Commercial Entry Control Using Robotic Mechanism and Mobile Application for COVID-19 Pandemic

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Abstract. The control of entry to commercial premises has always existed, but with the pandemic, this has been adapted to include biosecurity measures that guarantee the safety of customers. Technology makes it possible to automate these activities, among the most popular tools are mobile applications that allow easy implementation and good reception from users. This work presents the entrance control to a commercial premise using a robotic mechanism and a mobile application connected through a cloud database. The system is implemented using accessible and low-cost components, among the tools are 3D printing, the ESP32 board, servo motors, proximity sensors, temperature, and heart rate. The mobile application is developed in App Inventor and Firebase is used for the remote database. The system automates the provision of hand sanitizer at the entrance and records these vital signs of the customers, allowing to generate a report of the attendees. The results show the readings carried out by validating the implemented system and a measure of acceptance of this technology is applied with a score of 73%, evidencing the deficiencies of the proposal from the users' perspective.

Keywords: Robotic mechanism · Mobile application · Cloud database · COVID-19

1 Introduction

The pandemic caused by COVID-19 has caused great changes worldwide, countries have had to incorporate biosecurity measures to take care of citizens [1, 2]. Commerce has been directly affected, requiring adaptations in the facilities to continue commercial activities, among the measures are social distancing, use of a mask, application of hand sanitizer, and others [3, 4]. Another action to take is monitoring vital signs, body temperature is the first variable to be checked, although an increase in heart rate has also been recorded in

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some cases [5]. In optimizing these activities, technological options have been developed that help control biosafety measures [6, 7]. These systems are commonly implemented when entering the local, using sensors and actuators that automate the control processes [8].

Robotics has been a tool used in the fight against COVID-19, robots are installed in different fields to control biosafety measures, in some cases robots assist medical activities avoiding the exposure of doctors, disinfect buildings using different technologies cleaning, controlling the temperature of people in closed places, providing disinfectant gel and more [9, 10]. Robotics still has more solutions that have not yet been explored and in the future, there will be greater dependence on this technology, but the implementation costs are high, this has forced the use of more accessible technologies in solving the problems caused by the pandemic [11, 12].

Mobile devices such as smartphones and tablets are widely used to achieve fast and effective solutions, developing mobile applications that allow the incorporation of support measures to prevent the spread of the virus [13]. In some cases, mobile devices alert users in areas with a high number of infections to avoid these places, some applications allow entering information on the user's health status to make decisions regarding a possible contagion, ruling out symptoms not related to the disease [14, 15]. These solutions incorporate other technologies such as the internet of things, databases, cloud computing, and others [16].

Cloud databases have been useful when implementing mobile applications and web applications displaying information of interest in real-time, in the development of telemedicine solutions, and remote data monitoring [17]. These technologies are constantly growing, allowing the creation of portable applications that guarantee the availability of information from anywhere in the world [18]. The combination of robotics, mobile applications, and cloud databases promises multi-featured tools to improve user acceptance.

This work presents a support system in the commerce entry control in the context of COVID-19, for a robotic mechanism is built for the reading of vital data through sensors and the activation of a hand sanitizer, managing the system from a mobile application that uses a database in Firebase. The document is distributed as follows: i) An introduction to the subject; ii) Materials and methods, iii) Results; iv) Conclusions [19].

2 Materials and Methods

In the context of the COVID-19 pandemic, the business's adaptations have been very creative, using mechanical devices to dispense gel through digital skin thermometers to control the temperature of those attending the premises. Thus, it is important to develop new tools that help to combat contagion, the main objective of this work is to implement a system to control entry through low-cost technology, Fig. 1 shows the general scheme of this proposal. The scheme is presented based on referential images and boxes of continuous lines (__) that contain blocks of some function or action within the scheme, the dashed lines (--) group the three main elements of the control system. The requirements include measuring vital signs and providing disinfectant to the user, for this the construction of a robotic mechanism with an electronic circuit and integrated

programming for operation, and a mobile application for the management of the system through the global network is designed. Once the proposal is implemented, tests of the system are carried out through measurements of the temperature and heart rate of the users. Finally, a measurement of acceptance of the proposal is applied to measure satisfaction with the characteristics of the system.

