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Development of a monitoring system for COVID-19 monitoring in early stages

J. G. Maradey – Lázaro[1*], A. D. Rincón-Quintero[2,3], J. C. Romero Garnica[1], D. O. Segura-Caballero[1], C. L. Sandoval- Rodríguez[2,3]

[1*,1]Mechatronic Engineering Program, Universidad Autonóma de Bucaramanga, Avenida 42#48-11 Cabecera del Llano, Bucaramanga, 680003, Colombia.
[2] University of the Basque Country, Ingeniero Torres Quevedo Plaza, 1, 48013 Vizcaya Spain.
[3] Faculty of Natural Sciences and Engineering, Unidades Tecnológicas de Santander, Student Street 9-82, Bucaramanga, 680005, Colombia

ABSTRACT

Covid-19 is considered the most infectious virus today. Likewise, the struggle to mitigate the effects of the variants, the flexibility in some measures such as the use of face masks, the advancement of vaccination and prevention and self-care campaigns continue to be topics of research and of global interest. The world health authorities published that the disease was characterized by presenting the same symptoms as the flu along with a complex picture where in the most serious cases they lead to difficulty breathing due to pneumonia, sepsis and septic shock that can lead to death. Some systems implemented for taking body temperature such as thermographic cameras, digital thermometers, for the description of symptoms in the people they analyze at the time of carrying out the epidemiological fences are not enough, since they handle low precision, are taken in isolation, individually or randomly and is not suitable for characterizing interest groups. Then, establishing risk levels by measuring non-invasive variables can be considered inputs into prevention campaigns and a low-cost way of monitoring the community. This article shows the design of a non-invasive embedded device for the measurement of 5 priority variables for the detection of the risk of covid-19 infection. The proposed device was duly calibrated and synchronized for the acquisition of data from 594 people in the city of Bucaramanga, Colombia, who authorize the monitoring of the symptoms. The people must be in a state of rest to be able to acquire the data with great accuracy, in this way the data is entered into the system in charge of doing the monitoring analysis. Additionally, the implementation of an interface that allows the visualization of results, laying the foundations for the development of automatic learning techniques or models for the risk classification in future work.

Keywords: Covid-19, SARS-CoV-2, IoT, detection, monitoring.

Corresponding Author:

Jessica Gissella Maradey Lázaro
Mechatronic Engineering Program
Universidad Autonóma de Bucaramanga,
Avenida 42#48-11 Cabecera del Llano, Bucaramanga, 680003, Colombia
E-mail: jmaradey@unab.edu.co

1. Introduction

On December 31, 2019, the organizations of Wuhan (China) reported to the World Health Organization (WHO) that 27 individuals were diagnosed with pneumonia with unknown origin[1]. After the first outbreak of the disease, the authorities stopped reporting new cases until January 19, where they would give the value of 49 infected by COVID-19. For March 2020, the covid -19 was considered as pandemic [2]. By that same date, the first cases were also being registered in other countries. The world health authorities published that the disease was characterized by presenting the same symptoms as the flu along with a complex picture where in the most serious cases they lead to difficulty breathing due to pneumonia, sepsis and septic shock

that can lead to death. At the beginning, the nature and specific characteristics of the virus were not known, so, to mitigate the effects and since there was no treatment or vaccine, actions were taken such as temperature measurement, isolation, and continuous use of face masks.

The development of effective diagnostic tests that allow timely treatment of the disease received more attention and participation, however, the high cost of these, the time it took to obtain reliable results and the discomfort reported by some users when performing the test limited their mass implementation. Table 1. shows a summary of covid-19 test, including advantages and disadvantages of each one. Molecular and Serological tests are very effective, but very expensive too [3][4].

Table 1. A Summary of Covid-19 Diagnosis Tests.

Diagnostic Test	**Hight lights**
PCR Polymerase Chain Reaction (i.e Molecular)	Rapid monitoring, greater sensitivity. This is considered as "gold standard" for the diagnosis and detection of viral RNA by fluid sample of the person [3].
RT-PCR (Reverse transcription-polymerase chain reaction)	The molecular test or PCR is a test conducted through a sample of mucosa or saliva in which the RNA of the virus is analyzed to verify its presence in the infected person. The test can take a few hours to analyze, but the percentage of sensitivity it presents is 90%. So far, it is the most reliable test, but it offers a delay in the processing of tests, which is why it is necessary to use faster test utilization strategies as a first filter. The test is conducted in the laboratory. Also, this test is indicated in early stages but can be performed at any stage maintaining its high effectiveness[3]. It is the most recommended to Covid-19 diagnosis.
Others Molecular Tests	LAMP: Loop mediated amplification isotherm CRISPR: Clustered regularly interspaced short palindromic repeats systems Microarray based methods LSPR: localized surface plasmon resonance
Antigen Test	The antigen test is a test carried out in a very similar way to the PCR because it is taken through the patient's mucosa or saliva, this differs from the PCR since the virus envelope is analyzed in search of proteins that characterize COVID-19. The test offers a very important help in the first part of mass diagnosis of people thanks to the fact that the results are obtained in a few minutes, but it has a shortcoming in which the sensitivity is approximately 70%. The test is carried out in the laboratory. Also, this test provides enhanced performance and efficiency, sensitivity, and real-time monitoring.
Serology Test	The rapid serological test consists of taking blood from the patient to be analyzed, with which the presence of IgM and IgG antibodies is studied by means of a device in which the blood acts with a reagent, this test can be carried out approximately 7 days after the affected person has contracted the virus, it presents a high sensitivity, but it cannot be defined if the user has gone through the coronavirus or is in the stage of the disease. Medical institutions apply this method as a first filter and test treatment optimization. One of the advantages of this diagnostic method is the ease of performance, the test can be performed at home, although it needs a health professional for its execution, it can avoid increasing the rate of contagion.
Others Serological / antibody tests	ELISA: Enzyme-linked immunosorbent assay LFA: Lateral flow assay CLIA: Chemiluminescent immunoassay GFET: Graphene-based field-effect transistor SPR: Surface plasmon resonance

Eventually, the first infrared cameras appeared as alternative of monitoring that showed potentially infected people in real time through a heat map but considering to having a fever was not necessarily typical of covid-19, so analyzing the symptoms was key to monitoring, detecting, and diagnosing the disease. The most common reported symptoms are shown in the Figure 1 and less common symptoms in Figure 2.

