Article

Design and development of a biometric electronic instrument with gel dispenser, based on IoT using ESP32, for access control in private spaces oriented toward health and hygiene

Diseño y desarrollo de un instrumento electrónico biométrico con dispensador de gel, basado en IoT mediante ESP32, para el control de acceso en espacios privados orientado a la salud e higiene

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Classification:

Area: Física-Matemáticas y Ciencias de la Tierra
Field: Physics
Discipline: Electronics
Subdiscipline: Circuit design

https://doi.org/10.35429/JEA.2025.12.33.1.1.14
History of the article:
Received: March 28, 2025
Accepted: May 30, 2025

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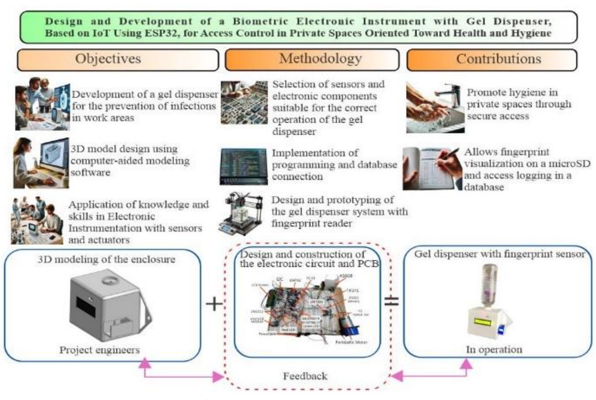
Abstract

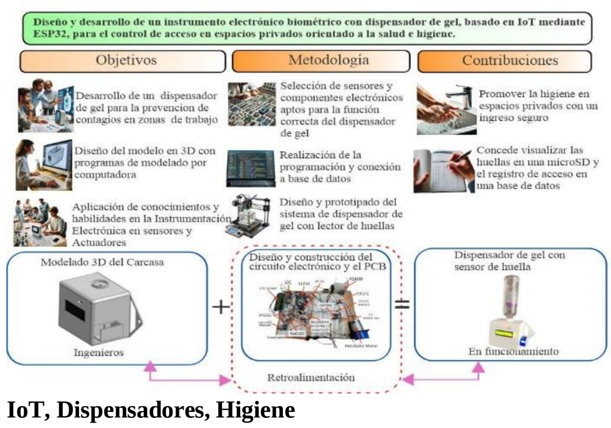
This paper presents the design and development of an automated antibacterial gel dispenser with IoT capabilities for hand disinfection and body temperature monitoring, intended for access control in private spaces. All collected data are stored in a dedicated database. The system was developed using Arduino IDE, XAMPP, Blynk, Autodesk Eagle, Autodesk Fusion 360, and OnShape, integrating sensors such as the MLX90614, FC-51, and AS608. A compact PCB was designed using Autodesk Eagle, while a simple, easy-to-assemble enclosure was modeled with OnShape. A local server was configured using XAMPP to store data in a MySQL database via a PHP script, and the ESP32 microcontroller ensured the overall functionality of the dispenser. The device allows switching between user registration mode, stored data visualization, and standard operation mode, all controlled via the Blynk platform. This system promotes hygiene habits and enables early disease detection. It is currently operational at the Technological Center of Aragón, in the Measurement and Instrumentation Laboratory of the FES Aragón [UNAM].



IoT, Dispensers, Hygiene

Resumen

El presente trabajo describe el diseño y desarrollo de un dispensador automatizado de gel antibacterial con IoT para la desinfección de manos y medición de temperatura corporal acceso en espacios privados, cuyos datos se almacenan en una base de datos. Se usaron Arduino IDE, XAMPP, Blynk, Autodesk Eagle, Autodesk Fusion 360 y OnShape, con sensores MLX90614, FC-51 y AS608. Se diseñó una PCB compacta con Autodesk Eagle y un gabinete sencillo de ensamblar con OnShape. Con XAMPP se gestionó un servidor local para almacenar datos en MySQL mediante un archivo PHP, mientras que la tarjeta ESP32 garantizó la funcionalidad del dispensador. El equipo permite alternar entre registro de usuarios, visualización de registros en memoria o modo estándar, todo controlado mediante Blynk. Fomenta hábitos de higiene y la detección temprana de enfermedades. Actualmente opera en el Centro Tecnológico Aragón, en el laboratorio de Medición e Instrumentación de la FES Aragón [UNAM].



IoT, Dispensadores, Higiene

Area: Development of strategic leading-edge technologies and open innovation for social transformation

Citation: González-Galindo, Edgar Alfredo, