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Design for IoT Embedded Board for Monitoring Biomedical Signals in Telemedicine

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***Abstract*—Due to the covid-19 pandemic, people were forced to spend the last 2 years in confinement due to the high rate of contagion that it presented. As a consequence, the term of telemedicine reappeared, many medical consultations went tothe technological level, thus reducing the contact of people with the possible contagion from abroad, but the effectiveness of the consultations decreased since the touch and use of the equipment with those that doctors count to monitor the signals that the body provides to know its status.**

In this investigation, an embedded board with IoT functions was developed to monitor the vital signs of a person through analog and digital sensors, using a TCP protocol to transport the data. Using communication with the Ubidots web application for real-time data reading and data collection, thus creating a medical history to be analyzed by the doctor and having a better vision of possible risk scenarios in the patients health.

The results were accepted as healthy people were examined in a controlled environment. The final prototype design proved to be effective and was reviewed by healthcare professionals who found that a tool like this could be very useful.

***Index Terms*—IoT, Telemedicine, vital signs, embedded board, TCP**

I. Introduction

In the era of the coronavirus disease, the need to reduce face-to-face medical consultations without compromising the quality and access of this essential service was seen world-wide, thus revitalizing telemedicine.[1].
IoT technology allows a connection of objects such as embedded systems, sensors or software with the purpose of being able to exchange this information through the Internet. In the health area, IoT technology contributes mainly to monitoring patients and thus knowing their health status in real time.

II. Theoretical Framework

Technological growth in recent years has made devices increasingly smart, making use of the Internet of Things, keeping these smart devices interconnected with each other. This has allowed a large number of services in different areas to be teleoperated, thus giving birth to the concept known as the Internet of Things.

In medicine, the concept of telemedicine has been used in recent years, this concept has not been optimal given that it focuses more on teleconsultations, leaving the measurement of the patient's physiological data in uncertainty, preventing doctors from giving an accurate diagnosis and accurate and consequently giving an erroneous service to patients.
Medicine and technology are two branches that should work together to develop devices that make it easier for health professionals to collect information from their patients, given that the population increases exponentially, resulting in an increase in numbers of patients in hospitals, making it even more difficult for doctors to give quality care to them.
The measurement of physiological variables outside of public institutions is usually very expensive, since the measurement equipment for these variables has high prices and most of them do not have the ability to upload this data to an online platform.
The Internet of Things (IoT) is a tool that can make it much easier to obtain patient data, since devices can be built with the use of these technologies that allow data to be obtained and communicated to a health service. Allowing doctors to observe in real time the conditions of their patients.
It's important to expose the situation both in the macroenvironment and in the microenvironment of the current technologies used in the IoT and the monitoring of physiological signals thanks to this technology.

A. Macroenvironment

- China

China possess a large population and even more so a large industrial framework within the country. It is thanks to its economic development that its industrial areas and consumption have increased.[2] affirms that it is thanks to this that both the production field and home consumption have increased their demand for IoT technology.
In the area of signal monitoring and telemedicine, the Asian country carried out a survey in 2019 with the aim of studying the professionals who practiced these methods. Data were collected by The Telemedicine Informationization Professional Committee of China (TIPC) & The National Telemedicine Center of China (NTCC).[2]

- Europe

Europe is a continent that has invested more than €95 million in innovation and the study of new technologies and one of them is the IoT. The European Union engages in proactive cooperation with industry, organizations and academia to release the potential of the Internet of Things through Europe and beyond.[3]
They have a data strategy which helps to create a European market for the Internet of Things. With this strategy, Europe proposes both political and legal measures for the free flow of data over its borders within the European Union.
This also offers better security for the transmission of medical data, thus giving way to better privacy in which the doctor will also take advantage of being able to provide better treatment according to the symptoms presented.

- United States of America

In the United States, the implementation of home monitoring systems for telemedicine and telehealth has been successful. Columbia University located in New York, NY, USA created an in-home telemedicine device through its Informatics for DiabetesTelemedicine and Education actions.
This unit designed for home telemedicine has the capability of video conferencing, acquiring health records, distributing collected data with clinicians, accessing clinical data via the web, and accessing web-adapteddiabetes education. [4]

B. Microenvironment

- Honduras

In Honduras, the training needs of the doctor increase and diversify more and more. This is why several institutions and medical centers have already started experimenting with systems for conducting educational videoconferences for doctors.