Fever is a very common symptom in symptomatic people due to the high margin, however, it cannot be a discriminating variable since this symptom occurs as an immune response to the presence of different viruses and foreign bodies. Therefore, it would not be appropriate to propose detection or monitoring systems based solely on temperature given for reliable and accurate results. Other non-common symptoms (i.e, nasal congestion, sore throat, running nose, aches, and pain) should be considered [3]. Then, considering only symptomatology is not enough either, since asymptomatic involve a different treatment for detection [5][6].

In addition, image processing has played an important role in determining the progress of the disease and indicating treatment [7]. However, is relevant to developed accurate, cheap, and rapid diagnostic methods [3]. Biosensors combined with electromechanical methods and immunosensors are some challenges that have been prioritized to address the diagnosis of covid-19[3][4][8].

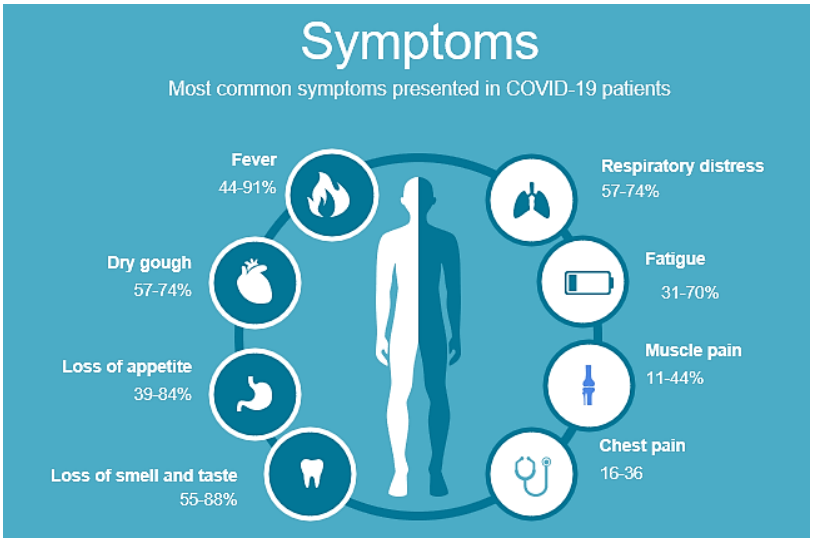


Figure 1. Most Common Symptoms to Covid-19.

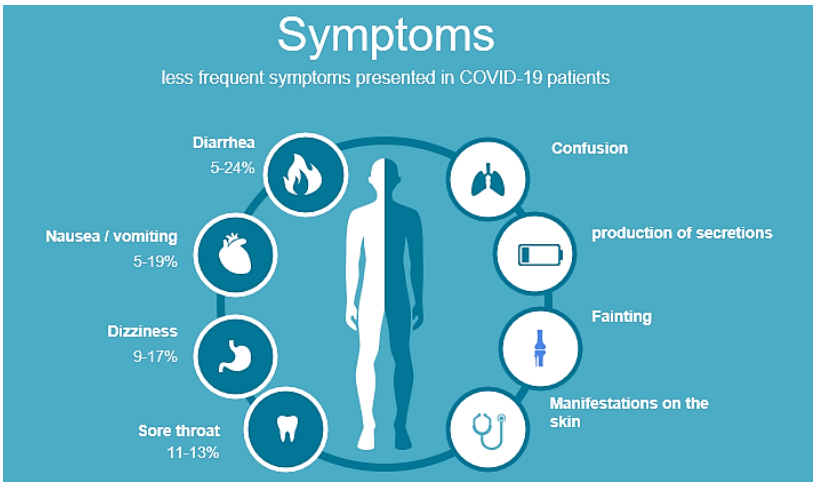


Figure 2. Less Frequent Symptoms to Covid-19.

Artificial intelligence, through its algorithms and methods such as Support Vector Machine (SVM), Neural Network, Naïve Bayes, K-Nearest Neighbor (K-NN), Decision Table, Decision Stump, OneR, and ZeroR [2], facilitates the treatment of monitoring information in such a way that, with the training, validation system and adequate test[5], a model can be created with a success rate greater than that of simple monitoring or control methods[6]. Also, it allows identifying high-risk patients specially in early stages[7], find similarities between countries[1] and provides real-time monitoring suggestions to mitigate the effects of the disease that afflicts the world population[8][9] improving the schedule, surveillance, detection, treatment and prevention [10]. In fact, the most important advance of use AI strategies is helpful for the future virus and diseases prevention,

with the help of previous mentored data over data prevalent at different time[8] or levels of risk [11] and is a less time-consuming technology [3]. Predictive models taking uncertainty into account have been developed in several universities around the world with the purpose of estimating pandemic lifecycle [9] [15][16]. On the other hand, dimensionality reduction techniques have also been applied such as PCA and CUR algorithm [17].

Moreover, some framework developed include[8]: Symptom Data Collection using wearable sensors[10][18], data analysis (i.e with health physicians, engineers, and doctors)[1] and IoT infrastructure (i.e., Cloud Computing)[2][3][19]. Future trends include: Telemedicine, Robotics, 3D Printing, remote patient monitoring[20], virtual assessment [10] smartphone[8], smartwatch [18] and digital health [21][13]; about AI approach, the development of deep learning (DL), convolutional neural network (CNN) [19][22], generic machine learning and XGBoost Model [3][12].

This article aims to show the development of monitoring system in preliminary stages of covid-19 just as to infer the risk of infection by acquiring continuous signals such as heart rate, oxygen saturation, temperature, electrocardiogram wave (i.e, QT), blood pressure. Likewise, characteristics such as previous symptoms, health status (e.g., diabetes or hypertension), if you have been vaccinated or if you know if you have suffered from the disease, some demographic data such as gender and age, was considered, respectively. The implemented instrumental system represents a non-intrusive, low-cost, and reliable bet to classify the risk, allowing the development of public policies that manage to reduce the impact of the disease. Also, the sample size taken for study represents the greatest contribution of this work.

2. Materials & Methods

Due to the rate of growth and contagion of the virus, the limited accessibility to highly effective tests, both due to the processing time of the samples and the high cost, an instrumental system was designed that would allow the acquisition of measurements such as: temperature, saturation of oxygen (SPO2), blood pressure, heart rate, heart rate, electrocardiogram (i.e., QT wave).

So, based on Devas-Shetty methodology, is necessary to define the variables to measure and select of appropriate sensors. Next, an integrate and a comprehensive low-cost data acquisition, monitoring, and processing system, as well as the HMI interface the detection of COVID-19 is developed.

2.1 ECG: Electrocardiogram

So, the ECGs used in Colombia must be governed by the standards imposed by the ANSI/AAMI (American National Standards Institute/Association for the Advancement of Medical Instrument), the Ministry of Health and the IEC (International Electrotechnical Commission), these standards are reported in Appendix A.

