UPN
UNIVERSIDAD PRIVADA DEL NORTE

FACULTAD DE INGENIERÍA

Carrera de **INGENIERÍA DE SISTEMAS COMPUTACIONALES**

"MOBILE APPLICATION FOR THE TIMELY DETECTION OF POTENTIAL COVID-19 INFECTIONS"

Tesis para optar el título profesional de:

Ingeniero de Sistemas Computacionales

Autor:

Wilson Fernando Carrasco Teran

Asesor:

Dra. Patricia Janet Uceda Martos
https://orcid.org/0000-0003-1771-9970

Cajamarca - Perú

2022

JURADO EVALUADOR

Jurado 1 Presidente(a)	**Fidel Oswaldo Romero Zegarra**	**40589719**
	Nombre y Apellidos	Nº DNI

Jurado 2	**Daniel Alexis Pérez Aguilar**	**71132678**
	Nombre y Apellidos	Nº DNI

Jurado 3	**Rosa Marleny López Martos**	**45523761**
	Nombre y Apellidos	Nº DNI

Mobile Application for the Timely Detection of Potential COVID-19 Infections

Wilson Fernando Carrasco-Terán
Faculty of Engineering
Universidad Privada del Norte
Cajamarca, Peru
N00018881@upn.pe

Patricia Uceda-Martos
Faculty of Engineering
Universidad Privada del Norte
Cajamarca, Peru
https://orcid.org/0000-0003-1771-9970

Abstract*— The objective of this study is to determine user acceptance of a mobile application for the timely detection of possible COVID-19 infections in the city of Cajamarca. For this purpose, the mobile application Covid Alerta (Covid Alert) was developed for devices with the Android operating system. The OpenUp software development methodology was used for the development of this application. The applied, quantitative, exploratory research used 2 survey forms: one to measure how the detection of COVID-19 was carried out in the city of Cajamarca, and another to measure the impact of using a mobile application to detect infected contacts. The results indicated that the most reliable screening tests are molecular tests; in addition, 85% of respondents felt much safer receiving alerts of infected contacts on their mobile devices. Likewise, 88.5% indicated confidently that the application complies with registering and reporting infected contacts. This shows that 88.8% of users accepted the use of mobile applications for the timely detection of possible COVID-19 infections.

Keywords— Infection detection, mobile application, Android, COVID-19, contagion reduction.

I. INTRODUCTION

The year 2020 will be marked in history by a pandemic, which was triggered by new coronavirus-associated pneumonia, Severe Acute Respiratory Syndrome (SARS) Coronavirus 2, which started in late December 2019 in the city of Wuhan, China [1]. Then, due to the exponential increase in infections, the World Health Organization declared COVID-19 a very high-priority international emergency [2], and, to date, recommendations continue to be offered to minimize the spread of the disease [3].

In some U.S. cities, the need for early detection of declining forms of transmission for some diseases, such as tuberculosis, HIV, and Ebola infection, has led to proposals of potential solutions to impending pandemic outbreaks using smartphones and contact tracing [4].

Collado, Escudero, Villanueva, Herranz, and Sanjurjo [5] showed that approximately more than 5 billion people used smartphones; therefore, the vast majority of the world's population had access to mobile applications. In addition, they identified that the use of such applications could support the fight against the pandemic caused by COVID-19 through remote monitoring of infected people by health experts, among other initiatives.

Bradshaw, Alley, Huggins, Lloyd, and Esvelt determined that the absence of technologies such as mobile applications for the detection of COVID-19 infection meant that tests (molecular, antigen, and blood) were the main options used during the pandemic. However, these solutions were also not highly accepted by patients because of the additional time spent in queues, cost, or possible source of infection [6].

The detection of COVID-19 consists of identifying the virus within the body of a human being through comprehensive laboratory testing. The safest and most effective protocol is swabbing. The detection of an infected person can be done through saliva tests (molecular or antigens), bloodstream tests (antibody tests), symptoms (muscle pain, fever, cough, diarrhea, loss of smell and taste), and a person who has had contact with an infected person is also suspected of possible infection [7]. At the price level, in Peru, as of June 2020, molecular tests ranged between S/. 700 and S/. 400 (Nuevos soles), and rapid tests, between S/. 158.5 and S/. 230 [8].

For this reason, the research seeks to answer the following question: Do the inhabitants of the city of Cajamarca accept the use of a mobile application for the timely detection of possible COVID-19 infections as a proposal that minimizes the number of infections?