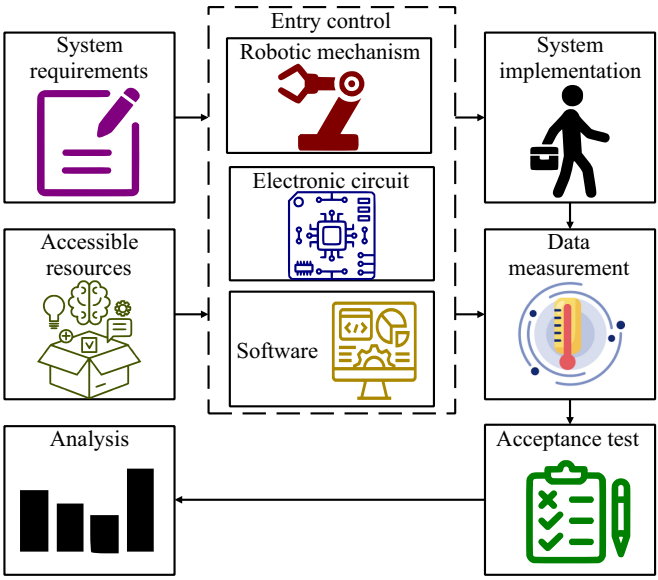

Fig. 1. General scheme of the proposal.

2.1 Components

Figure 2 presents the components to be used in the implementation of this proposal, these resources have been selected mainly for the accessibility and ease of use. In the hardware, a 3D printer is used to manufacture the mechanical components of the robotic mechanism, the required actuators are servomotors for the joints and a buzzer to generate alerts, the required sensors are proximity detectors and temperature and heart rate meters. To manage these elements, the ESP32 board is used, which is a System On Chip device that is characterized by WiFi connectivity, in this way the system is connected to the net. On the other hand, the application is developed in App Inventor and the remote database is implemented in Firebase, both tools belong to Google.

2.2 Hardware

In hardware development, two components are distinguished, the mechanical structure and the electronic circuit. Figure 3 presents images of the mechanism in 3D design computer-assisted. The mechanism starts from a dark gray lower base that contains the

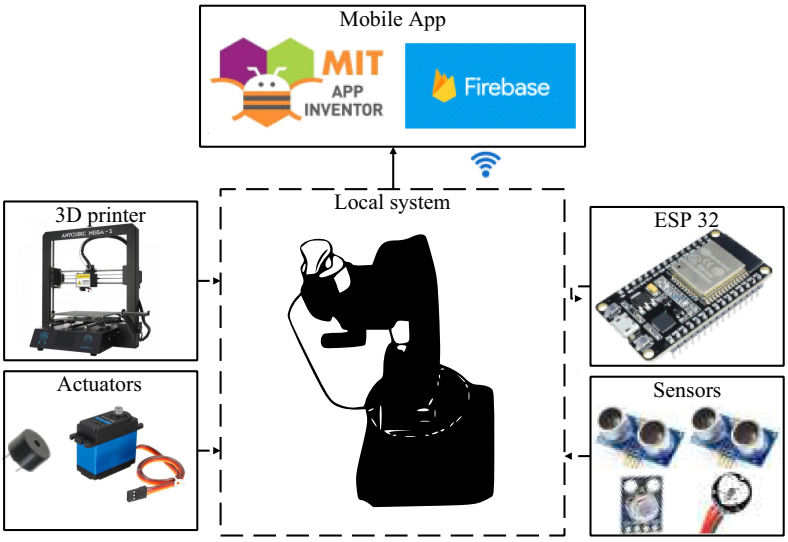

Fig. 2. Selected components to implement the system.

circuitry and one of the proximity sensors, and the yellow cylindrical base that contains the first servomotor that rotates the entire upper mechanism. Then there are have two links driven by servo motors that are placed serially to build a kinematic chain, similar to a robotic arm. At the end there is an extrusion mechanism to provide the hand sanitizer, this works by converting rotating movement to linear movement using a gear and rack, the mechanism includes a circular bracket to place the alcohol bottle.

