

Technological Solution to Optimize the Monitoring of CoViD-19 Symptoms in Seniors Patients in Lima

Sara Haro-Hoyo, Edgard Inga-Quillas and Willy Ugarte^{1a}
Universidad Peruana de Ciencias Aplicadas (UPC), Lima, Peru

Keywords: CoViD19, Technological Solution, IoT, Monitoring, Patients.

Abstract: The aim of the article is to present the implementation of a technological solution based on the use of wearable that allows optimizing the monitoring process of elderly patients with CoViD19. This is a current big problem since the pandemic has made a lot of issues emerge for elderly patients. For instance, since elderly people are more vulnerable for CoViD19, they require to avoid social contact or follow more strict rules for lockdowns. This work addresses and applies aspects from the use of IoT for the monitoring of elderly patients, application of technological models in real time, and the supervision of symptoms of CoViD19. Our results show the feasibility of our approach.

1 INTRODUCTION

On January 30, 2020, the World Health Organization (WHO) reported the existence of a total of 7,818 people infected with CoViD19 worldwide, most of them from China.

According to the Pan American Health Organization (PAHO), the WHO declared China as very high risk and the other countries as high.

Likewise, the WHO published the Strategic Preparedness and Response Plan of the international community, to help states with poor health systems to protect themselves from the new virus.

More than 2.9 million people worldwide have died from the new SARS-CoV-2 coronavirus and about 134.1 million infected.

It is worth mentioning that the country most affected by 2021 is the United States with more than 31 million infections and 560,000 deaths; Brazil follows, with over 13.2 million diagnosed and with 345,000 deaths; and India exceeds 13 million infected and 167,000 deaths.

According to the latest report from the Ministry of Health of Peru (MINSA), as of September 2021, 199,727 deaths were registered in our country, where the most affected province was Metropolitan Lima with 81,389 deaths, with a 9.23% fatality rate of the virus.

With these indicators, many countries are in a state

of health emergency due to this pandemic, hence the need to find technological solutions based on innovation within the field of medicine.

Hence, this article aims to contribute with a proposal for improvement in the process of monitoring patients with symptoms of this disease, as well as in the recovery process of the patient infected with this virus.

A precedent is the study of Remote health monitoring of elderly through wearable sensors (Al-Khafajiy et al., 2019), which focused on the design and implementation of an intelligent health monitoring system that can observe the elderly remotely.

The objective of this article is to present a technological solution based on 2 mobile applications:

- “CoViDSalud.Paciente” and
- “CoViDSalud.Atención”

Seeking to optimally monitor the symptoms of CoViD-19 in elderly patients in Metropolitan Lima.

Therefore, the main matrix of the technological solution is to have a mobile application that can be linked to a “wearable” device; to obtain constant control and monitoring of the patient.

This application presents a friendly interface; in other words, it is easy to use for the target audience, who are older people, who present specific and distinctive needs, as well as significant demands regarding the use of ICTs.

The development of this APP contributes as a data control and monitoring tool that can refer to a possi-

^a  <https://orcid.org/0000-0002-7510-618X>

ble CoViD19 alert; o provide support in the process of a patient who has already been diagnosed and that these can serve as an accurate reference for the doctor and thus also contribute to the recovery process of the patient throughout their process from beginning to end of the disease.

- We analyze the main technological tools that allow the development of the solution to optimize the process of monitoring the symptoms of CoViD19 in elderly patients.
- We validate the solution of the technological model proposed in elderly patients through the use of wearable.
- We propose a business continuity plan for the implementation of the technological solution for monitoring the symptoms of CoViD19 in elderly patients.

This paper is organized as follows. In section 2, we will describe the differences and comparisons with other works about the evaluation of the level of depression; in section 3 we will address the key concept for the core of our approach in the evaluation of depression level with facial and voice analysis and the aggregated value of the our work according to the evaluation of the level of depression. Subsequently, in section 4 we will present the validation of the technological model functionalities in a simulated scenario.

Finally, in section 5 we will specify our main conclusions and results of the finished application.

2 RELATED WORKS/DISCUSSION

For the development of the proposed technological solution, 2 mobile applications were implemented that are linked to a “wearable” device to obtain constant control and monitoring of the patient with CoViD19.

