ESP32-based low-cost health monitoring

Abd-Alfatah Alodainy

UA3AGW

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1. Abstract:

In 2020 covid 19 has spread around the world and many people got affected, most people were not ready for such an epidemic so this virus spread very fast, in contrast, this kind of problem always motivates people to start working on solutions and ideas, in this project I am suggesting a device that can continuously monitor different measurements from human and predicts his health state. In the first part of this paper I will show what kind of measurements are used for continuous health monitoring, in this project I have used the most common health vital signs, those signs when fluctuate can be the symptoms for some health problems either simple or serious health problems, in the second part I will specify the type of device used for prototype, reasons why did I use it and how it is used as an IoT device. Finally, I will purpose a method to predict human health and give suggestions based on the current measurements.

2. Introduction:

As stated in the abstract the need for a continuous health monitoring device is becoming crucial as this device can expect your current health state and suggest you some activities to do, or even suggest whether you should visit the doctor or not. The parameters used in this project are heart rate, oxygen level, temperature, and skin humidity and of course, these other features like age, height, and sex will be considered in the health monitoring. In the next part of this paper, I will introduce those parameters and give a small description of them.

2.1 Temperature

Temperature is defined as “the balance between heat lost and heat produced by the body.” Heat is lost through perspiration, respiration, and excretion (urine and faeces). [1]

Food metabolism, as well as the activities of the muscles and glands, produce heat. The ideal health state for the human body is homeostasis, which is a continuous fluid equilibrium. Body temperature controls the speed of chemical reactions within the body. The body's fluid balance is therefore impacted by extremes in body temperature.

2.2 Variation of body temperature

The normal range of body temperature is 36.1-37.8 Celsius and this may vary depending on individual differences, time of the day, and body state. We can define three types of temperature measurements, firstly, oral temperature, which is taken in the mouth and this one is the most common and comfortable method but eating or drinking hot meals will alter the temperature in the mouth. The second one is the rectal temperature, which is taken in the rectum, this one is the most accurate as it measures the internal temperature. The third one is the axillary temperature, which is taken in the armpit, under the upper arm and this is the type used in this project.

2.2.1Body temperature variation and its consequences

The body temperature variation can happen for many reasons like

• Causes of increased body temperature: illness, infection, exercise, excitement, and high temperatures in the environment [1]

• Causes of decreased body temperature: starvation or fasting, sleep, decreased muscle activity, mouth breathing, exposure to cold temperatures in the environment, and certain diseases [1]

Body temperatures that are abnormally low or high are a sign of aberrant circumstances. A body temperature below 95 F (35 C) when measured rectally is considered hypothermia. It may result from repeated exposure to cold.

If the body temperature falls below 93 F 8 8 (33.9 C) over an extended length of time, death frequently results. When measured rectally, a fever is an elevated body temperature that is typically higher than 1018.8 F (38.3 C). Fever is also known as pyrexia. A fever is indicated by the term febrile, while afebrile denotes either the absence of a fever or a temperature that falls within the normal range. Infections and injuries are the usual causes of fever. When the body temperature is higher than 1048.8 F (40 C), measured rectally, hyperthermia is present. It can be brought on by severe illnesses, brain injury, and extended exposure to high temperatures. As soon as the body temperature rises above 1068 degrees Fahrenheit (41.1 degrees Celsius), seizures, brain damage, and even death might occur.

2.3 Heart rate

Pulse refers to the pressure of the blood pushing against the wall of an artery as the heart beats and rests. In other words, it is a throbbing of the arteries that is caused by the contractions of the heart. [1]

The rate is measured as the number of beats per minute. Pulse varies depending on sex age and body size.

- **Adults**: typically, between 60 and 100 beats per minute.
- 60-70 beats per minute for adult men
- 65-80 beats per minute for adult women
- Over 7-year-old children: 70-100 beats per minute
- **Children** from one to seven years old: 80 to 110 beats per minute
- **Children**: 100–160 beats per minute
- **Bradycardia**: a heartbeat that is less than 60 beats per minute
- **Tachycardia**: a heartbeat that is greater than 100 beats per minute (except in children)

NOTE: Pulse rate fluctuations or extremes should be reported right away.