The regulations shown above show the necessary criteria to safely implement and market ECGs, electrocardiograms can be categorized according to the level of channels it shows and the function it can offer. Some studies have focused to demonstrate that it is possible to perform ECG on the forearm accurately, with dry electrodes and minimally invasive. Although the amplitude is affected, there are techniques that can improve the measurement of this, according to the study conducted by Villegas et al [12], they place the electrodes in the transverse and axial part of the forearm, achieving a clear signal.

Multichannel electrocardiographs offer information from different leads while single-channel electrocardiographs can only measure in one channel. It can also be categorized according to the function it performs:

- Diagnostic EKGs – offer high resolution so you can discover heart conditions and require the patient to lie flat and at rest.
- Holter electrocardiographs: used for prolonged periods of time when the resolution does not represent a relevant characteristic in certain diseases.
- Monitoring electrocardiographs: they are used in hospitals as a method of observing patients to prevent risks.

2.2 Oximetry

Oximetry is a noninvasive technique that allows the measurement of oxygen saturation in the blood and may be as important in medicine as taking temperature and blood pressure[13]. Also, this technique shows

the level of arterial hemoglobin in the composition of oxyhemoglobin, which is the protein in the blood that transports oxygen. Therefore, this form of measurement allows early diagnosis of respiratory and cardiovascular diseases.

SARS-CoV-2 is associated because its main condition in the body is pneumonia, but recent studies have shown that the disease can affect the union between oxygen and hemoglobin because a protein can cause this dysfunction, and that can lead to considerable decreases in SpO_2 [14]. According to the calculation of the oxygen levels of the blood, must be obtained as a percentage where the variables that are taken are the functional hemoglobin's (HbO_2) since these have the property of binding to oxygen. Then, when hemoglobin carries less than four oxygen charges, they are called reduced hemoglobin's (Hb) and optically, with the support of the equation, peripheral oxygen saturation (SpO_2) can be measured. The adequate and healthy percentage of oxygen in the blood is between 95% and 100%. The equation 1 shows the relations between variables to define the percentage of oxygen saturation.

$$\%SpO_2 = \frac{HbO_2}{Hb+HbO_2} x100 \quad (1)$$

Blood has an optical characteristic in which its main determining agent is the amount of oxygen it contains[15].HbO_2 is characterized by having a pigmentation other than red and the light absorption coefficient is greater than that of Hb where this value can vary depending on the length. The principle of emission and reception of light is applied with the implementation of a red and an infrared LED accompanied by a photodiode, on the opposite side of the finger since it can also be applied in other body parts. So, two lights are implemented because the visible light in the spectral region of the blood is approximately 400 and 700 nm while in the infrared light it is 700 to 1000 nm that is why HBO_2 has an absorption of 940 nm approximately and the Hb of 600 nm, these two LEDs are required. Another point is the configuration in which the arrangement is made for the oximeter to work is divided into two types, which are the transmissive and the reflective, where the first positions the photodiode on the opposite side of the finger to the LEDs and the reflective one positioned in such a way that the photodiode can take the variation of the LEDs.

Furthermore, the ISO 80601-2-61 standard suggests that before an oximeter is released to the public, it is necessary to conduct tests (in vivo). These tests are performed on the test subjects where they inhale different gases and are exposed to variations in oxygen where this relationship that is collected from the oximeter under test is associated with the Beer-Lambert model.

2.3 Blood Pressure

Blood pressure is the pressure exerted by blood on the arteries at the time of being pumped by the heart, blood pressure is higher when the heart beats pumping blood and is dominated by systolic blood pressure and when the heart is at rest between beats is called diastolic blood pressure.

Blood pressure is one of the vital signs that must be kept more stable since it is the main sign to start having cardiovascular problems, although over the years people are prone to suffering from high blood pressure, another way in which blood pressure can be altered due to taking some type of medication or having a particular medical condition. In fact, the instrument used to measure blood pressure is a sphygmomanometer.

Indeed, the methods to measure blood pressure are detailed below:

- ***Manual measurement:*** This is the traditional or best known measurement today that resulted from the work of precursors such as Harvey, Hales, Poiseuille, von Basch, Riva-Rocci and Korotkoff, this type of measurement is performed by means of mercury manometers, this type of pressure gauges have been changing for aneroid sphygmomanometers which do not contain toxic mercury and these types of pressure gauges require constant calibration, the limitations of this type of measurement is that it has a single and instantaneous reading in time normally during the hours daytime and in the sitting position only.

Automatic measurement: It is the measurement of blood pressure with a fully automatic device while the patient rests quietly and alone in a room, this type of measurement is taken in a room in which the patient is at rest, this blood pressure measurement arterial has a higher precision, and the data is obtained digitally, it must also be calibrated, but not as frequently.

- ***Ambulatory blood pressure monitoring*:** This measurement system is performed by means of a device that is responsible for taking blood pressure data over a 24-hour period and then averages the data obtained and is the result of the measurement.
- ***Ultrasonic/Doppler method***: This method uses ultrasound to determine the maximum and minimum pressures of the blood as it passes through the arteries. The values are recorded digitally. The arterial probe is placed on the artery to be observed and the Doppler effect measures the value of the maximum and minimum blood pressure. The Doppler effect is based on the variation of the frequency of the wave due to the relative movement between the emitter and the observer.
- ***Direct or intra-arterial method***: It consists of measuring the maximum, minimum and mean dynamic pressure of the blood as it passes through the channeled artery through a transducer that transforms these pressures into observable digits. It is necessary to heparinize the pathways for their correct functioning. It is the only exact method, but it is the most traumatic. Too, it is only used for monitoring in Intensive Care Units.

2.4 Temperature

Body temperature is a variable which changes taking into account the type of person, the age, the activities they perform and the time of day, the average temperature is in the range of 36.1 °C to 37.2 °C. The temperature of over 38°C almost always indicates a fever due to infection or illness, and the use of glass and mercury thermometers is currently not recommended, as glass is breakable and toxic.

For the preparation of the thermometers, the only thing that is required is that they not be made with mercury or any other type of element that is toxic or harmful to people's health. Some types are detailed bellow:

- ***Glass or liquid thermometer:*** The glass thermometer, also known as a liquid thermometer, is the most well-known and prototypical type of thermometer. It is also called a manual or mercury thermometer, since, traditionally, it was filled with this liquid metal and does not require batteries to work.
- ***Non-contact thermometers***: The non-contact thermometer is a type of thermometer that works without the need to touch the object whose temperature is to be measured, measuring the temperature using infrared.
- ***Bimetallic Foil Thermometers:*** Bimetallic foil thermometers measure temperature through a mechanism that contains two diverse types of metal, which, depending on how they contract or expand, will help indicate the temperature of the object being measured. is taking the temperature.
- ***Digital thermometers***: Digital thermometers are very similar to glass thermometers, since they are used as an electronic substitute for them.