For this, an analysis of the state of the art was carried out, selecting its most relevant scientific articles:

In the paper (Mohammadzadeh et al., 2020), the author achieved the optimization in the information reporting processes of the main symptoms of CoViD19, so that it serves as part of the process of studies considered in possible diagnoses.

What differs from our paper is that we will consider four measurement indicators, temperature, heart rate, sleep status and blood saturation.

In the same way, in the paper (de Morais Barroca Filho et al., 2021), the authors manage to demonstrate the need for an intelligent diagnosis and monitoring of infected patients to reduce hospital care,

since they are the most vulnerable people, and this could have great consequences.

The objective of this research is to present a platform designed for constant monitoring of patients in critical condition, using portable sensors to monitor patients infected with coronavirus.

What sets us apart from this paper is that we not only rely on monitoring, but we also provide virtual medical assistance to those who use our application.

Another study that follows the same line of research is the paper (Rathee et al., 2021), which delves into the 2 studies already mentioned, since it explains the importance of the use of AI in the health sector, mainly, in medical systems, which can be very useful to automate and remotely quantify CoViD19 patients and improve recognition of infected patients in the early stages of contagion.

What differentiates us from this paper is that they are based on the first stages of contagion, however, we already work with patients infected with CoViD-19, providing them with continuous monitoring, medical and laboratory assistance from day one.

Hence, when we are faced with the inexplicable situation of a pandemic that has not yet been overcome, the motivation of the researchers of the paper (He et al., 2021) is observed, to propose extensive analyzes and evaluations on the technological solutions that can help in the fight against the expansion of CoViD-19, and thus continue to inspire other researchers to continue making their contributions to mitigate the damages of the pandemic.

What differentiates us from this paper is that we already apply a solution to CoViD-19 patients monitoring the main symptoms and there will also be a caregiver who will also follow the steps of a respective patient.

However, one of the most vulnerable groups and that suffered high mortality rates were the elderly, therefore, in paper (Gordon et al., 2020), it refers to the importance of constant monitoring with the elderly, since they are more vulnerable due to the possible congenital diseases, or those already developed by age.

Therefore, and according to the positions, it is vitally important to interconnect with the integrated systems developed to combat CoViD19.

Compared to this paper, our solution implements an alert system to our elderly patients that is sent both to the patient, caregiver, and GP.