The electronic circuit in this proposal is based on the 30-pin ESP 32 Dev Module board, Fig. 4 shows the design of the connections to the sensors and actuators. The proximity sensors (HC-SR04) use 4 pins configured as digital inputs and outputs, one of these sensors is located at the base of the robot to detect the presence of the user, and the other is located at the end to detect the hands and provide the disinfectant. The infrared temperature sensor (GY-906 MLX90614) uses pins D21 and D22 for synchronous serial communication (I2C). The heart rate sensor (XD-58C) uses pin D34 configured as an analog input. Regarding the actuators, the buzzer uses a digital output and the servomotors are connected to a 16-channel motor driver (PCA9685) that is controlled using I2C communication. The first three servomotors (SF3218MG) reach a torque of up to 20 kg-cm and the fourth servomotor (MG995) maximum torque of 10 kg-cm. The entire system uses a 5 V 4 amperes electrical dependent supply.

The components of the mechanical structure of the robot are manufactured using the Anycubic Mega S 3D printer and PLA material, Fig. 5 shows the robotic mechanism built, observing a rectangular wooden base that fixes all the robot and the circuitry, evidencing the correct assembly of the entire mechanical system. Preliminary tests show the correct operation of all built-in sensors and actuators.

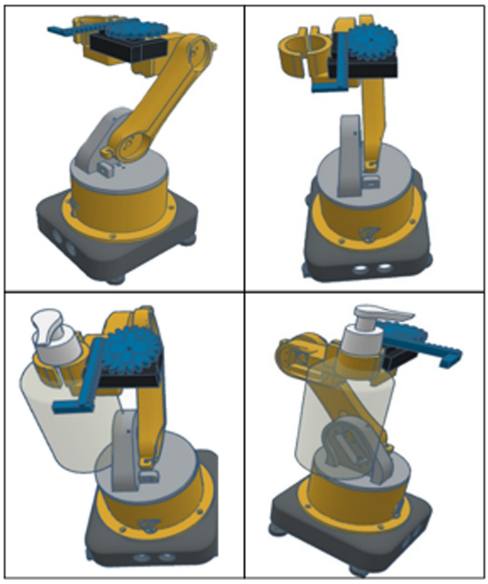

Fig. 3. 3D design of the robotic mechanism.

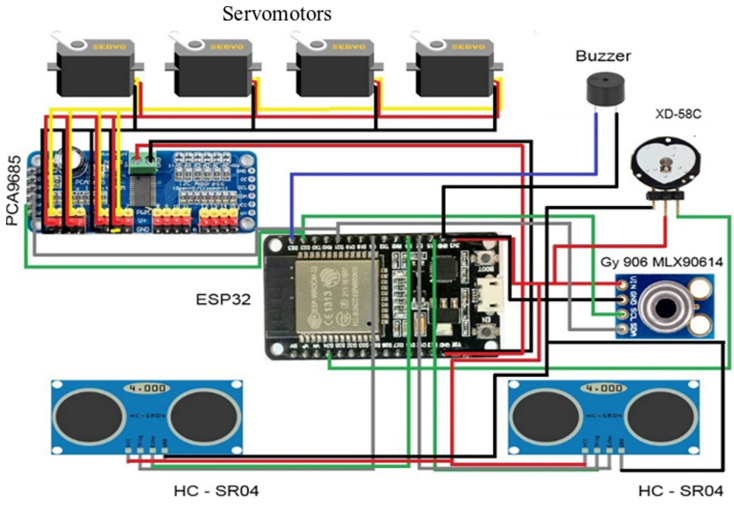

Fig. 4. Electronic circuit based on ESP 32 board.