2.4 Respirations

is the process of taking in oxygen (O_2) and expelling carbon dioxide $(CO)_2$ from the lungs and respiratory tract. One respiration consists of one inspiration (breathing in) and one expiration (breathing out). [1]

Gas exchanges occur in the lungs (O2 diffuses from the alveoli into the pulmonary blood and CO2 diffuses in the opposite direction). [2]

Molecular oxygen is carried in blood in two ways: bound to haemoglobin within red blood cells and dissolved in plasma. Oxygen is poorly soluble in water, so only about 1.5% of the oxygen transported is carried in the dissolved form. Indeed, if this were the only means of oxygen transport, a PO2 of 3 atm or cardiac output of 15 times normal would be required to provide the oxygen levels needed by body tissues! Haemoglobin, of course, solves this problem—98.5% of the oxygen is carried from lungs to tissues in a loose chemical combination with the haemoglobin.

Haemoglobin in arterial blood is 98% saturated at resting PO2 of 5 to 100 mm Hg, and there are around 20 ml of oxygen per 100 ml of systemic arterial blood. The oxygen percentage in arterial blood is 20 vol% (volume per cent). A Hb saturation of 75% and an O2 content of 15% are produced in venous blood as arterial blood passes through systemic capillaries and releases approximately 5 ml of oxygen for every 100 ml of blood. This indicates that significant amounts of oxygen are typically still present in venous blood (the venous reserve) and may be used if necessary. See fig 1 and fig 2

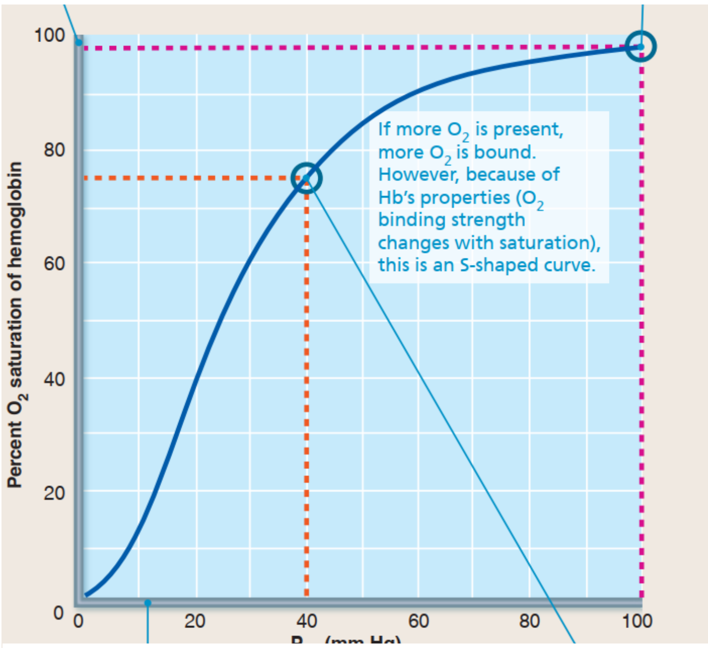

Figure 1 The Oxygen-Hemoglobin Dissociation Curve [3]