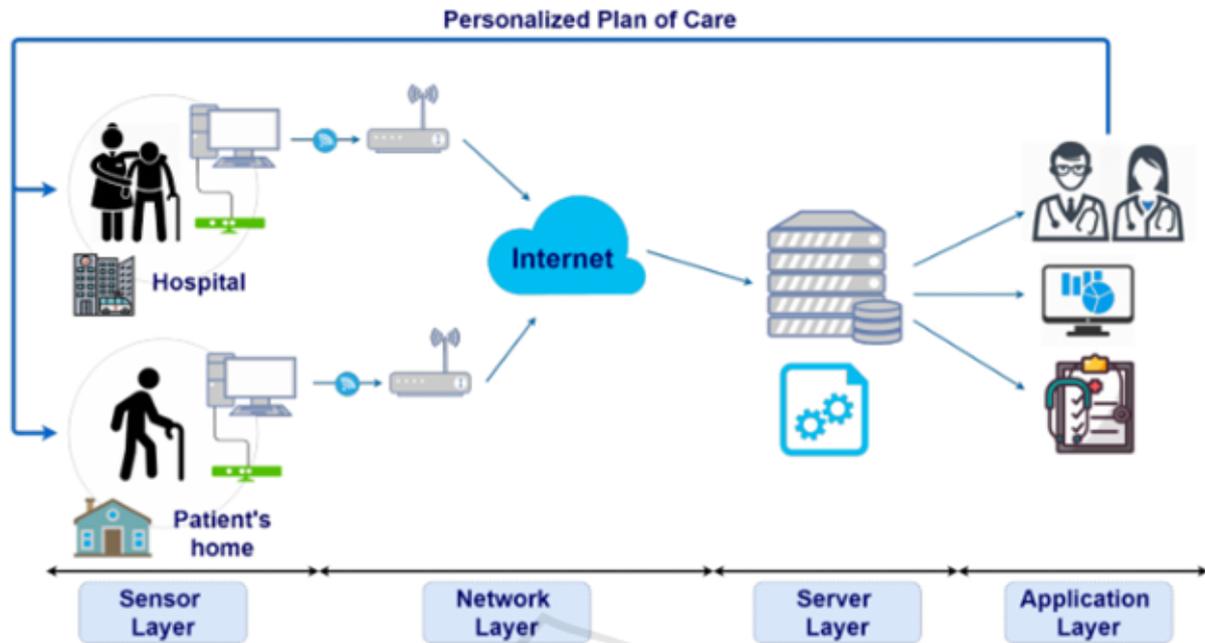


Figure 1: Remote Monitoring Validation Engineering System (ReMoVES) Architecture (Trombini et al., 2021).

3 TECHNOLOGICAL SOLUTION

3.1 Preliminary Concepts

In this section, the main concepts involved in our research will be developed.

We propose that, for each concept, there is a definition and a respective example based on a review of the literature on depressive disorder and facial and voice recognition.

Definition 1 (Use of IoT technologies (Blas et al., 2021; Trombini et al., 2021; de Morais Barroca Filho et al., 2021; Rathee et al., 2021; Vedaei et al., 2020)). *The concept of IoT refers to a digital interconnection of everyday objects with the internet. It is the internet connection more with objects than with people.*

According to Forbes, with the appearance of CoViD19, at the beginning of 2020, thermometers began to be used, which were connected by a 5G network, such as smart rings and / or bracelets that had the function of collecting data from patients such as the blood oxygen level and heart rate (Milenkovic, 2020).

Example 1. *In (Trombini et al., 2021), the research, presents a system based on IoT that provides us with a program where the patient can perform his totally personalized rehabilitation and is reviewed by a professional to monitor the performance and efficiency*

of workouts from any device. This work used a ReMoVES architecture which has 4 layers as shown in Fig. 1:

3.1.1 Wearable Sensors

Advanced technology to "carry", mobility is its main characteristic and the IoT the basis of its approach, since sensors allow data to be constantly collected and transmitted to different devices, accessories, and garments.

While it might seem like most wearables are worn on the wrist, there are devices designed to be worn almost anywhere on the body.

For this reason, in addition to bracelets, wearables can be found in rings, necklaces, headbands and even shoe inserts with advanced functions (Motti, 2020).

According to Filho (de Morais Barroca Filho et al., 2021), an analysis of the various previous studies for the spread of CoViD19 based on IoT technologies, cloud computing and mobile applications can be carried out.

Which are already being used to process patient data regarding health monitoring and obtain an immediate response as soon as the patient needs it. See Fig. 2.

According to the Pan American Health Organization (2021), the epidemiological update caused by SARS-CoV 2 has had different variants that affect public health.

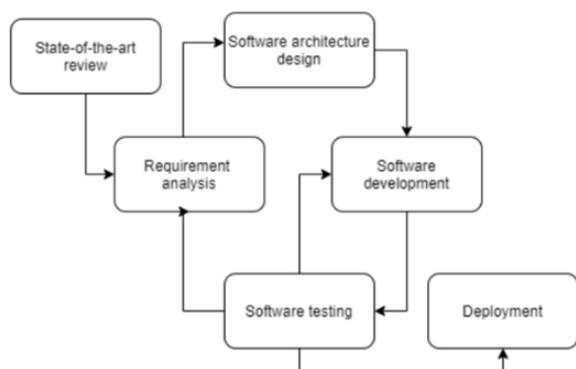


Figure 2: Methodology to develop PAR (de Morais Barroca Filho et al., 2021).

In October 2020, a new variant was detected in India called B.1.617, which is under investigation. Also, other variants of great interest for public health have emerged, such as variant P.1, lineage B.1.1.28 on January 9, 2021, in Japan, which was detected in travelers coming from Brazil.