Thus, to measure temperature is necessary to put a thermometer in:

- ***The mouth*:** place the bulb under the tongue and close the mouth. Breathe through your nose. Use your lips to keep the thermometer firmly in place. Put the thermometer in your mouth
- ***The rectum*:** This method is for babies and young children. They are not able to hold the thermometer in their mouths safely. Lubricate the bulb of the rectal thermometer with petroleum jelly. Place the child face down on a flat surface or on your lap. Spread your buttocks apart and insert the bulb end of the thermometer a little more than 1/2 to 1 inch (1 to 2.5 centimeters) into the anal canal.
- ***The armpit*:** put the thermometer in the armpit, press the arm against the body.

2.5 Spirometry

Spirometry is a non-invasive method that measures the rate and volume of respiration, apart from arterial blood gases, it is one of the most widely used pulmonary analysis tests in the medical community. Spiro metric values can vary depending on the characteristics of the person such as height, age, and gender, to know if the value taken coincides with the normal values of the person, prediction models are used according to their characteristics.

Particularly, to measure the ventilatory capacity and how the alteration can affect the functions of the lung, even though they are not specific to determine a disease, can be associated with different diseases, according to the values provided by the generated graph. A study carried out in the city of Bogotá based on the Mexican American Hankinson equation showed to give the best results in a population aged 18 to 65 years and according to a study also carried out in Chile, this equation is the most adequate to predict the values of FVC and FEV1 where FVC represents the maximum forced capacity to capture and expel air and FEV1 represents the maximum amount of air during the first second of expiration. The ministry suggests this equation as the most accurate. Therefore, the study mentioned recommended considering the following ranges:

- **Normal spirometry** is when the IC is greater than 95% and when the FEV/FVC is less than 70.
- **Obstructive spirometry** occurs when FEV/FVC is less than 70 and its severity is measured based on FEV1.
- ***Restrictive spirometry*** is when there is a decrease in CVD that is less than the 95% CI and the FEV/FVC ratio is normal.
- ***Mixed spirometry*** is when the FEV1/FVC ratio is low and FVC also shows a decrease.

To summarize, Table 2 report the commercial sensors used in this project, as well as the description of the variables measured and description about means. Some technical specifications to sensors are shown in Table 3.

Table 2. A Summary of Covid-19 Variables and Sensors

Sensor	Variable	Description
AD8232	Electrocardiogram (ECG) Heart Rate	COVID-19 is characterized by affecting respiratory functions, despite the fact that the heart does not have much direct participation in the process of oxygenation in the blood, it is the one that carries out circulation, in addition, the heart is directly connected to the heart through of the two pulmonary arteries where the blood oxygenation process takes place. Also, given that both functions of these organs are associated, various studies show that COVID-19 really affects the heart. The Inter-American Society of Cardiology suggests that the prolongation of the QT segment may be the cause of the arrhythmias caused by the virus. Heart rate, another important variable that can be obtained from the ECG, can also show irregularities in the body, and can be associated with COVID-19 if a strong relationship with the other symptoms can be demonstrated.
MAX 30102	SP02	SARS-CoV-2 is associated because its main condition in the body is pneumonia, but recent studies have shown that the disease can affect the union between oxygen and hemoglobin because a protein can cause this dysfunction, and that can lead to considerable decreases in SpO_2[14] .
Smartwatch 4 pro	Blood Pressure	The relationship between COVID-19 and blood pressure has had a sigmoid relationship, at first it was believed that their relationship was very minimal, but as the days passed and the advances that have been made regarding this specific virus, has determined that there is a high relationship since it is known that the partial pressure of oxygen in arterial blood (SpO_2) maintains a relationship with oxygen saturation (SaO_2). In other words, decreases in (SpO_2) from normal influence SaO_2, and therefore the amount of oxygen transported by arterial blood (CaO_2) to the tissues; on the other hand, the increase in body temperature also causes changes that alter blood pressure.
MLX90614 infra red	Temperature	The increase in body temperature is one of the main symptoms in symptomatic people who carry the virus, as it is one of the reactions that the body takes in order to attack or eliminate the virus. Regarding the clinical characteristics of confirmed cases of COVID -19 in the city of Wuhan, China, a retrospective cohort of 41 patients showed that the average age was 49 years, with a male

Sensor	Variable	Description
		prevalence. Important signs and symptoms of COVID-19 were considered: fever (98%), dry cough (76%), dyspnea (55%), myalgia or fatigue (44%), and lymphopenia (63%). The onset of COVID-19 manifests itself mainly as a fever, but sometimes only chills and respiratory symptoms occur due to a mild dry cough and gradual dyspnea, as well as fatigue and even diarrhea.
Arduino Mega	Control of Variables	Battery: 9 volts Communication protocol: I2C PCB printed circuit

Table 3. A Summary of Covid-19 Sensors Selected

Components	Specifications	Techniques
AD8232	Voltage	3.3 V
	Current	170 uA
	Noise Rejection	80dB
	Configurations	2 or 3 electrodes
MAX30102	Wavelength	660nm/880nm
	Voltage	3.3V-5V
	Current	60 mA
	Output	I2C
Arduino One	Microcontroller	ATmega328
	Input Voltage	7V-12V
	Memory Flash	32kb
	SRAM	2KB
	EEPROM	1KB
	CLK	16MHZ

Thus, after the selection of components and the quotation, the best sensors with the highest score were selected, which are shown in Figure 3 schematically.