Honduras is a country that has been suffering from shortcomings in its public health system for years, and the government has taken some measures over the years to meet the population's requirements[15] that is why in 2020, a free virtual platform for telemedicine was launched, this Aliv.io platform allowed the patient to create their own electronic file in order to share it with doctors.

- Chile

Chile is one of the few countries in Latin America with a high growth in utility to the Internet of Things (IOT), in addition to being the Latin American benchmark in industry 4.0.
With this it can be understood that Chile is one of the countries in the Latin sector, most capable of developing telemedicine in its territory.
But at the same time, it is not exempt from conditions that could complicate the development of telemedicine in this country, since, as in most countries, there isa high rate of digital illiteracy.
Cybersecurity is something that limits the development of telemedicine in Chile in its territory, since they do not have a law similar to the "Health Insurance Portability and Accountability Act" (HIPAA) of the United States.

- Mexico

In Mexico, the COVID-19 pandemic prompted the entry of telemedicine into its territory, with the purpose of stopping the spread of the disease caused by this virus which is a highly contagious virus that spreads quickly through direct or indirect contact with surfaces[16]. The telemedicine used in Mexico has been oriented towards teleconsultations to patients who may mean a risk of contagion.
In Mexico, teleconsultation has been used in the psychology sector, in a study carried out by the Center for Economic and Budgetary Research, indicates that telemedicine can boost access to psychological services, from 2013 to 2019 teleconsultations for psychiatry they decreased by 87%, they went from 70 thousand to less than 9 thousand by the end of 2019. [5]

C. Internet of Things(IOT)

Advancements in IoT technology has seen an increase in recent years asit has received great attention from industries and academic areas thanks to its great versatility in areas such as real- time monitoring, location or its integration with the artificial intelligence.
Wang [6] states: "The rise of the Internet of Things (IoT) signifies a substantial advancement beyond conventional ways of thinking, as it allows for the networking of a diverse array of objects in the environment, possibly even all of them."
IoT allows companies to create and implement new business models and strategies as it combines engineering skills, business studies and science under one roof that can turn the world into a smart and interconnected ecosystem, where almost everything is conveniently accessible, leading to a decrease in overall effort. and time that we previously dedicated to these. [7]

D. Benefits of IoT in medicine

In the context of healthcare, IoT technology has transformed the healthcare industry by allowing for the digital connection of a network of smart sensors and physical devices that can instantly collect, monitor, and manage healthcare data. [8].
Within medicine, the applications performed by the IoT can increase the general well-being of patients and thus reduce the costs of the services provided in the institution.
It is thanks to the continuous development of technology that the devices that work with an IoT base have managed to convert the different health systems into a more intelligent one that can be closer to the needs that the patient presents.
In this way, Bhatt [9] mentions that IoT technology has revolutionized the health system by generating new and personalized opportunities for eHealth services.

E. Big data in the cloud

Al-Badi [10] describes Big Data as data that exceeds the conventional processing capacity of data systems, this because this data moves too fast, is excessively large or in other words it can be said that it cannot be contained in the data structure of a database.
Its purpose is to study these large amounts of data in order to extract information from it, this information may present relationships or patterns that are relevant to the organization

that uses it.
It is because of the internet of things that Big Data has progressed in different environments, whether industrial or urban, by helping to monitor temperatures, relative humidity, or air quality.

The health sector has also been integrated using sensors and thermal cameras to assist with the early detection of possible sources of infection. [11]

F. Biomedical signals

A biomedical signal is defined as any signal that can be perceived from the body of a living being. These signals are indicators that reflect the physiological state of the vital organs and express the functional changes that occur within the organism. [12]
Its importance lies in the detection of pathologies in patients and monitoring to provide correct treatment. As a way of a better understanding of this project, the signals that will be observed and the scope they provide will be written in more detail.

- Heart Rate [bpm]

The heart rate is detailed as the number of times that the heart carried out a complete cycle of filling and emptying its internal chambers in a given time. This is quantified in Beats per minutes [bpm] or contractions per minute.
Table 1 shows the regular values of the heart rate in different possible scenarios.