According to the virologist Kamil, one of the mutations of this new variant is like those identified in the countries of Brazil and South Africa and he considers it to be less infectious compared to the variant in the United Kingdom¹

According to (Rathee et al., 2021), the authors propose the use of monitoring of 15 symptoms of infected patients in an-ANN-based system to manage patient data, to improve the classification of CoViD19 infected patients.

The model used in this research is the multilayer perceptron network (MLP) which is considered a type of ANN those researchers often use frequently, see Fig. 3.

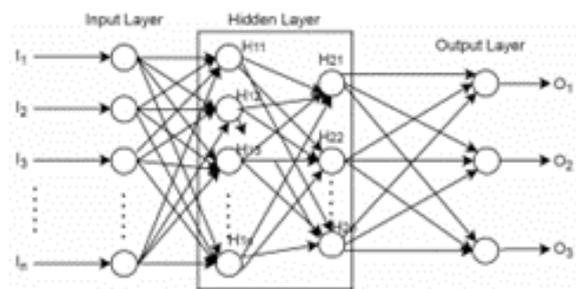


Figure 3: Multilayer perceptron architecture network (Rathee et al., 2021).

3.2 Method

Prior to the development and proposal, a benchmarking analysis was carried out as the methodology to ex-

tract the data, using Gartner², which has a wide field regarding the evaluation of tools from different areas.

On this occasion, this methodology was adapted to generate a quantitative report that serves to qualify the tools in question.

3.2.1 Phases

The project development approach was based on five phases, which are detailed below:

- In the first phase, the scope of the project was defined together with the Product Owner. Likewise, an in-depth investigation was generated regarding the initially agreed requirements. With these premises, the Project Charter documentation begins.
- For the second phase, an analysis was carried out regarding the technologies that would be involved for the proposed solution.
- In the third phase, the technological model was designed, validated by the Product Owner.
- During the fourth phase, the development of the proposed solution (product) that was delivered to the Product Owner was carried out. Additionally, the corresponding validations were generated based on the initial requirements.
- Finally, in the fifth phase, the results of the project (final product) were presented.

3.2.2 Execution

Two mobile applications will be developed for the Android operating system as part of the technological solution, which will bear the name of "CoViD-Salud.Paciente" whose main purpose will be to optimize the monitoring of main symptoms of elderly patients to rule out or accompany the CoViD19, using a wearable device via Bluetooth connection.

And it will work together with another application called "CoViDSalud.Atención", whose main purpose will be to contribute to the management of doctors, caregivers and laboratories, to be able to provide medical assistance to patients, by appointment in an efficient manner.

This technological solution will contribute with the monitoring of the main symptoms to prevent the patient from getting worse his state of health, as well as keep a record in the reports of symptoms that keep the patient stable and collaborate with the tranquility of this (see Fig. 4).

This research is aimed at elderly patients, that is, 60 years and older, since according to WHO research