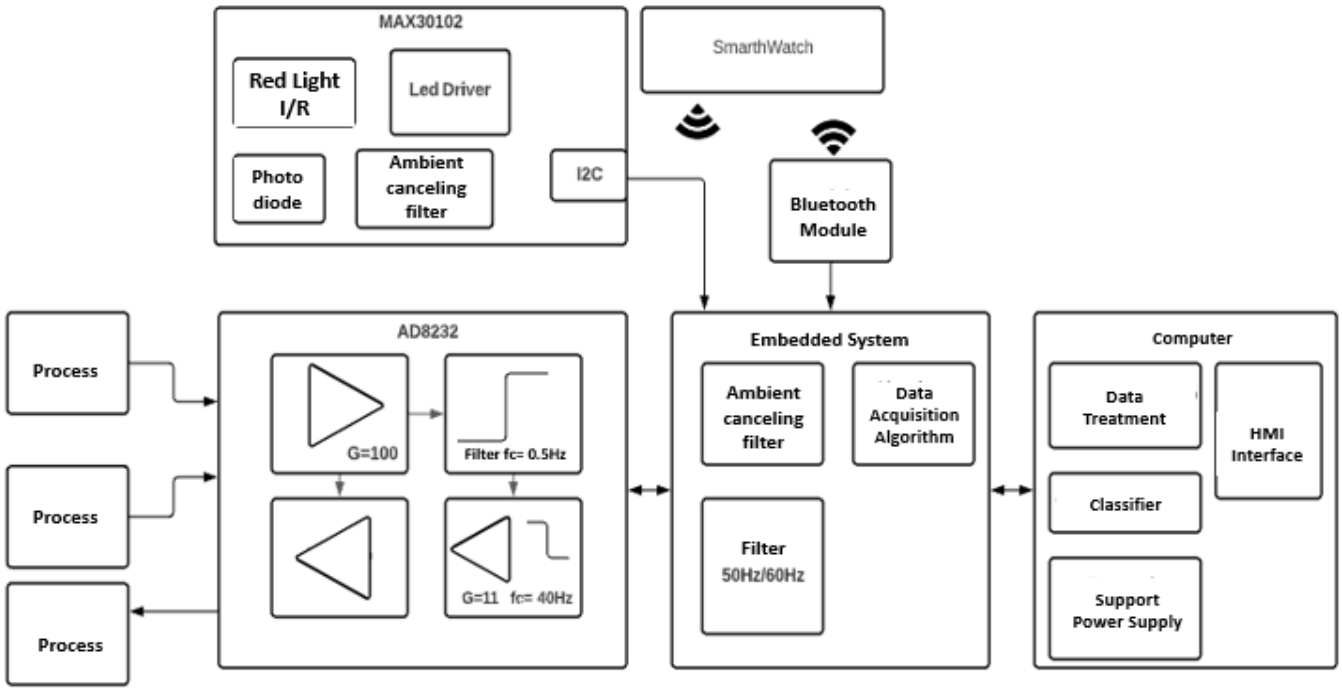
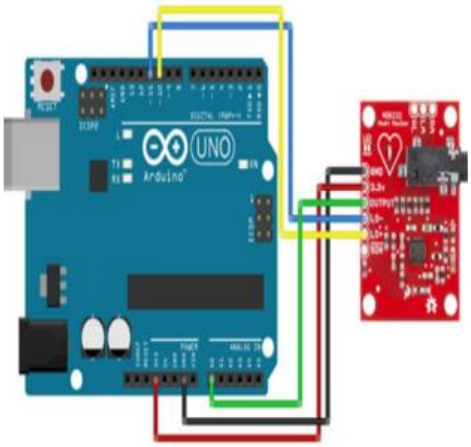


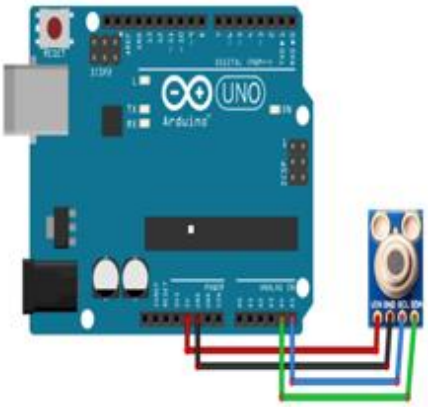
Figure 3. Embedded System Block Diagram.

Next, the connection pins between the controller (Arduino) and the AD8232 sensor can be seen in Figure 4. Similarly, Figures 5 and 6 show the connection between controller (Arduino) and MLX 90614 and MAX 30102 respectively.



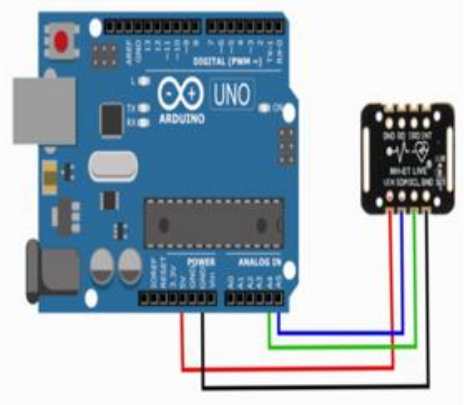
AD8232	Arduino
GND	GND
3,3V	3,3V
OUTPUT	A0
LO-	11
LO+	10
SDN	**Not Use**

Figure 4 . Connection between Arduino and AD8232 Sensor



MLX	Arduino
GND	GND
5V	VCC
SCL	A5
SDA	A4

Figure 5. Connection between Arduino and MLX 90614 Sensor



MAX	Arduino
GND	GND
5V	VCC
SCL	A2
SDA	A3

Figure 6. Connection between Arduino and MAX 30102 Sensor

As a result, the assembly of each circuit as embedded, a box is made to protect each sensor. Figures 7 show a scheme of how the samples will be taken, which, as can be seen, is non-invasive and indirect, but with good precision. In addition, the cost of each device is 60 dollars. Finally, Figure 8 shows the complete assembly of the developed embedded system which is previously calibrated and synchronized. Then, to give rigor to the study, each volunteer participant will give their written consent to proceed with the collection of variables that are the object of our study. While, in Figure 9 can be seen the real view of the monitoring system.