2.3 Software

Regarding the software, it is necessary to develop the programming of the control board and the user interface of the mobile application. The ESP 32 is programmed using Arduino IDE with the required libraries for the compatibility of the board, the libraries for the WiFi communication (WiFi.h), the temperature sensor (Adafruit_MLX90614.h), and

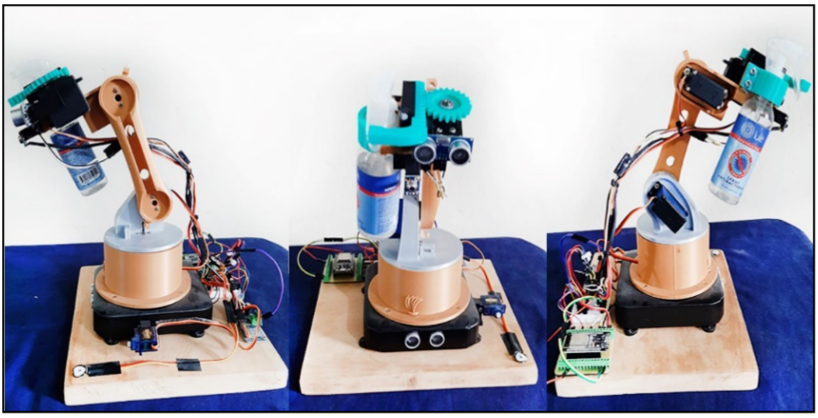

Fig. 5. Photos of the robotic mechanism built.

the driver of the devices are also included. servomotors (Adafruit_PWMServoDriver.h). The robot is programmed to initiate actions when it detects a presence, activities with measuring body temperature, heart rate, give disinfectant, possible alerts, and communication with the mobile application through the cloud.

The mobile application allows viewing the vital parameters (temperature and heart rate) of the user, control the actions of the robot, and present alerts. Alerts consist of an audible and visual warning at the remote site and an audible warning at the local site, at the remote site the alert is played on the administrator's phone, and at the local site, the audible alert is played with the circuit buzzer electronic. Figure 6 shows some screens of the mobile application, the interface includes control of access to the application and registration of frequent users. In addition, the generation of reports is implemented that allows reviewing the history of customers who attended the commercial.

The entire mobile application is developed in App Inventor. Figure 7 shows some blocks of the implemented application, each color implies a different function that is assigned by default (e.g. red = text, green = set). The greatest complexity of the software is in the communication with the remote database, for this Firebase is used, this platform is located in the cloud, it supports easily synchronizes the data without managing connections or using complex synchronization logic and does not require a server. In addition, allowing to implement functions of communication in App Inventor. In the Arduino IDE program, the database is managed through the FirebaseESP32.h library that allows reading and writing registers. The database created in the Firebase web interface is presented in Fig. 8, showing the elements of the tables for the clients, the robot, and the administrator.

3 Results

The proposed system is evaluated in a hardware store for a week, registering the owner of the premises as administrator and entering the most frequent customers to the database, while infrequent customers have a number assigned as they enter local, without wasting



Fig. 6. Mobile app screens.