¹Epidemiological Update - PAHO

²Benchmark Analytics

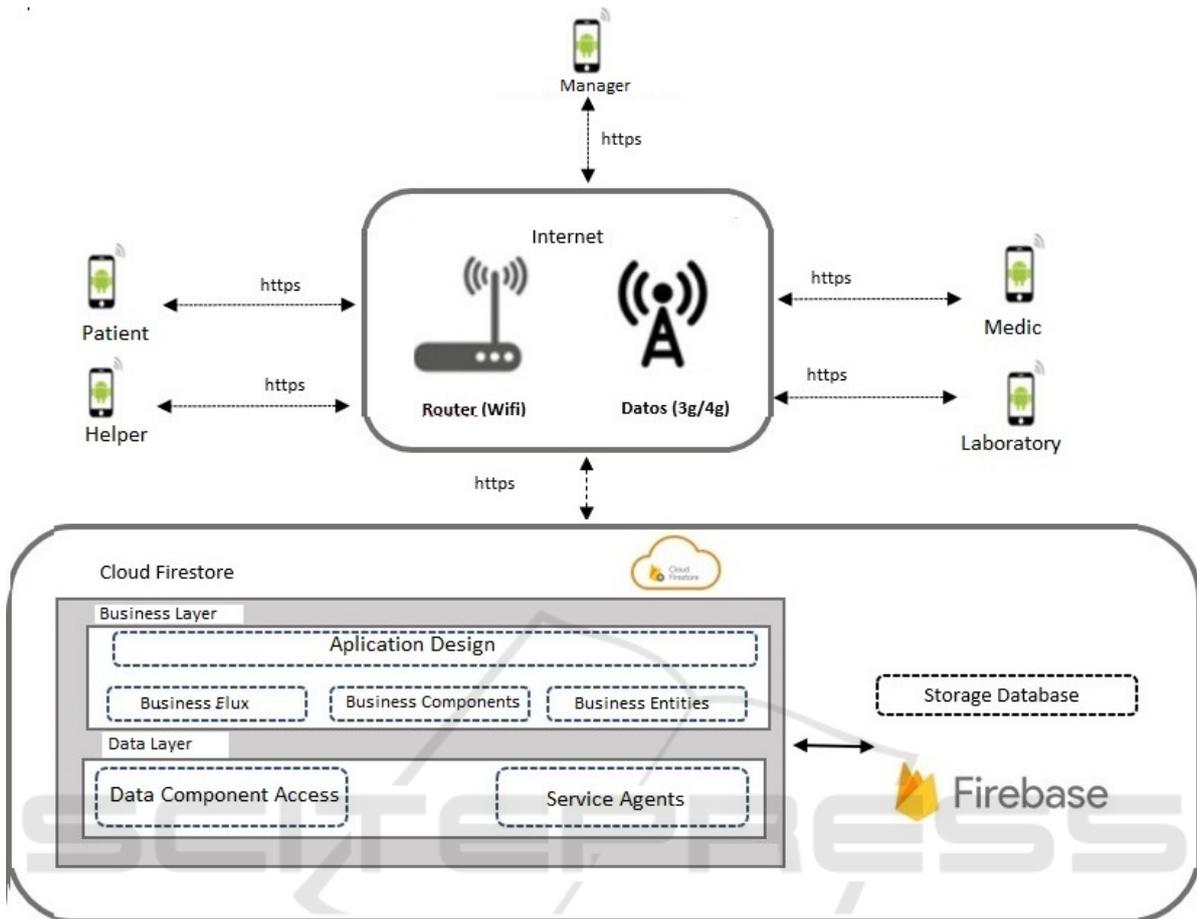


Figure 4: Physical Architecture Diagram.

statistics (2020), they are the society with the greatest vulnerability and/or risk against CoViD19.

This part of the population has a weaker immune system and, in most cases, they have one or more chronic diseases, such as diabetes, hypertension, cardiovascular and pulmonary conditions (COPD), so their ability to respond to infections is less.

The objective of this architecture, see Fig. 5, is to be able to identify the requirements that have an impact on the software structure and reduce the risks associated with its construction.

The architecture must support future changes in software, hardware and functionality demanded by customers (which occur very often).

Similarly, it is the responsibility of the software architect to analyze the impact of his design decisions and establish a compromise between the different quality requirements, as well as between the compromises necessary to satisfy the users, the software, and the business objectives, and which are functional and quality requirements, hence it is vital to determine the type of software to be developed.

Presentation Layer. It is the part of the system with which the user interacts. Your screens, forms are all user interfaces (UI) that are part of the presentation layer User interfaces can make use of components or user process controllers (UIC) to communicate with the back end and navigate or process the user interface.

Service Layer. The services layer in the architecture allows the functionality of the system to be exposed to client and external applications. It is also the key to achieving cross-platform and interoperable solutions. Service components expose the functionality of the components through contracts, which are the interfaces where service providers and service consumers agree and must be immutable.

Business Logic Layer. It contains all the processing logic to make the application possible. The Component is where you put this processing logic where each one can be coded in independent methods.