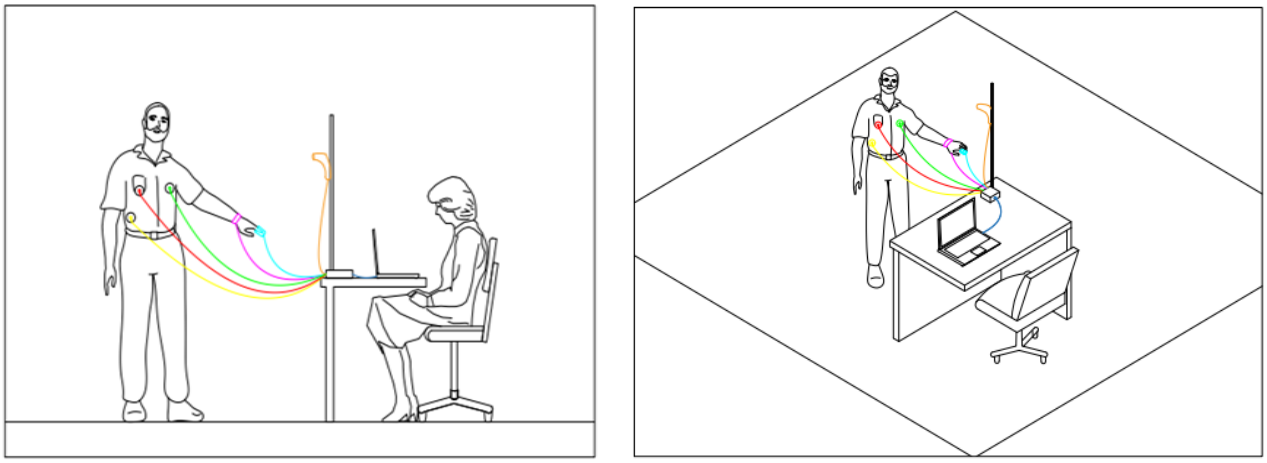


Figure 7. Front and side views of the developed monitoring system

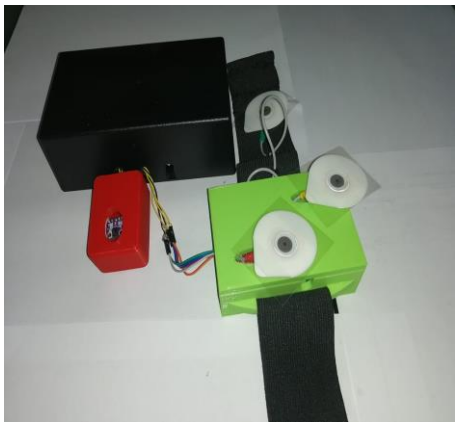


Figure 8. Covid-10 monitoring system

A view of the acquisition tests carried out can be seen in Figure 10. After, is necessary to carry out database treatment. The collected database had to go through the following processes:

- NAN'S type data deletion
- People who did not accept habeas data were eliminated.
- Qualitative data was digitized.
- Targets were set in binary form for the sensor measurements.

In addition to the measurements, a form must be filled out with questions such as age, gender, if you have been diagnosed with covid-19, if you have experienced symptoms, among others, data that is downloaded in Excel.

Figure 9. Real view of the Covid-10 Monitoring System.

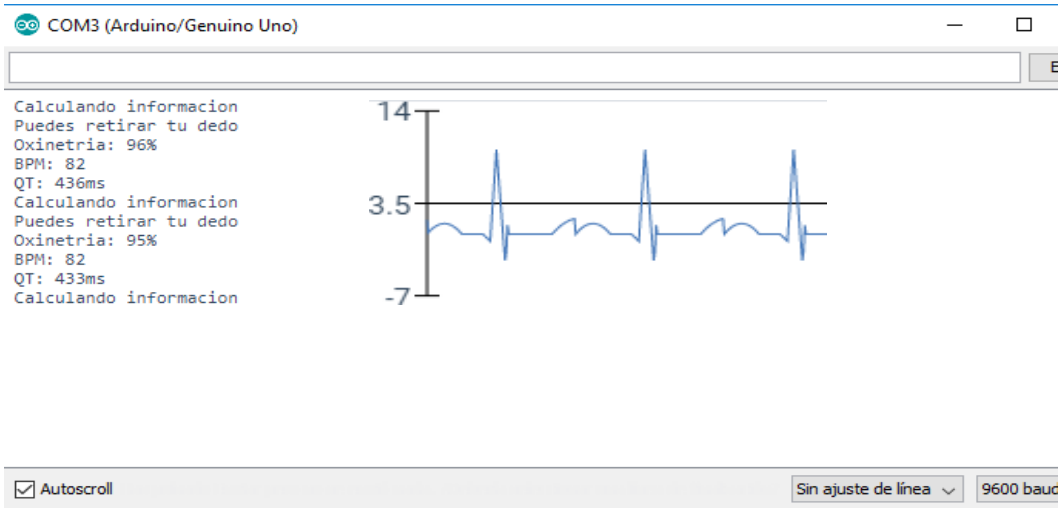


Figure 10. Monitor serie and ECG fixed and filtered in MATLAB

3. Results

The database acquired through the takings carried out by the plant that was implemented yielded the following results, these data were taken from around 500 people where the people were informed of the origin of the data through an informative consent, in this database questions regarding age were taken into account, if they had any symptoms related to COVID-19, if they have diseases related to the cardiac system, if they have diseases related to blood pressure, if they have been diagnosed with COVID-19, the time they have been elapsed after being confirmed to carry the virus and finally the variables measured by the plant (temperature, blood pressure, heart rate, oxygen saturation and QT wave). Figure 11 shows a summary of the characterization of the sample taken. According to the information obtained from the survey, the following parameters were considered, which were later modified: the age of the volunteers was defined in ranges, for better treatment in the model. 7 symptoms were surveyed and finally 5 were taken into the model due to the importance given and published in medical articles. The symptoms analyzed were cough, sore throat, decreased sense of smell, decreased sense of taste, fever of 38 °C.