Thus, the general objective of this research was to determine the acceptance of a mobile application for the timely detection of possible COVID-19 infections in the city of Cajamarca. Similarly, specific objectives were defined: (1) to determine how the timely detection of COVID-19 infections in the city of Cajamarca is carried out, (2) to design and implement a mobile application to timely detect possible cases of COVID-19 in the city of Cajamarca using the OpenUp methodology, (3) to timely detect possible infections through the implementation of a mobile application, and (4) to determine the acceptance of mobile applications for the timely detection of possible COVID-19 infection in the city of Cajamarca. The null hypothesis is the residents of the city of Cajamarca don't accept the use of a mobile application in the timely detection of possible COVID-19 infections; while the alternative hypothesis the residents of the city of Cajamarca accept the use of a mobile application in the timely detection of possible COVID-19 infections.

II. RELATED WORKS

Researchers have proposed technological solutions to mitigate the spread of infection worldwide, for example, the acceptability of a contact tracing application was analyzed in five countries affected by the pandemic, i.e., France, Germany, Italy, the United Kingdom, and the United States. A total of 68% were willing to protect their friends and family through the application, 53% installed it as a responsibility to the community, and 55% hoped that it would stop the pandemic. Most of them accepted contact tracing to stop the spread of the disease [9].

By 2020, many countries were already implementing software with the functionality to share data with users via Global Positioning System (GPS) or Bluetooth to stop contagions. Privacy and confidentiality terms were not explicitly stated in all cases, impacting user confidence. Applications using Bluetooth Low Energy technology were 60% more effective than those using GPS, and the population perceived greater distrust and invasion of privacy [10].

Other researchers compared the performance of the TraceTogether contact tracing application with a real-time location system based on portable tags and validated with medical records. Physicians and patients concluded that manual contact tracing reduced COVID-19 transmissions by 61%, while contact tracing via a mobile app, by 44%. The performance of the app generated high sensitivity in contact detection among Android device users [11].

In Latin America, applications with mobile geolocation systems were evaluated, and it was identified that regions close to capital cities represented a 90% risk of COVID-19 transmission, while rural cities had a 60% risk. In addition, it was recommended the mandatory use of mobile applications to detect movement patterns [12].

In Peru, 238,465 users participated in a study of possibly infected people. Based on GPS probabilities, it was found that people who traveled daily in the city had a high probability of infection. In addition, the accuracy for detecting possibly infected people was quite high and helped to adjust the epidemiological model [13].

III. THEORETICAL FRAMEWORK

A. Mobile Application

A mobile application is a software developed for different platforms such as Android, iOS, Windows 10 Mobile, etc., which are executed on a mobile device [14].

B. Timely detection of contagion through tracing

Contact tracing is the *follow-up* of infected persons, a function that is performed by health authorities. The purpose of tracing is to collect information on the contacts with whom an infected person socialized in the last 14 to 21 days [1], but contact tracing is also related to the monitoring of the potential routes of transmission of an infection through a certain population in order to isolate the individuals exposed [4].

IV. MATERIALS AND METHOD

According to the purpose, the research was applied because it solves problems of a practical, empirical and technological nature by applying the knowledge and results of basic research. It is quantitative-exploratory since its objective was to inquire about a little-studied topic [15]. It is pre-experimental since it applied a test to a group, before treatment, then the treatment was administered, and, subsequently, another test was applied [16].

The population for convenience was made up of the inhabitants of the city of Cajamarca, 388,329 people, by 2020 [17]. The city of Cajamarca was chosen because of its proximity to the research area; in addition, the researcher and the experts lived in the same area. The sample was calculated from the formula for an infinite population, with a confidence level of 95%, a Z of 1.65, and a maximum acceptable error of 5%; equivalent to 384 people, with the same number of surveys being carried out.

As inclusion criteria, users having smartphones with the Android operating system were considered, and users with iOS were excluded.

A survey was used as a data collection instrument, which was validated by 4 surgeons who were on the front line during the first two waves of COVID-19. The validation of the 5-item survey obtained an Aiken's V value of 1, with a confidence level of 95%. Then, a pilot test was run to determine the validity of the inferences after the obtained scores, giving a Cronbach's Alpha level of 0.94. Finally, a survey was applied to measure the impact of the use of the mobile application on the population of Cajamarca. The IBM SPSS software was used for data analysis and interpretation. [18].

Regarding ethical considerations, the people who participated in the study previously accepted the informed consent, and the research team safeguards the information. In addition, these details were specified in the terms and conditions of the software.

V. RESULTS

A: To determine how the timely detection of COVID-19 infection is currently carried out in the city of Cajamarca.