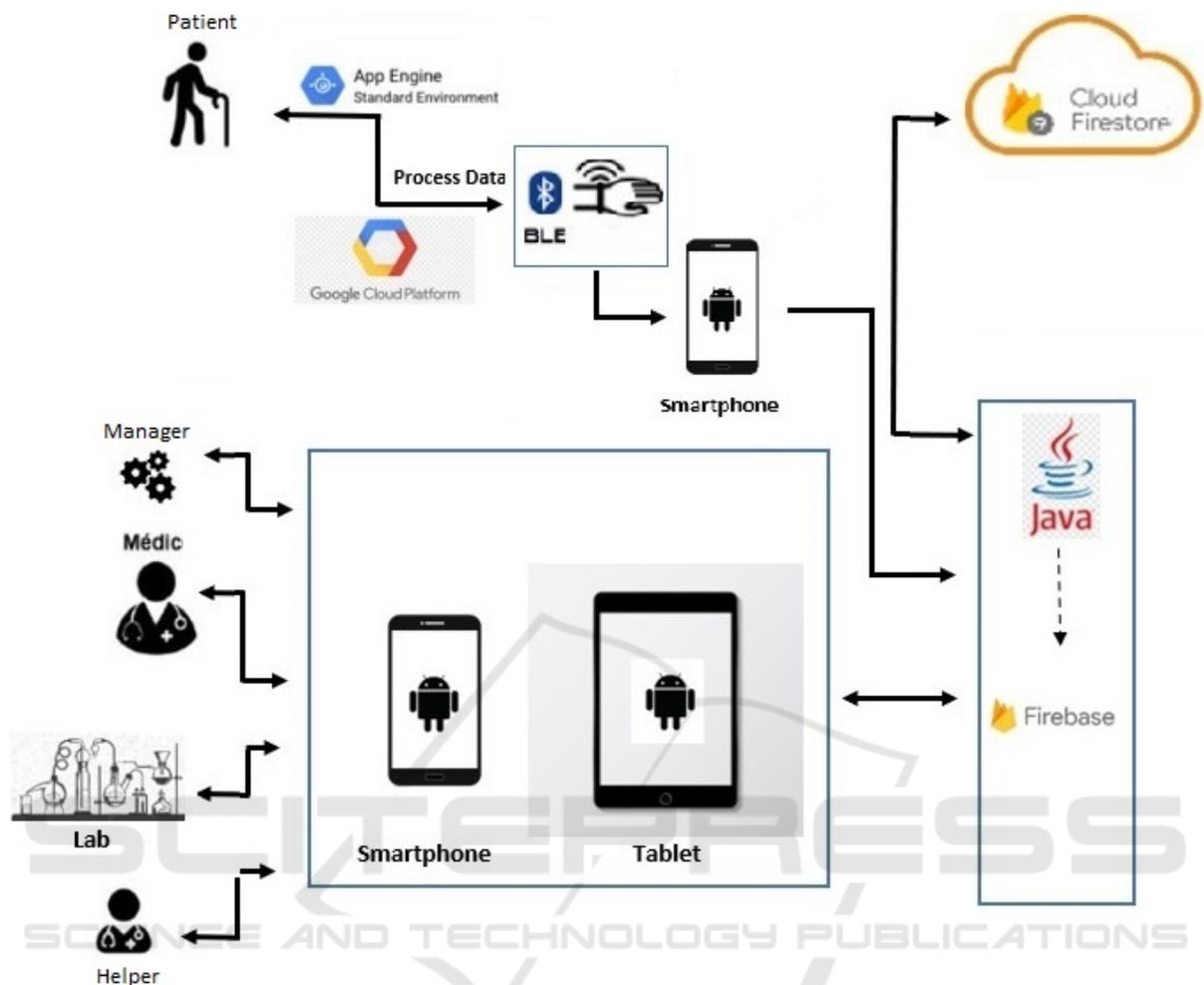


Figure 5: Integrated Architecture Diagram.

Table 1: Modules and responsibilities.

Module	Responsibility
User interface (UI)	Forms are all user interfaces (UI) that are part of the presentation layer.
Presentation logic components	Process a request, generating response content, and formatting the page for the client
Contracts (Service interfaces)	Allows data transfer, it applies specific actions (POST, GET, PUT and DELETE) on resources.
Services	Provide additional services that the application requires.
App	Expose the business logic.
Workflows	Organize the flow that carries out the execution of the business process
Components (edit)	Component that performs business tasks
Entities	Component that represents custom business classes.
Data access components to Data	Components that deal with the database tables

Table 2: Scenarios.