TABLE I: Heart rate scenarios

Normal	Athlete
55[bpm] – 100 [bpm]	40 [bpm] – 200[bpm]

- Blood oxygen saturation [SpO2 %]

Oxygen saturation measures the amount of hemoglobin currently bound to oxygen compared to the amount of hemoglobin that remains unbound [13]. Its measurement unit is [SpO2 %]. Its range of values is from 95% to 100%.

- Temperature [°C] & [°F]

Human body temperature is well established as one of the key vital signs. It is measured at regular intervals in the medical setting and often at home to try to estimate how "ill" an individual is. [14]
Its unit of measurement can be degrees Celsius [°C] or degrees Fahrenheit [°F]. In the following table, reference will be made to the values of body temperature of an individual, these have deviations with a limit of ± 0.6 °C (1.0 °F), once this threshold is exceeded, the person's condition changes to hypothermia or fever.

TABLE II: Body temperature values

Normal	Fever	Hypothermia
37 [°C] = 98.6 [°F]	40 [°C] = 104 [°F]	35 [°C] = 95 [°F]

- Blood pressure [mm Hg]

This is the measure of pressure that blood produces on the arterial walls when it is pushed through the arteries. It is observed that this moves in two types of waves, the systolic pressure, which is the pressure that is due to the contractions of the ventricles, and the diastolic pressure, which is the pressure that remains when the ventricles are relaxed.
Its unit of measurement is millimeters of mercury [mm HG].
Table 3 shows the BP (blood pressure) value classification proposed by the ACC/AHA (American College of Cardiology/American Heart Association).

TABLE III: ACC/AHA BP classification

Classification	SBP (Systolic Pressure)	DBP (Diastolic Pressure)
Normal	<120 [mm Hg]	<80 [mm Hg]
Elevada	120 – 129 [mm Hg]	<80 [mm Hg]

III. Method

Since the project involves the development of a mechatronic system, it is determined to use the V methodology.
This is dictated taking into account that this type of methodology facilitates what the organization is for the development of systems and subsystems, in the same way it is taken into account the need to apply the different knowledge for the different processes to carry out for the elaboration of an embedded board with IoT communication.
The main systems for carrying out the project are Electronics,

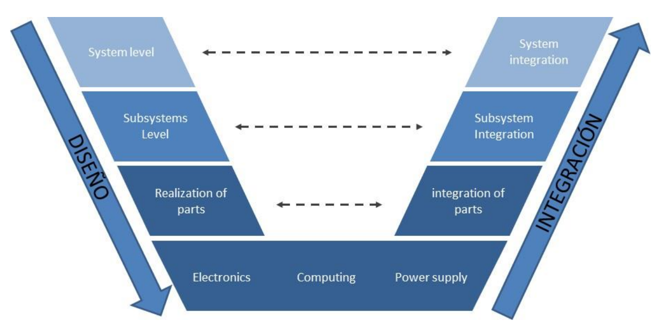

Fig. 1: V Method.

Computing and Desing, the purpose of these systems is to integrate to facilitate the development of the embedded board and enable the connection of the sensors, this will also allow the reading of the variables and then be able to be transmitted through the Internet of Things (IoT) to a web application. Within the electrical system shown in figure 13 are the selection of sensors to be used and their needs for correct functionality so that the variables obtained are read optimally. Both the design of the board and the simulation of the circuit of the same are included in this subsystem to define the necessary connections to avoid damage to the circuit.

The computer and control system, is the level where the connection between the controllers and the sensors to be used will take place.

The micro-controller will collect the variables with its values of beats per minute, oxygen saturation, temperature and blood pressure. Once this is done, a connection will be established with the ESP8266 Wi-Fi module to transmit these variables to a web application.

The power supply system whose purpose is to protect the plate and its different components to extend its useful life.

For the integration of of parts, we try to work all the systems individually in order to guarantee that the development and functionality of these perform in the most optimal way. First, the sensors are calibrated and their functionality limits are established, to then establish communication between the PIC micro-controller and the sensors.

Finally, the ESP8266 Wi-Fi module is used to transmit the data that is collected from said sensors to the Ubidots web application. With the sensors working together with the micro-controller and the module, Proteus is used to designthe board.

To energize the board, a 9V battery and an NI Elvis were used in the controlled environment tests, which provides 15V, since the board works with 5V, an LM7805 regulator was used to ensure and energize the board correctly. microprocessor and other components.