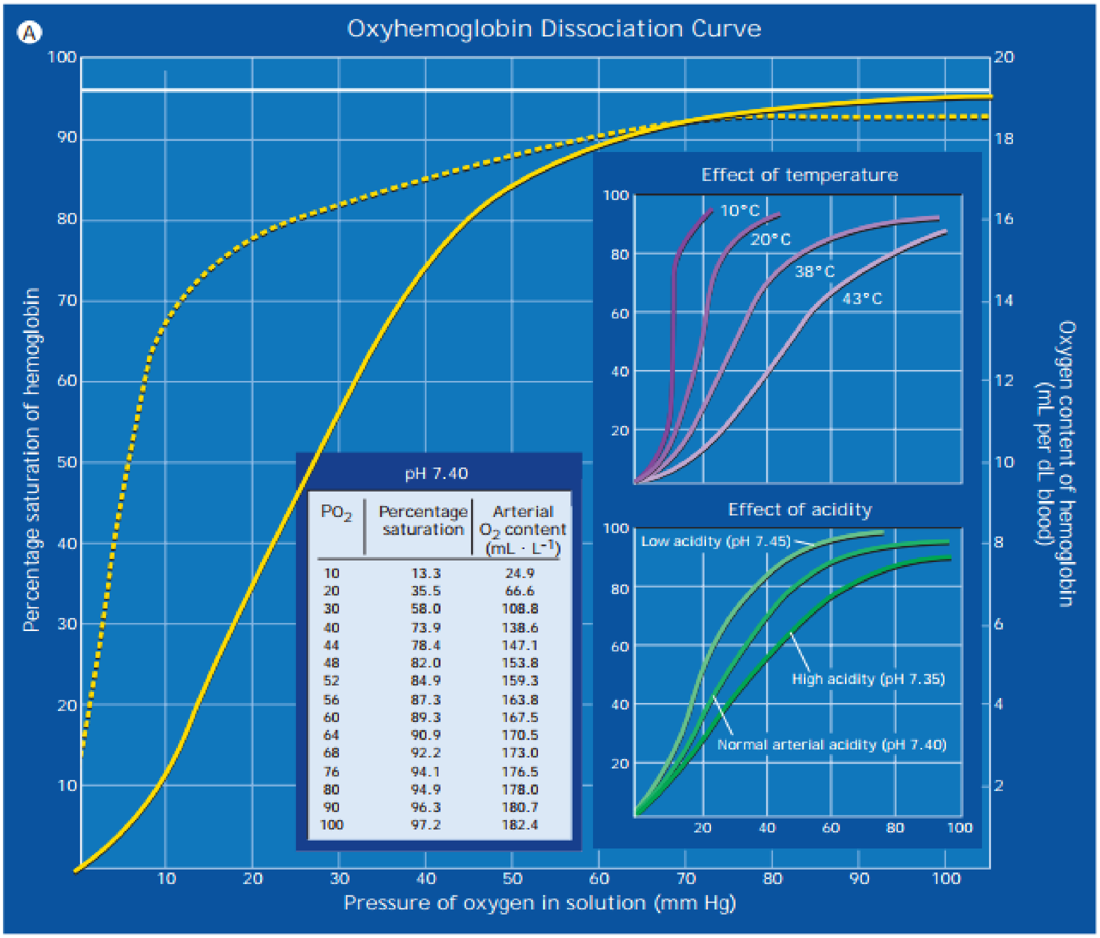

Figure 2 Oxyhaemoglobin dissociation curve. Lines indicate the percentage saturation of haemoglobin (solid yellow line) and myoglobin (dashed yellow line) in relation to oxygen pressure. The right ordinate shows the quantity of oxygen carried in each decilitre of blood under normal conditions. The inset curves within the figure illustrate the effects of temperature and acidity in altering haemoglobin's affinity for oxygen (Bohr effect). The inset box presents oxyhaemoglobin saturation and arterial blood's oxygen-carrying capacity for different Po2 values with a haemoglobin concentration of 14 g·dL blood−1 at a pH of 7.40. The white horizontal line at the top of the graph indicates the percentage saturation of haemoglobin at the average sea-level alveolar Po2 of 100 mm Hg [2]

2.5 TPR graphing

For logging respirations, pulse, and temperature, graphic sheets are specialized records. Although the forms change amongst healthcare facilities, they all contain the same fundamental data. The graphic chart displays a visual representation of the patient's vital sign variations. Compared to a list of numbers that provide the same information, the progress is simpler to track. The majority of graphic charts are utilized in long-term care homes and hospitals. The graph frequently shows also variables that have an impact on vital signs. Examples include operations, temperature-lowering drugs like aspirin, and antibiotics.