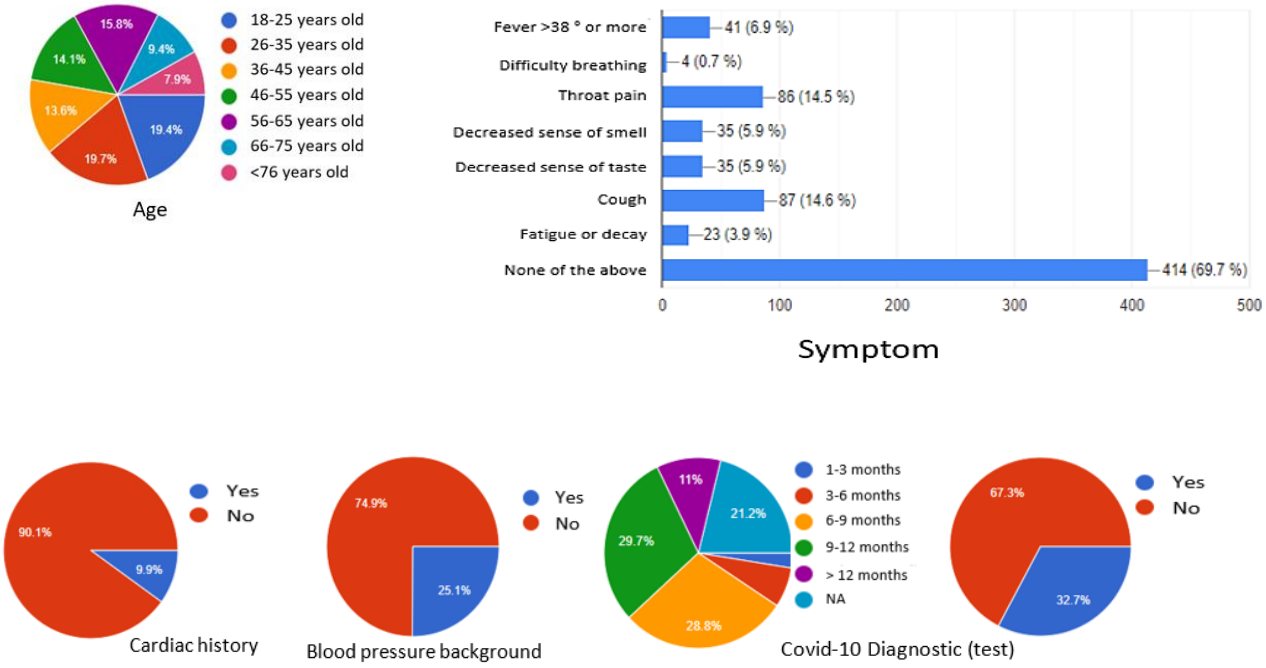


Figure 11. Summary of the characterization of the sample data

On the other hand, medical history was also analyzed: volunteers were asked about their medical history where specifically it was analyzed if the person had a cardiac or blood pressure history.

- History with COVID-19: the volunteers were asked if the people had been diagnosed as having COVID-19 and if so, how long they had had the disease, this characteristic was used in the model, but it was not an important characterizer since they did not want to discriminate in such a short process.
- Blood pressure: blood pressure was divided and studied in its two parts, diastolic pressure, and systolic pressure.

While the original measurement of the AD8232 sensor offers a series of analogous values in which a noise was graphically presented due to variations in the environment and the user's movement. In the process, it was decided to study the signal obtained from the thoracic part in MATLAB to apply the pan Tompkins filtering algorithm and know if the sensor was really taking the QT segment of the wave. It was found that even in the forearm this value can be recorded, although with a greater error than that of the thoracic part.

Also, a way for data collection, the code was adjusted, and it was fine-tuned for the delivery of the result with high precision and reliability, the parameter that was decided to take to give the result was a wait in the printing of data after 16 seconds. as adaptation time of the body to the devices and that the value is constant over time. Then, taking in to account the QT segment, it was necessary to adapt and program a conditional in which the counting of samples begins once the downward variation normally created in the Q variation begins until the end of the small peak of the T wave.

Finally, through the APP DESIGNER tool provided by MATLAB, the interface was designed in a way that the data recorded in the survey can be entered and subsequently returns the probability of carrying COVID-19 and the risk to which it belongs. In addition, the functions are projected as membership to demonstrate the evaluation criteria of the model as shown in the Figure 12. The interface was developed in Spanish, this study was carried out in Bucaramanga, Colombia.