Controlled tests took place within the university to verify its operation. Figure 2 shows the impression of the board with the integrated and energized components for the initial tests.

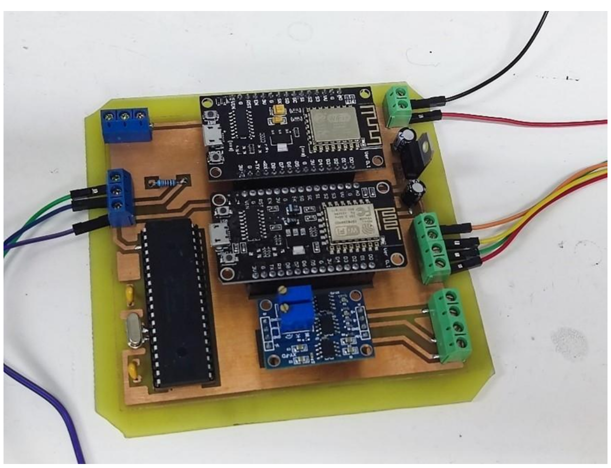

Fig. 2: PCB Board Mount

With the test successfully passed, another factor was the visual modification of the Ubidots interface so that both the patient and the doctor can see the information in a more orderly and coherent manner.

Figure 3 shows the final design of the platform, which includes all the parameters to be measured along with thetime and date and a small database of each parameter foreasy handling by the doctor.

Fig. 3: PCB Board Mount

IV. Results

It was possible to measure four different vital signs of the human body, making use of different infrared light type sensors to obtain the signals generated for the measurement of oxygenation percentage and heart rate, resistance thermometers to measure the temperature variable and piezoresistive transducer to obtain the signal of the pressure variable.

The measurements were made in a test environment, comparing the measurements made by the device in this investigation with devices that can be found in the medical industry, under the observation of knowledgeable personnel on the subject.

A. Heart Rhythm Analysis

In order to obtain the voltage signal to be studied for the heart rate measurement parameter, a light-receiving sensor wasused, which changes its information reading for each heart beat. The sensor used for this measurement is the XD-58C Heart Rate Sensor. In the following figure it is possible to observe the light absorption graph of said sensor, resulting in the observation of the heart rate.

Fig. 4: Heart Rhythm in a 10 second interval

In the figure, different types of pulsation can be observed, because the heart not only generates a pulse but also different parts of the heart generate different pulses in the case of the smallest wave on the left side of the cycle that is known in medicine as a P wave.

The magnitude can vary depending on the health of the person or their type of complexion, these measurements were taken from a healthy person, so if they had been taken from a person with some heart disease, the pulsations could be different,

making the cardiac pulse cycle greater or even much less in the case of a racing heart, and the magnitude of its pulsations smaller.
In the previous graph. The most important wave to analyze in the heart rhythm graph for this investigation is the wave with the largest magnitude known as the QRS complex, which corresponds to the bipolarization of the left ventricle of the heart, every time there is a peak of this wave.
It is taken as a pulse and the amount of pulse in a measurement time is averaged to obtain the number of beats per minute.

B. Oxygen Saturation Analysis

The analysis of oxygen saturation was carried out by the mikroe oximeter 5 click sensor, this has the max30102 integrated sensor that makes use of red and infrared LEDs together with a photodetector.
Its operation consists of obstructing the lights emitted by the LEDs with the index finger, the photodetector then detects the lights that shine back and converts them into electrical signals.
To find the oxygen concentration it is important to knowthat hemoglobin is responsible for moving the oxygen in our blood, if the hemoglobin is oxygenated (HbO2) it will absorb more infrared light and on the contrary if the hemoglobin is deoxygenated (Hb) it will absorb more Red light.
The following figure shows the comparison of the light received by the photodetector.

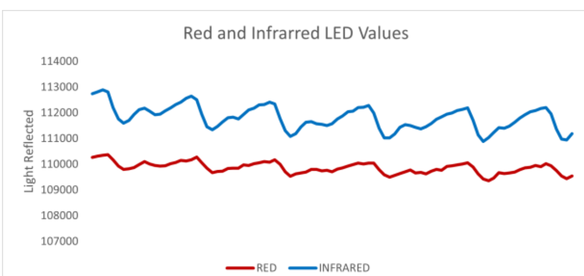

Fig. 5: Red and IR Values

It is observed that despite the different spectrum betweenboth lights, the graphs have to be similar even though their magnitude is different.
Now to determine the percentage of oxygen saturation, red light must be divided by infrared light.