In Cajamarca, it was determined that the detection of COVID-19 cases was carried out through molecular, antigen, and antibody tests, as well as through the symptoms that people presented. A total of 71.4% were infected by the COVID-19 virus, while 28.6% were not infected. Among those who were infected, 48.7% were tested to rule out infection, while 23.4% detected the virus only through symptoms.

TABLE I. CONFIDENCE OF PEOPLE WHO HAVE RULED OUT CONTAGION BY

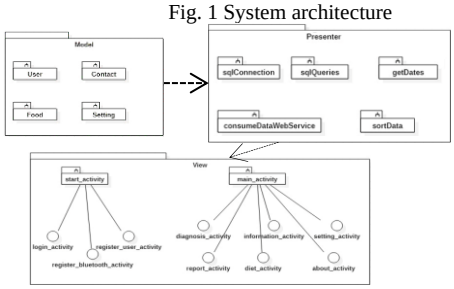
	Molecular test		Antigen test		Antibodies	
	Freq	%	Freq	%	Freq	%
Totally agree	344	89.60%	53	13.80%	17	4.40%
Agree	32	8.30%	288	75.00%	112	29.20%
Undecided	8	2.10%	36	9.40%	202	52.60%
In disagreement	0	0%	6	1.60%	47	12.20%
Strongly disagree	0	0%	1	0.30%	6	1.60%

Respondents indicated that the safest method for virus detection was the molecular test with 84.9%; whereas, the fastest test was the antibody (blood) test with 76.3%. A total of 89.6% fully agreed with the ruling out provided by the molecular test, and 75% preferred the antibody tests (Table I). As reported by the World Health Organization in its publication on diagnostic tests for SARS-COV-2 [19], the respondents validated that the safest detection of the virus is through laboratory testing.

B: To design and implement a mobile application for timely detection of possible cases of COVID-19

The OpenUp methodology was used for the development of the system since it directs the management and development of software projects to generate a quality product in an orderly and efficient way [20]. The architecture used was Model - View - Presenter (Fig. 1), which has the particularity of introducing the "Presenter" layer.

Fig. 1 System architecture



Communication between the layers in Android was done through interfaces: ProviderPresenterOps, ProviderModelOps, RequiredViewOps, RequiredPresenterOps [21].

The technology used for the development of the application was: Java programming language for the mobile app, PHP for the API, SQLite as the internal Android database, MySQL as the remote database, and Hostinger as the web server. Non-functional requirements were considered: Android version 6.0 or higher as a smartphone operating system, internet connection, and the use of Bluetooth. Regarding performance requirements, it was reported that it was recommended to have a smartphone with Android operating system version 6.0 or higher, with a minimum of 3GB of RAM.

C. To timely detect possible contagions through the implementation of a mobile application.

After applying the surveys to the population of Cajamarca and after having used the mobile app, it was observed that 88.8% of the people surveyed who used the mobile app trusted it. Likewise, 88.5% felt safe alerting their contacts that they had been infected anonymously. On the other hand, 88.8% of the population took the corresponding precautions after having received notification of infected contacts, having immediate tests to rule out infection. Likewise, it was observed that the most reliable test for the detection of COVID-19 among the population of Cajamarca was the molecular test, with 89.06% of approval, compared to 85% in the first survey. Likewise, the test that the population used to know more quickly whether or not they had COVID-19 was, in the pre-test, the molecular test, which represented 76% of respondents, but, at the post-test level, it was the antibody test, which represented 68.49%.

Regarding the use of the mobile application, 88.5% of the population of Cajamarca indicated that they were sure that the app registered the infection status and reported infected contacts; while 11.2% were undecided. Likewise, 89.1% indicated that the mobile application had detected possible infected contacts weekly; while 10.9% had no detection at all.

For 97.7% of respondents, it was complicated to register as a user for the first time, but, subsequently, it was very easy to use, since the interfaces were user-friendly and intuitive (Fig. 2); 88.8% indicated that the mobile application was reliable, while 11.2% were uncertain about it and did not accept it.

Fig. 2 Main interfaces of the mobile application

D. To determine the acceptance of mobile applications for the timely detection of possible COVID-19 infection in the city of Cajamarca.

To evaluate the acceptance of the application, the t-Student statistic was used based on the following hypotheses:
Null hypothesis H_0: The mean acceptance rate of the mobile application is the same before and after the application.
Alternate hypothesis H_1: The mean acceptance rate of the mobile application is different before and after the application.