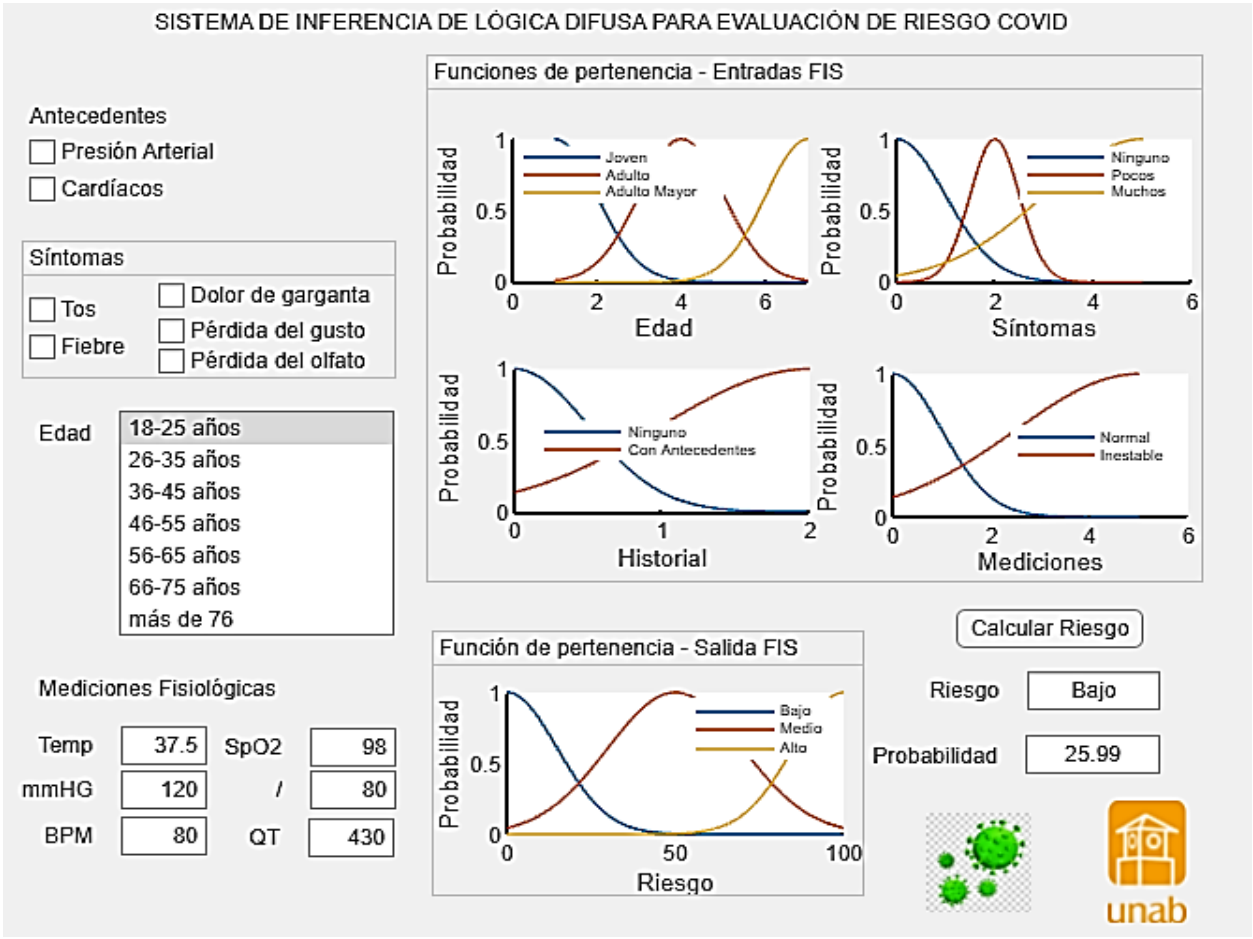


Figure 12. Interface designed using APP Designer

4. Conclusions

SARS-CoV2 was categorized among the diseases with the greatest impact since humanity has had a record, where even though statistically it does not have a high mortality rate, its contagion rate has been high enough to reach a large part of the world population, with high death figures in the most vulnerable groups. COVID-19, being a virus acquired recently, has a very relevant characteristic, which is the evolution of the virus as such, since evolutions have been recorded in its genetic structure and, on the other hand, a scientific evolution of researchers focused on the analysis of SARS-CoV2, for these reasons, as many variables as necessary must be considered to achieve good monitoring of symptoms in people. Due to the short time that has elapsed since the disease appeared, the investigations, despite having a scientific methodology, are prone to being refuted due to their premature knowledge, if future investigations with better scientific support manage to find or develop better techniques for monitoring and diagnosis, this project has the possibility of being the basis for better ways of solving current and future diseases. Nowadays, there are several vaccines, rapid and home diagnostic tests, and treatments, however, the virus continues to spread due to its mutations and variants. It continues to be a challenge to be able to mitigate its effects.

Particularly in the present article, the design of the plant (i.e microcontrollers, communication protocol among others), to select variables to be measured, from which the most optimal options about the instrumentation (i.e sensors) were chosen for each of the measurement variables, seeking efficiency at the time of carrying out the measurements and the comfort of the person when putting on each of the implemented sensors. The implementation of the ECG sensor in the forearm was important since it was desired to make the measurement as less invasive as possible, as it is usually the measurement in the thoracic part or in different members of the body. By integrating the infrared temperature sensor, its great variation was observed depending on the distance from the person, therefore, the decision was made to record the temperature through the Smartwatch sensor, since this sensor at being designed with a handle, it will always have the same distance between the sensor and the person's wrist and will give better results. In addition, through the libraries offered by MATLAB, it was possible to create an adequate interface in which data can be entered and also analyzed without the need to be connected to a specific plant, but rather data can be obtained from other types of sensors or monitoring/ measurement equipment and enter them manually to the interface designed and it throws the corresponding analysis.

Future works should be focused on:

- Design a system which allows linking, feeding, and saving the data collected in the HMI interface with the samples taken from each person, without the need to carry out the survey designed for data collection.
- Acquire a system of sensors with greater capacity and thus achieve greater stability in data collection and be able to produce a pre-diagnosis with a higher percentage of effectiveness.
- Implement the new variables and the respective sensors in the measurement system, thus achieving a measurement of the symptoms that the body presents as a reaction when it is infected with the virus and its different strains.
- Include in the recording of variables of the monitoring system if the person has been vaccinated, what type of vaccine has been applied and the number of doses that have been injected.
- Increase the data base increase the database (number of samples) and include information on the number of times symptoms have occurred or if the disease has occurred several times in each period of time.
- propose a risk classification system using machine learning techniques

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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References

[1] J. Riofrío, C. Muñoz-Moncayo, I. R. Amaro, and I. Pineda, "Identifying Similar Groups of Countries According to the Impact of Corona Virus (COVID-19) by a Two-Layer Clustering Method," *Adv. Intell. Syst. Comput.*, vol. 1326 AISC, pp. 34–48, 2021.

[2] M. Otoom, N. Otoum, M. A. Alzubaidi, Y. Etoom, and R. Banihani, "An IoT-based framework for early identification and monitoring of COVID-19 cases," *Biomed. Signal Process. Control*, vol. 62, no. April, p. 102149, 2020.

[3] V. Mohite, K. Vyas, G. Phadke, and D. Rawtani, "Challenges and future aspects of COVID-19 monitoring and detection," *COVID-19 Environ.*, pp. 131–150, 2022.

[4] N. Ravi, D. L. Cortade, E. Ng, and S. X. Wang, "Diagnostics for SARS-CoV-2 detection: A comprehensive review of the FDA-EUA COVID-19 testing landscape," *Biosens. Bioelectron.*, vol. 165, p. 112454, 2020.

[5] H. Rohmetra, N. Raghunath, P. Narang, V. Chamola, M. Guizani, and N. R. Lakkaniga, "AI-enabled remote monitoring of vital signs for COVID-19: methods, prospects and challenges," *Computing*, vol. 2019, 2021.

[6] L. F. C. Ossa *et al.*, "A hybrid model for COVID-19 monitoring and prediction," *Electron.*, vol. 10, no. 7, pp. 1–13, 2021.

[7] D. R. Seshadri *et al.*, "Wearable Sensors for COVID-19: A Call to Action to Harness Our Digital Infrastructure for Remote Patient Monitoring and Virtual Assessments," *Front. Digit. Heal.*, vol. 2, no. June, pp. 1–11, 2020.

[8] R. Vaishya, M. Javaid, I. H. Khan, and A. Haleem, "Artificial Intelligence (AI) applications for COVID-19 pandemic," *Diabetes Metab. Syndr. Clin. Res. Rev.*, vol. 14, no. 4, pp. 337–339, 2020.

[9] A. T. Purnomo, D. B. Lin, T. Adiprabowo, and W. F. Hendria, "Non-contact monitoring and classification of breathing pattern for the supervision of people infected by covid-19," *Sensors*, vol. 21, no. 9, pp. 1–26, 2021.

[10] V. D. and T. Y. W. Daniel Shu Wei Ting, Lawrence Carin, "Digital technology and COVID-19," *Nat. Med.*, vol. 26, no. 4, p. 458, 2020.

[11] C. Melo, S. Dixe, J. C. Fonseca, A. H. J. Moreira, and J. Borges, "Ai based monitoring of different risk levels in covid19 context," *Sensors*, vol. 22, no. 1, pp. 1–18, 2022.

[12] A. Villegas, D. McEneaney, and O. Escalona, "Arm-ECG wireless sensor system for wearable long-term surveillance of heart arrhythmias," *Electron.*, vol. 8, no. 11, pp. 1–26, 2019.

[13] P. C. W. Beatty, "Design of Pulse Oximeters (Medical Science Series)," *Physiol. Meas.*, vol. 19, no. 2, 1998.

[14] J. Gea, A. Ferrer, and J. M. Martínez-Llorens, "Posibles limitaciones en la utilización de la presión arterial de oxígeno en procesos respiratorios por SARS-CoV-2," *Arch. Bronconeumol.*, vol. 56, no. January, pp. 9–10, 2020.

[15] D. Higgins, "Pulse oximetry.," *Nurs. Times*, vol. 101, no. 6, pp. 34–35, 2005.