3. Hardware architecture

For the prototype device, I used an esp32s microcontroller with 2 cores Xtensa® 32-bit LX6 microprocessors. Figure 3 shows the construction of this microcontroller. More info about the microcontroller can be found in the datasheet []. The reason why I chose this type of controller is that it has double cores and a flash memory of 32 MB size. However, note that this controller has some factory issues, for example when you try to upload a code file to the controller the compiler through a fatal error, and this issue can be resolved by connecting the enable button with a 10 μF capacitor to the ground.

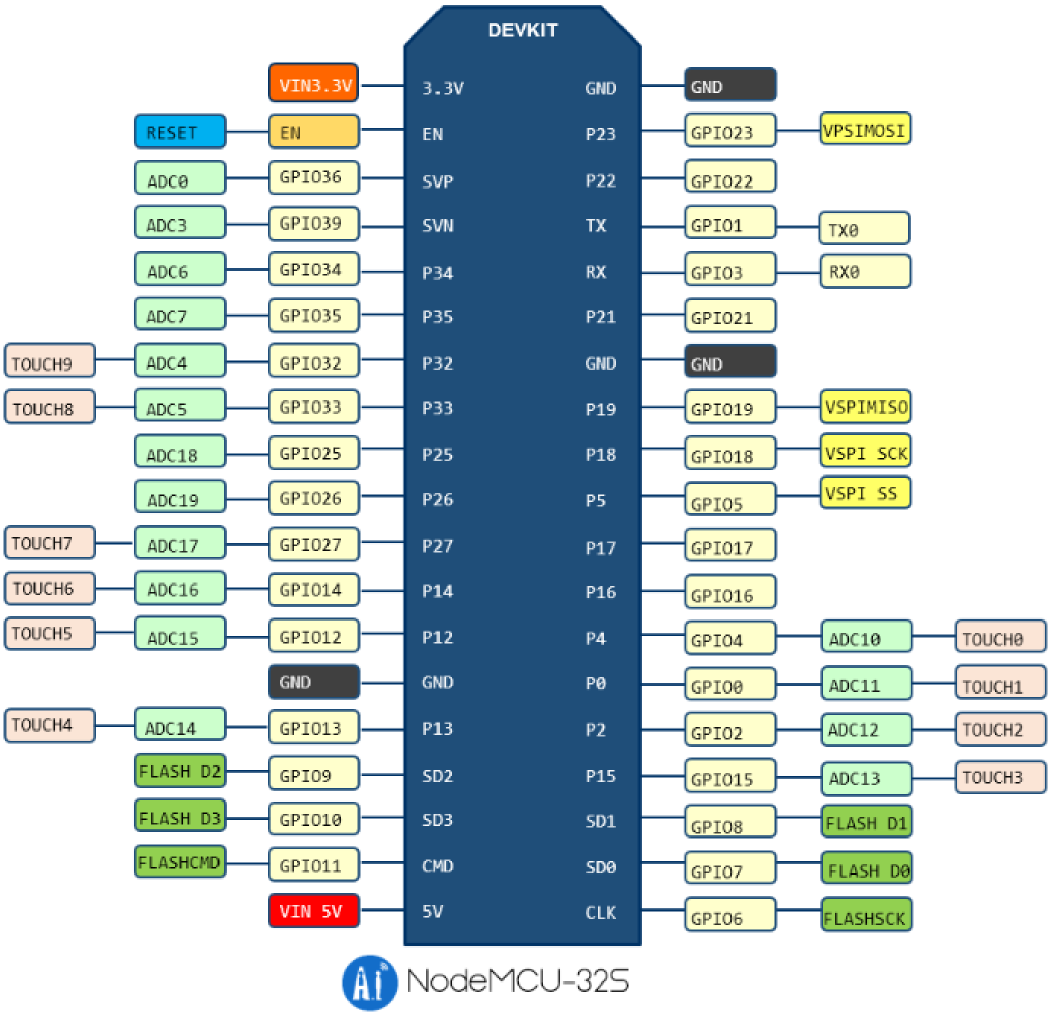

Figure 3 architecture of esp32s microcontroller [4]