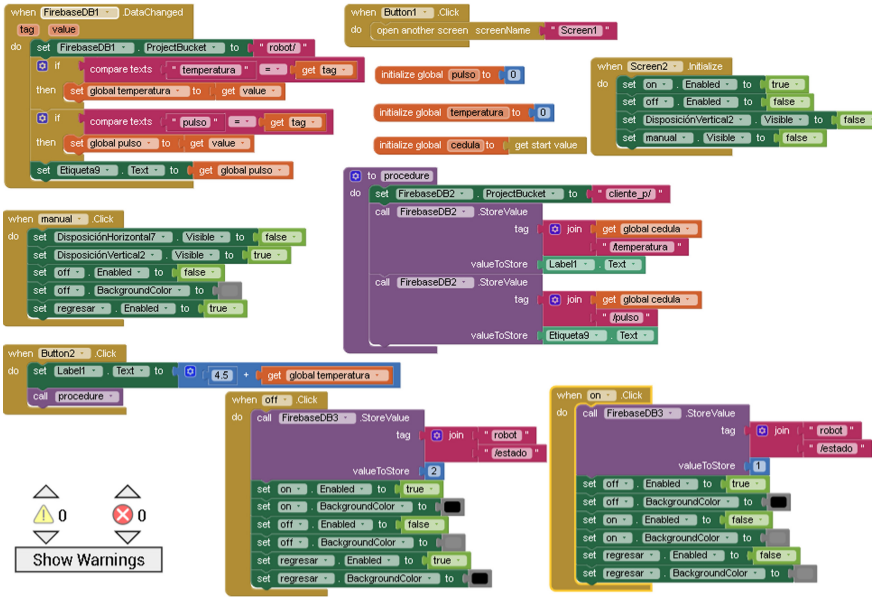

Fig. 7. Block diagram segment implemented in App inventor.

time. Figure 9 shows photos of the system in operation, observing a client receiving the sanitizer in their hands and the mobile application showing the information obtained

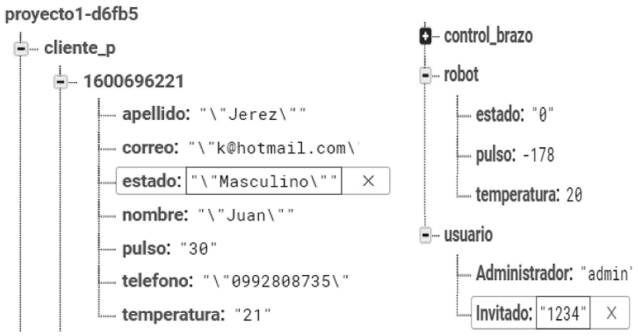

Fig. 8. Database implemented in Firebase.

from the local site. The dispenser works manually and automatically, so that the client receives the disinfectant upon entering and when the application administrator wishes.

3.1 Measurements

During the testing period, data from 41 people are taken, which are reported in the mobile application, the report shows the customer data, entered manually to the database, and the history of the measurements taken by the sensors, as shown in Fig. 10. The alert trigger is configured for temperatures above 37.5 °C, and in the evaluation period no alerts are generated, i.e., 100% of the participants had adequate temperature values.

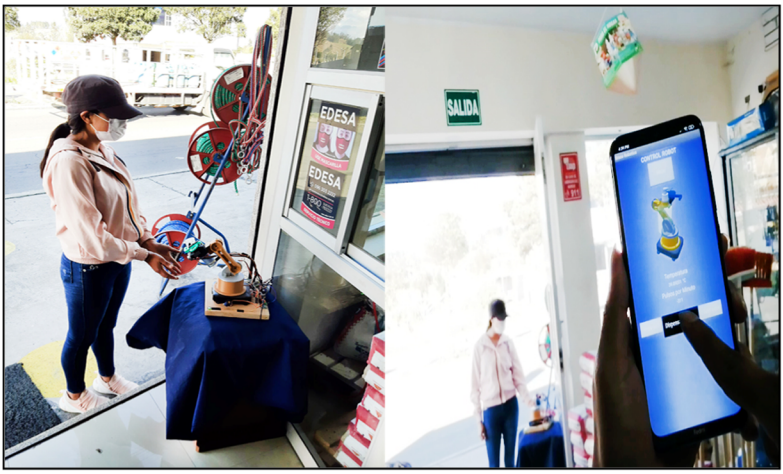

Fig. 9. Photos of the system in operation.

Temperature and heart rate measurements are presented in Fig. 11. The unit of measurement for temperature is in degrees Celsius ([°C]), with an average temperature of 35.9 [°C] and a standard deviation of 0.8 [°C], these data are consistent with common



Fig. 10. Mobile app report.

human temperatures, since the sensor is calibrated using a commercial thermometer. Heart rate is presented in units of beats per minute ([bpm]), with a mean rate of 78 [bpm] and a standard deviation of 8 [bpm].