Since the t-statistic = ±8.389 is out of the acceptance region H_0 {-1.963, +1.963}, the null hypothesis was rejected and the alternative hypothesis was accepted, which shows the acceptance of the population of Cajamarca to use the mobile application for the timely detection of COVID-19.

VI. DISCUSSION

It was observed through the Chi-square statistical method that the implementation of a mobile application helped to timely detect possible COVID-19 infections in the city of Cajamarca.

After data collection and making use of the mobile application, 85% of the population was found to be much safer by alerting and receiving alerts of infected contacts; similar to the proposal by Altman et al. Based on this, it can be confirmed that the population is confident that a mobile application can stop the outbreak of COVID-19.

Regarding the tests used, it was observed that most of them used the molecular test despite its high cost [8].

Regarding the use of the mobile application in this research, it was identified that 88.8% of respondents trusted it, while 11.2% were uncertain about it, similar to the results obtained by García-Iglesias et al. [10] since people did not have much confidence in those applications that used GPS, due to the invasion of the privacy of their data by governments. For this reason, they recommended ensuring the confidentiality of their data, and this was endorsed in the terms and conditions.

Similarly, after using the mobile application, 88.5% of the respondents indicated that the software complied with the registration and infection status, and reporting infected contacts; while the study conducted by Huang et al. [22], which compared the performance of the contact tracing application TraceTogether to that of a real-time location system, reported that contact tracing through an application reduced COVID-19 transmissions by 44%, but that manual follow-ups were necessary to significantly reduce the outbreak of COVID-19. Although the system indeed used was the Global Positioning System, it was still necessary to test other types, in this case, the Bluetooth Low Energy system.

Like Altmann et al. [9], most of the population of Cajamarca agreed with the use of this type of application to stop the spread of COVID-19 (88.8%), valuing the importance of sharing and receiving alerts.

As recommended by García-Iglesias et al. [11], smartphone Bluetooth has been used for information transfer because it generated a higher level of confidence in the population, and this promoted the acceptance of applications.

Finally, the most reliable tests for the detection of COVID-19 for the population of Cajamarca were molecular tests, increasing from 84.9% in the pre-test to 89.1% in the post-test, and indicating that they continue to be the most reliable after the application has detected possibly infected people with whom they have had contact in the last few weeks.

VII. CONCLUSIONS AND RECOMMENDATIONS

A mobile application was designed and implemented for the timely detection of possible COVID-19 infections in the city of Cajamarca. Likewise, the steps of the Open Up methodology were taken into account and followed.

The level of acceptance of users in Cajamarca regarding a mobile application for the timely detection of COVID-19 was determined.

It was possible to determine how the timely detection of COVID-19 infection was carried out through a survey applied to urban inhabitants of Cajamarca, where it was evident the prevalence of rule-out tests instead of only analyzing symptomatology.

Several possible COVID-19 infections were timely detected through the implementation of the COVID ALERT mobile application, through which 85% of respondents felt safer alerting and receiving alerts of infected contacts. Likewise, 88.5% of the surveyed population indicated with certainty that the application complied with registering and reporting infected contacts.

Since there is still mistrust among the population regarding the handling of their data when GPS activity is involved, it is recommended to work on ethical issues, which should be clearly registered in the applications to leave no room for subjectivity or assumptions. The clearer the acceptance criteria for the use of applications, the greater the trust of users.

It is recommended to continue promoting the financing of this type of initiative at the level of universities, institutions, and government agencies, so that the costs required for other operating systems, such as iOS, can be covered.

ACKNOWLEDGMENT

The researchers would like to thank the people of Cajamarca who selflessly participated in the study, as well as the experts and judges who, with their knowledge and experience, validated the instruments.

REFERENCES

[1] N. Ahmed *et al.*, "A Survey of COVID-19 Contact Tracing Apps," *IEEE Access*, vol. 8, pp. 134577–134601, 2020, doi: 10.1109.

[2] M. Santos-López, H. Catrian-Fernández, M. Santos-López, and H. Catrian-Fernández, "COVID-19 and the Dentist's New Role in the Health Team," *International journal of odontostomatology*, vol. 14, no. 3, pp. 296–298, Sep. 2020, doi: 10.4067/S0718-381X2020000300296.

[3] Organización Mundial de la Salud, "Información básica sobre la COVID-19," 2020. https://www.who.int/es/news-room/questions-and-answers/item/coronavirus-disease-covid-19.

[4] T. M. Yasaka, B. M. Lehrich, and R. Sahyouni, "Peer-to-Peer Contact Tracing: Development of a Privacy-Preserving Smartphone App," *JMIR mHealth and uHealth*, vol. 8, no. 4, p. e18936, Apr. 2020, doi: 10.2196/18936.