For measuring the pulse rate and the oxygen level in the blood I used the so-called pulse oximeter sensor. This sensor is known in the market as max30100. This sensor is cheap and can be bought for 3$ to 4$. However, it has many issues, module RCWL-0530 has 4.7k pulling-up resistors that reduce the voltage to be pulled to 1.8 volts which do not work for the 5v Arduino microcontroller (the minimum is 2.0 Volts). But this is not a big problem as it can be solved by Removing the three 4.7k resistors from the circuit and swapping them out for two additional 4.7k resistors or simply cutting the line that connects the third resistor and connecting only the remaining two as you can see in figure 4.

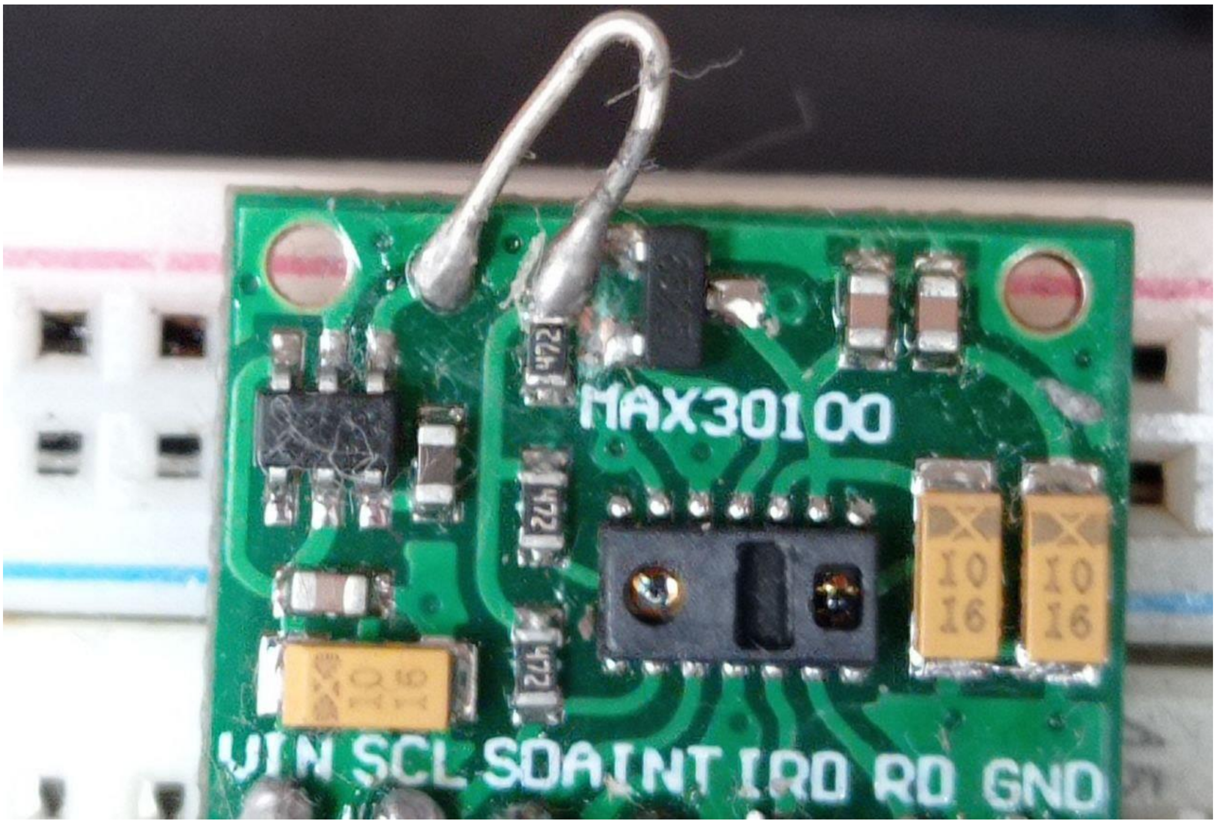

Figure 4 RCWL sensor issue and solution, removing one of the three resistors

And for measuring the temperature and humidity I used the well-known sensor SHT 21, this sensor is cheap and works in high frequencies, it costs around 3$. You can see the sensor in figure 5.

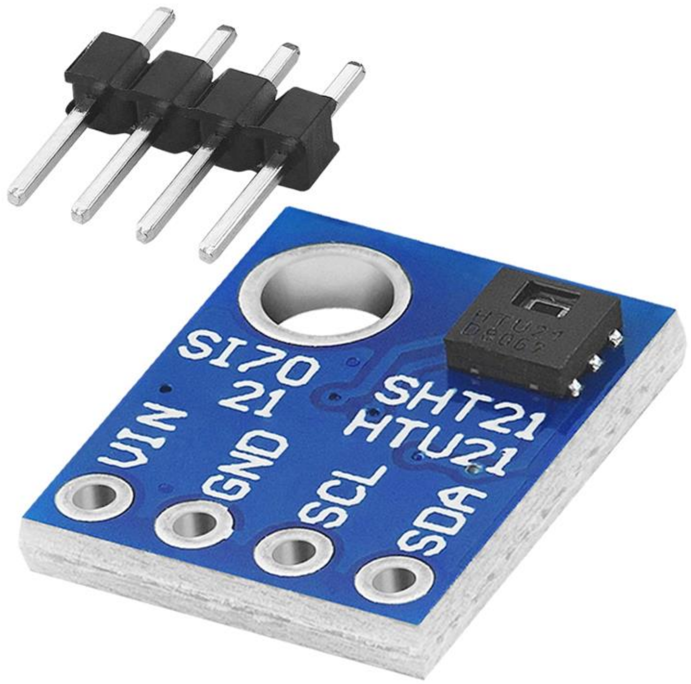

Figure 5 sht21 htu21 temperature and humidity sensor

The microcontroller and the sensors are connected as can be seen in the following schematic. See fig 6