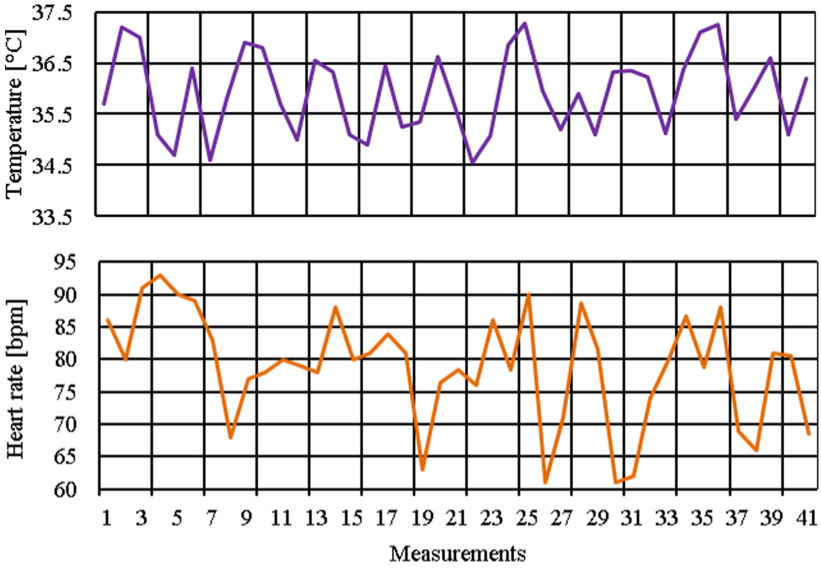

Fig. 11. Temperature and heart rate measurements.

3.2 Acceptance

As a complementary tool, an acceptance indicator is applied to clients and the manager of the commercial premises, using measure of technology acceptance model of [20], this is evaluated with each participant using the Likert scale, the scores are in the range from

"I disagree" (1) to "totally agree" (5). Table 1 presents Acceptance scores, the system has a final score of 73%, which is favorable for this proposal, but in productivity the customers believe that the system does not help in the commerce and does not facilitate entry control, while that measures of ease of use have good scores.

Table 1. Results of the acceptance measure

Measure	Score
Using the system would improve control entry performance	3.3
Using the system would enhance the effectiveness on the control entry	3.2
I would find the system useful in the control entry	3.9
Using the system in the control entry would increase the productivity	2.7
Using the system would enable me to accomplish control entry quickly	3.1
Using the system would make it easier to do the control entry	3.0
Learning to operate the system would be easy for me	4.2
I would find the system easy to use	4.2
I would find it easy to get the system to do what I want it to do	4
It would be easy for me to become skillful at using the system	4.4
Learning to operate the system would be easy for me	4.2
Total	40.2/55 (73%)

4 Conclusions

The COVID-19 pandemic changed the shape of trade around the world, and although there is currently a vaccine, it is not yet available to everyone, especially in developing countries. Thus, biosafety measures continue to be applied and it is necessary to continue developing technological tools to combat the spread of this or any other virus. The entry control in times of pandemic includes the measurement of body temperature and disinfecting the assistants. This work proposes an automated mechanism based on a space robot to measure physical health variables and provide disinfectant, managing the information through a mobile application. The system is implemented using accessible resources for easy reproduction. In addition, the system includes a cloud database to access the records from the application and from anywhere in the world.

The results of the system evaluate the operation of the proposal through the readings obtained and an acceptance indicator. The measurements made are within the correct range, showing normal temperatures and heart rates in all readings. The mobile application allows reviewing the history of customers who attended the commercial in a report generated from the remote database. The acceptance measure indicates a score of 73/100, expressing some dissatisfaction with the proposal, the participants rate the system as unproductive. In summary, some characteristics and conditions of this system

are not accepted by users, requiring improvements to achieve a more effective product. The robot's appearance can be improved to achieve greater user acceptance. This information is useful in future work by authors or readers who propose an entry control system that considers the current health problem.

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