[5] R. Collado-Borrell, V. Escudero-Vilaplana, C. Villanueva-Bueno, A. Herranz-Alonso, and M. Sanjurjo-Saez, "Features and Functionalities of Smartphone Apps Related to COVID-19: Systematic Search in App Stores and Content Analysis," *Journal of Medical Internet Research*, vol. 22, no. 8, p. e20334, Aug. 2020, doi: 10.2196/20334.

[6] W. J. Bradshaw, E. C. Alley, J. H. Huggins, A. L. Lloyd, and K. M. Esvelt, "Bidirectional contact tracing could dramatically improve COVID-19 control," *Nat Commun*, vol. 12, no. 1, p. 232, Jan. 2021, doi: 10.1038/s41467-020-20325-7.

[7] A. Melián-Rivas *et al.*, "Detection of COVID-19 (SARS-CoV-2) by Saliva: A Low-invasive Diagnostic Alternative," *International journal of odontostomatology*, vol. 14, no. 3, pp. 316–320, Sep. 2020, doi: 10.4067/S0718-381X2020000300316.

[8] Diario Médico del Perú, "La lista y precios de laboratorios privados autorizados para realizar pruebas de descarte COVID 19," 2020, https://www.diariomedico.pe/la-lista-y-precios-de-laboratorios-privados-autorizados-para-realizar-pruebas-de-descarte-covid-19/

[9] S. Altmann *et al.*, "Acceptability of App-Based Contact Tracing for COVID-19: Cross-Country Survey Study," *JMIR mHealth and uHealth*, *v*ol. 8, no. 8, p. e19857, Aug. 2020, doi: 10.2196/19857.

[10] J. J. García-Iglesias, J. Martín-Pereira, J. Fagundo-Rivera, and J. Gómez-Salgado, "Herramientas de vigilancia digital para el rastreo de contactos de personas contagiadas de SARS-CoV-2," *Revista Española de Salud Pública*, vol. 94, no. 1, pp. e1–e8, 2020

[11] García-Iglesias et al. "Herramientas de vigilancia digital para el rastreo de contactos de personas contagiadas de SARS-COV-2," Rev. Esp. Salud Pública, vol. 94, Jun. 2020

[12] P. S. Peixoto, D. Marcondes, C. Peixoto, and S. M. Oliva, "Modeling future spread of infections via mobile geolocation data and population dynamics. An application to COVID-19 in Brazil," *PLOS ONE*, vol. 15, no. 7, p. e0235732, 2020, doi: 10.1371/journal.pone.0235732.

[13] Lossio-Ventura et. al. "DYVUC: DYnamic VIrus Control in Peru", 2020 IEEE International Conference on Bioinformatics and Biomedicine (BIBM), 2020, doi: 10.1109/BIBM49941.2020.9313419

[14] A. M. Vallvé, *El mobile marketing y las apps: Cómo crear apps e idear estrategias de mobile marketing (epub)*. Editorial UOC, 2017.

[15] Carlos Muñoz Razo, *Cómo elaborar y asesorar una investigación de tesis (2a. ed.)*. Pearson Educación, 2018.

[16] R. Hernández Sampieri, C. Fernández Collado, and M. Pilar Baptista Lucio, *Metodología de la investigación*. México: McGraw-Hill, 2014.

[17] Instituto Nacional de Estadística e Informática, "Perú Instituto Nacional de Estadística e Informática," *INEI*, 2020. https://www.inei.gob.pe/

[18] "IBM SPSS, Software estadístico académico," Feb. 25, 2021. https://www.ibm.com/pe-es/analytics/academic-statistical-software

[19] "Pruebas diagnósticas para el SARS-CoV-2," "Organización mundial de la salud," 2020,

[20] E. Flores Aredo, "Sistema web para la gestión de pedidos en la Empresa Representaciones Saldaña S.A.C. utilizando una plataforma de servicio y la metodología OpenUP," 2020

[21] "Modelo Vista Presentador (MVP) en Android," *Develapps*. https://www.develapps.com/es/noticias/modelo-vista-presentador-mvp-en-android

[22] Z. Huang, H. Guo, Y.-M. Lee, E. C. Ho, H. Ang, and A. Chow, "Performance of Digital Contact Tracing Tools for COVID-19 Response in Singapore: Cross-Sectional Study," *JMIR mHealth and uHealth*, vol. 8, no. 10, p. e23148, 2020, doi: 10.2196/23148.