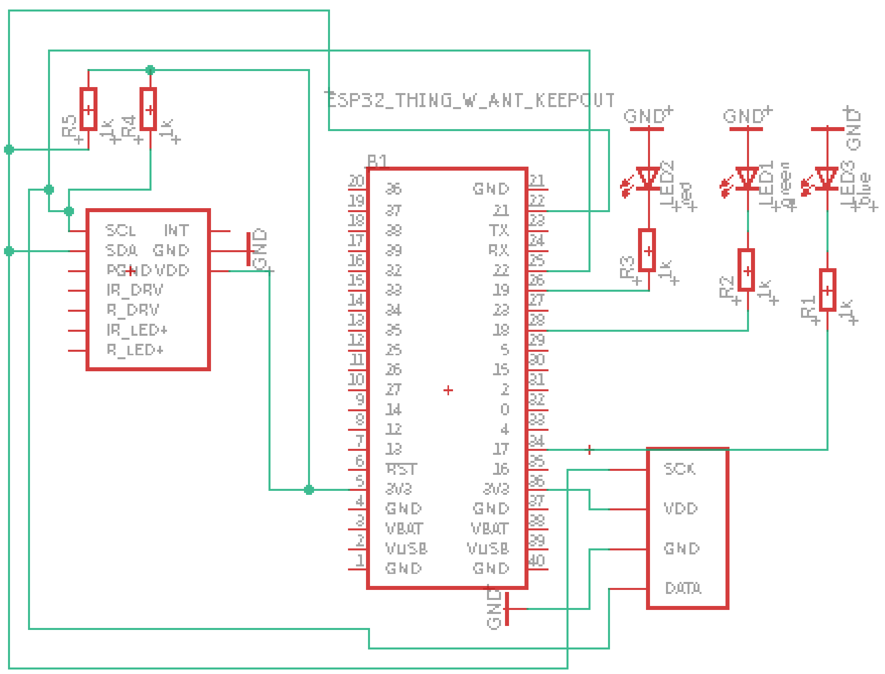

Figure 6 Hardware schematic

3.1 Device architecture

This health monitoring device is an IoT device that measures the different vital signs and then sends the measurements to the user's smartphone this structure can be seen in fig7.

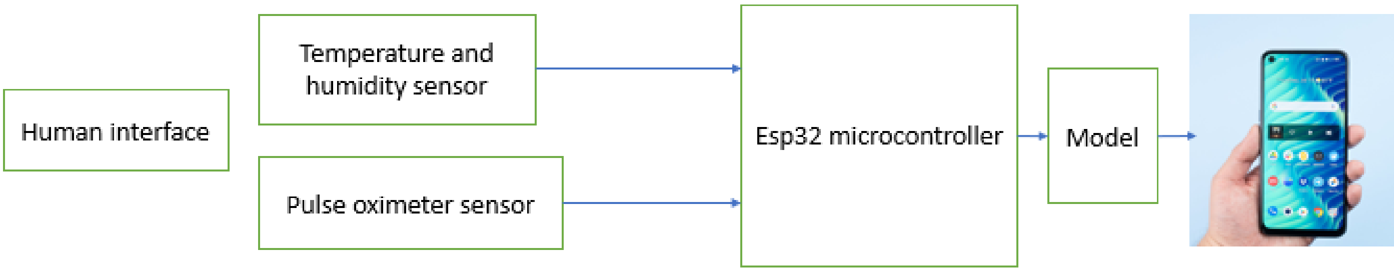

Figure 7 Device architecture

I used an already existing tool for IoT projects, this tool is an Android application that is called Blynk. It provides a nice environment for developers to build their prototypes in which you can add widgets and other stuff either to control the device or to get sensor measurements. In figure 8 you can see the main screen of this application and the widgets used.

4. Software architecture

For writing the program I used C and C++ programming languages since C provides easy access to the memory level of the controller. Each sensor library is included at the top of the program, and then the following part of the code starts getting executed after these header files.

For connecting the controller to the Wi-Fi, I used the so-called "Wi-Fi Manager" library, this library provides multi-functions in which you can use your controller as a server and let others connect to it, or just connect your controller to the available routers, and there is an available

HTML design for the login website in which you can insert the password of your target network. See fig 9

Figure 8 Blynk application main screen

Also as stated above the pulse oximeter cheap sensor needs to be updated every 60 ms, of the running program cycle however if we used a single core it is difficult to connect to the database and at the same time measure the different signs in one single core, so that is why I used the dual-core of the controller, core 0 is responsible for connecting the device to the Wi-Fi and core 1 gets the measurements from the sensors. So, in this way, I ensure that the device will run smoothly for a long time, with low power consumption.

5. Proposed position of the device.

As stated in the introduction, for measuring the temperature it is preferred to put the sensors in certain positions, so I chose the armpit to be the place where the sensor should stay. And in addition, the heart rate sensor can be placed also near this sensor, so both can be stuck there and continuously monitor the different changes.

