Classification of blood pressure for adults (over 18 years)

	systolic (Mm Hg)	diastolic (Mm Hg)
hypotension	<90	<60
Desired	90-119	60-79
prehypertension	120-139	80-89
Stage 1 Hypertension	140-159	90-99
Stage 2 Hypertension	160-179	100-109
hypertensive Crisis	≥ 180	≥ 110

```
#include <eHealth.h>
void setup ()
{ Serial.print (F ( "glucose measurement"));
  eHealth.readGlucometer ();
  Serial.begin (9600);
  delay (100);
}
void loop ()
{ uint8_t numberOfData = eHealth.getGlucometerLength ();
  Serial.print (F ( "Records stored glucose measurement"));
  Serial.println (numberOfData, DEC);
  delay (100);
  for (int i = 0; i <numberOfData; i ++) {
    Serial.println (F ( "------------------------------------------ ---------------------- "));
    Serial.print (F ( "Take No."));
    Serial.println (i + 1);
    Serial.print (F ( "Date"));
    Serial.print (eHealth.glucoseDataVector [i] .day);
    Serial.print (F ( "/"));
    Serial.print (eHealth.numberToMonth (eHealth.glucoseDataVector [i] .month));
    Serial.print (F ( "/"));
    Serial.print (2000 + eHealth.glucoseDataVector [i] .year);
    Serial.print (F ( "Time"));
    Serial.print (eHealth.glucoseDataVector [i] .hour);
    Serial.print (F ( ":"));
    Serial.print (eHealth.glucoseDataVector [i] .minutes);
    if (eHealth.glucoseDataVector [i] == .meridian 0xBB)     Serial.println (F ( "pm"));
    else if (eHealth.glucoseDataVector [i] == .meridian 0xAA)
      Serial.println (F ( "AM"));
    Serial.print (F ( "glucose value"));
    Serial.print (eHealth.glucoseDataVector [i] .glucose);
    Serial.println (F ( "mg / dL"));
  }
  delay (20000);
```

Figure 8. Using the sphygmomanometer for sampling.

Figure 9. Connecting Arduino sphygmomanometer.

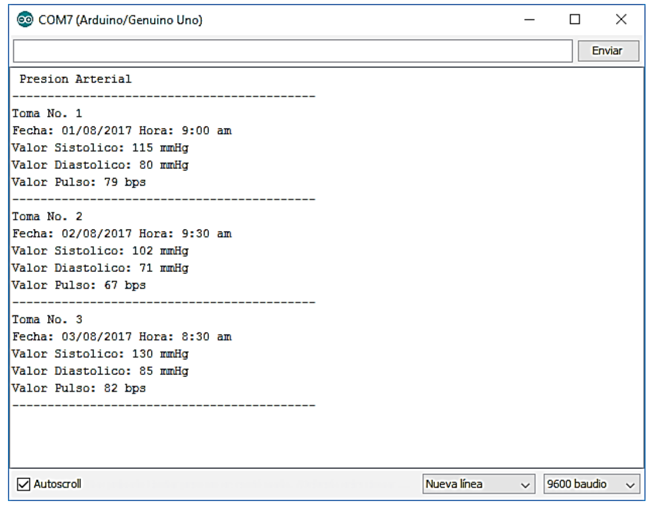

Figure 11. Results obtained under the use of blood pressure meter developed.

```
#include <eHealth.h>
void setup ()
{ Serial.print (F ( "Hypertension"));
  eHealth.readBloodPressureSensor (); // Initialize Device
  Serial.begin (9600);
  delay (100);
}
void loop ()
{ uint8_t numberOfData = eHealth.getBloodPressureLength ();
  for (int i = 0; i <numberOfData; i ++) {
    Serial.println (F ( "------------------------------------------- -------| "));
    Serial.print (F ( "Take No."));
    Serial.println (i + 1);
    Serial.print (F ( "Date"));
    Serial.print (eHealth.bloodPressureDataVector [i] .day);
    Serial.print (F ( "/"));
Serial.print (eHealth.numberToMonth (eHealth.bloodPressureDataVector [i] .month));
    Serial.print (F ( "/"));
    Serial.print (2000 + eHealth.bloodPressureDataVector [i] .year);
    Serial.print (F ( "Time"));
    Serial.print (eHealth.bloodPressureDataVector [i] .hour);
    Serial.print (F ( ":"));
    Serial.println (eHealth.bloodPressureDataVector [i] .minutes);
    Serial.print (F ( "systolic"));
    Serial.print (30 + eHealth.bloodPressureDataVector [i] .systolic);
    Serial.println (F ( "mmHg"));
    Serial.print (F ( "diastole"));
    Serial.print (eHealth.bloodPressureDataVector [i] .diastolic);
    Serial.println (F ( "mmHg"));
    Serial.print (F ( "Pulse value:"));
    Serial.print (eHealth.bloodPressureDataVector [i] .pulse);
    Serial.println (F ( "bpm"));
  }
  delay (20000);
}
```

Figure 10. Example of coding suggested on Arduino platform.

4. Conclusions

A concern that achieving prevention of diseases such as obesity, diabetes and hypertension, has generated worldwide initiatives from various sources, mainly focused on finding ways to monitor and control common risk factors as well as generate and strengthen healthy behaviors in people. In response, the design and development of two prototypes inexpensive, whose main objective is the measurement of blood pressure and glucose levels in the blood, as technology strategy for monitoring and control of chronic non-communicable diseases such was considered such as hypertension and diabetes. The result was quite satisfactory.

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