Patient Preexisting Morbidity	1	2	3	4	5
	Alzheimer's	Irritable colon, Gastritis	Type 2 diabetes	Low back pain	Migraine
Age	89	89	67	65	61
<i>Heartrate (bpm)</i>					
CONTEC-CMS50D	91	90	90	88	89
AFK-YK009	89	88	89	86	87
HUAWEI BAND 6	92	91	92	90	90
<i>SpO2 (%)</i>					
CONTEC-CMS50D	97	98	97	99	98
AFK-YK009	95	96	95	97	96
HUAWEI BAND 6	98	99	98	99	99
<i>Temperature (°C)</i>					
Thermometer Mercury	36.3	36.5	36.5	36.5	36.8
Thermometer Digital	36.2	36.4	36.4	36.5	36.7
<i>DreamState</i>					
Galaxy Wacth (h/d)	7:15	6:15	7:46	8:20	7:00
HUAWEI BAND 6	8:15	7:15	8:10	8:40	8:15

Data Layer. The data layer is where we save our components as CRUD operations, which handle the insertion (Create), the selection (Read), the modification (Update) and the elimination (Delete) of data, see Table 1. In this presentation we show the different modules with their respective responsibilities.

4 EXPERIMENTS

In this section we are going to treat an experimental study to show the feasibility of our project, in each of the following paragraphs the experimental protocol, the results measuring the efficiency of the proposal and a short discussion will be detailed.

4.1 Experimental Protocol

For the development of our solution, an IDE called Android Studio 3.6 was used, where the Java and Kotlin language were used for the entire Front-end part.

Firestore cloud-based platform for the back end, HMS Core (Huawei Mobile Services) for wearable and mobile device connectivity.

However, for those users who do not have mobiles with an Android operating system, an emulator called

Blue Stacks 5 with an instance in Android 9.0 was used to run the tests of our application.

In the same way, to run the programs used, a computer with 10th generation Core i7, 16GB of RAM and a 10GB reserved storage for the application was used.

Likewise, to carry out the respective tests, a Samsung Galaxy Note 20 Ultra cell phone with Android 11.0 operating system was used, accompanied by a Huawei Band 6 Smart Band with Bluetooth connection.

Then install the Huawei Health Kit and create an account that will be associated with the wearable. When opening the app, it will ask to connect with Huawei services, for this Huawei HMS Core will be downloaded.

Immediately after downloading it, you will enter the application and you will be prompted to enter your Huawei account email and password.

Finally, it will ask for the permissions to read your data, it should be noted that all the data it reads is saved in Firebase.

Our code and our data are publicly available at the following links:

For the main apk: <https://github.com/retto710/CoViDSaludAppAndroid> and for the patient apk: <https://github.com/retto710/CoViDSaludPaciente>.



Figure 6: Comparison of results.

4.2 Results

This section will show the solution developed from the proposed architecture.

In addition, to validate the developed solution, the test to which it was subjected, and the results obtained from it in different elderly patients with different morbidities are shown.

Our final IoT-enabled prototype is designed with a Huawei Band 6 wearable and a mobile device where the measurements of the main symptoms will be displayed.

The accuracy of heart rate and oxygen saturation measurement are compared using two handheld devices: CONTEC-CMS50D and AFK-YK009.

As shown in scenario 1, see Table 2, measure-

ments with the Band 6 device are more effective, see also Fig. 6 for variations.

On the other hand, the temperature measured by the device is compared with the Thermometer mercury thermometer.

It can be seen in Table 2 that the results shown for 5 patients with different ages by the proposed IOT-enabled wearable device are almost close to the values obtained by the smart band and the thermometer.

Finally, for the sleep state, a comparison was made between two wearable devices: Galaxy Watch and Huawei Band 6, in which the following results are shown.

4.3 Discussion

We describe the implementation and impact of a CoViD-19 senior monitoring solution, in which we found that the RPM program was associated with significantly lower risk from our endpoint and the percentage of hospitalized or readmission patients hospitable has decreased.

In addition, among patients who have used our app, 67% did not produce alerts for symptoms that require manual monitoring, suggesting that PROM for CoViD-19 patients can provide extensive monitoring without the need to directly contact a physician. for your review.