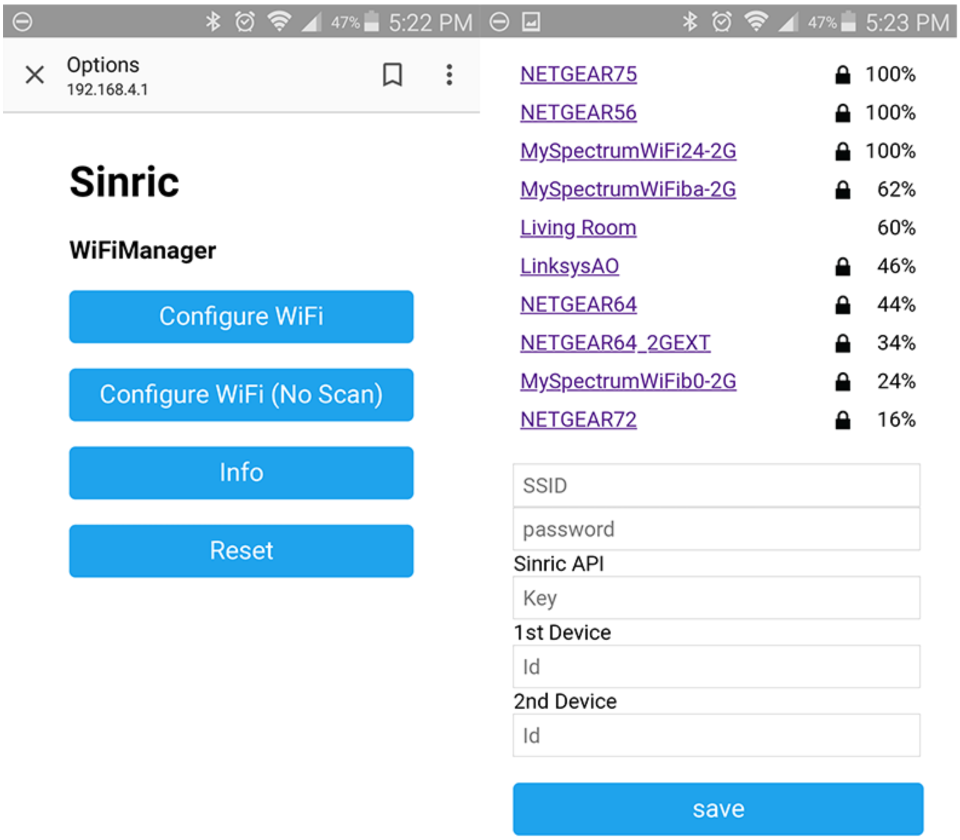

Figure 9 Wi-Fi setting of the device

6. Proposed health monitoring method and future work

From the introduction, we can see that the fluctuation of the human body's vital signs is a real problem and can be a sign of many issues in human health, so that is why having a health monitoring device is something appreciable. The model I suggest is that based on the theoretical knowledge about the effects of these signs changes an initial model will be built. There will be many errors in the first part, but I am going to keep all these measurements in a CSV file and meanwhile do analysing for the data being recorded and using a machine learning model to predict the health state based on the current measurements and the real current state of the human health, and that's what I will be doing in the recent future.

7. Conclusion

These developments aim to continuously monitor the health state of any person to avoid any expected health problems and to provide continuous health recommendations and advice. Furthermore, this device will be cheap, and easy to use, and a wider range of the community can use it. The built model for prediction is still under development as this device needs to measure and record that data and based on this data update and correct the model.

References

[1] B. M. R. K. S.-N. S. S.-K. Louise Simmers, "Vital Signs," in *SiMMerS DHO Health Science*, Boston, Cengage, 2015, pp. 446-477.

[2] F. I. K. V. L. K. William D. McArdle, "Gas Exchange and Transport," in *Exercise Physiology Nutrition, Energy, and Human Performance*, Tokoyo, Wolters Kluwer Health, 2015, pp. 275-290.

[3] S. Anxinke, "Nodemcu-32s Datasheet," Ai-Thinker Technology Co, 2019.

[4] E. N. M. •. K. Hoehn, "The Respiratory System," in *Human Anatomy & Physiology*, Malaysia, Pearson, 2019, pp. 866-874.

8. External links for the code and the video of the device

1- https://github.com/Abd-Alfatah/Health_monitoring.git
2- https://drive.google.com/file/d/1Vq5qFXXfzC-m7P_X3li3odqy-USa0flH/view?usp=sharing