C. Temperature Analysis

The signal to study of the temperature variable was taken by the LM35 thermoresistor sensor, with a probe-type encapsulation to be able to place it in certain parts of the body of people.
The output signal of the LM35 is of analog voltage, so it is linearly variable with respect to time, this makes it easy to monitor its signal since each change of 20mV corresponds to 2°C.
In the following figure it is possible to observe the graph of the temperature measurement of a healthy person.

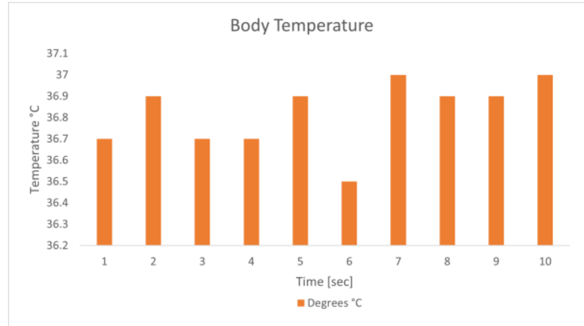

Fig. 6: Body temperature fluctuation in a 10 second interval

In the previous figure it is possible to observe the temperature changes with respect to time, the small values, since the position of the sensor can change caused by movements of the person from whom the values are being taken, causing the meter to take different readings.

D. Blood Pressure Analysis

For the analysis of the blood pressure variable, a piezoresistive transducer was used, with an encapsulation that allows an air inlet to generate a pressure, the sensor used is known as MPX-10DP.
In order to obtain the person's data, the sensor was adapted to a band for an aneroid sphygmomanometer, this being introduced by an insufflator knob.
In order to be able to read the pressure data, an AD620 instrumentation amplifier with a gain of 1.2 Kohm was also needed, since the voltage output of the pressure sensor isvery small, preventing the micro-controller from reading the voltage changes accurately. accurate.
The unit to use for measuring blood pressure is millimeters of mercury (mmHg). The data obtained were taken from a young and healthy person, whose pressure should not be higher than 120 mmHg. The next figure shows the graphobtained by a pressure measurement.

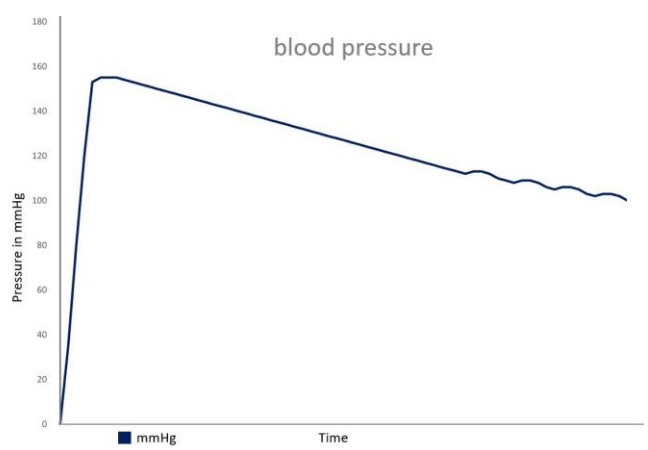

Fig. 7: Blood pressure reading in 40 seconds

In the previous figure it can be seen that the person had a blood pressure of 113 mmHg. It is also possible to observe that the pressure increases up to 150 mmHg, and the air is let out, so the pressure decreases until it reaches a point where the graph has refractions.
These refractions are caused by the pulses of the heart, in the The first moment in which these appear in the graph indicate the level of pressure that the person from whom the data is being obtained has.

V. Conclusion

We concluded the realization of the embedded plate prototype with IoT functions for the monitoring of vital signs in real time and it was shown that the IoT together with medicine can facilitate the collection of patient information in order to keep track of the patient's conditions.

VI. Recomendation

It is recommended to improve the connection when replacing the wireless network with ethernet to prevent data loss and provide greater stability to the system.
Consider alternative use of the Mpx 2050 sensor to expand the magnitude of blood pressure cuff data collection.
The adaptation of a holter monitor for continuous cardiac monitoring is taken into account for patients suffering from arrhythmias.

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