5 CONCLUSIONS AND PERSPECTIVES

The main objective of this research was to analyze the main technological tools regarding the different types of follow-ups to patients with CoViD-19, during the first stage of contagion.

The paper determines the management of scientific information, as well as the capture of data in terms of health monitoring and analysis of results with the laboratory approach.

As a second conclusion, the solution of the proposed technological model was validated, since IOT technology was used using a wearable to capture data on oxygenation in the blood, heart rate and sleep status, and thus see the progress and monitoring of the main symptoms of CoViD-19 patients in a timely manner.

The experimental results of the proposed solution show higher precision and shorter response time in various functions of our application using Huawei's smart band 6 device.

Therefore, this project represents a preliminary study, a precedent to continue developing improvements in the Peruvian health system with the use of technologies and encourage the involvement of private companies for the creation of I+D+I, Research, development, and innovation.

Evenmore, using Genetic information to seek for historical data about a patients (Arroyo-Mariños et al., 2021) or monitoring symptoms with a similar technological solution for other diseases (Jorge-Lévano et al., 2021).

REFERENCES

- Al-Khafajiy, M., Baker, T., Chalmers, C., Asim, M., Kollivand, H., Fahim, M., and Waraich, A. (2019). Remote health monitoring of elderly through wearable sensors. *Multim. Tools Appl.*, 78(17):24681–24706.
- Arroyo-Mariños, J. C., Mejia-Valle, K. M., and Ugarte, W. (2021). Technological model for the protection of genetic information using blockchain technology in the private health sector. In *ICT4AWE*.
- Blas, H. S. S., Mendes, A. S., Encinas, F. G., Silva, L. A., and González, G. V. (2021). A multi-agent system for data fusion techniques applied to the internet of things enabling physical rehabilitation monitoring. *Applied Sciences*, 11(1).
- de Moraes Barroca Filho, I., Aquino, G., Malaquias, R. S., Girão, G., and Melo, S. R. M. (2021). An iot-based healthcare platform for patients in ICU beds during the COVID-19 outbreak. *IEEE Access*, 9:27262–27277.
- Gordon, W. J., Henderson, D., Desharone, A., Fisher, H. N., Judge, J., Levine, D. M., Maclean, L., Sousa, D., Su, M. Y., and Boxer, R. (2020). Remote patient monitoring program for hospital discharged COVID-19 patients. *Appl. Clin. Inform.*, 11(05):792–801.
- He, W., Zhang, Z. J., and Li, W. (2021). Information technology solutions, challenges, and suggestions for tackling the COVID-19 pandemic. *Int. J. Inf. Manag.*, 57:102287.
- Jorge-Lévano, K., Cuya-Chumbile, V., and Ugarte, W. (2021). Technological solution to optimize the alzheimer's disease monitoring process, in metropolitan lima, using the internet of things. In *ICT4AWE*.
- Milenkovic, M. (2020). *Internet of Things: Concepts and System Design*. Springer.
- Mohammadzadeh, N., Gholamzadeh, M., Saeedi, S., and Rezayi, S. (2020). The application of wearable smart sensors for monitoring the vital signs of patients in epidemics: a systematic literature review. *Journal of Ambient Intelligence and Humanized Computing*, page 3.
- Motti, V. G. (2020). *Wearable Interaction*. Human-Computer Interaction Series. Springer.
- Rathee, G., Garg, S., Kaddoum, G., Wu, Y., Jayakody, D. N. K., and Alamri, A. (2021). ANN assisted-iot enabled COVID-19 patient monitoring. *IEEE Access*, 9:42483–42492.
- Trombini, M., Ferraro, F., Morando, M., Regesta, G., and Dellepiane, S. G. (2021). A solution for the remote care of frail elderly individuals via exergames. *Sensors*, 21(8):2719.
- Vedaei, S. S., Fotovvat, A., Mohebbian, M., Rahman, G. M. E., Wahid, K. A., Babyn, P. S., Marateb, H. R., Mansourian, M., and Sami, R. (2020). COVID-SAFE: an iot-based system for automated health monitoring and surveillance in post-pandemic life. *IEEE Access*, 8:188538–188551.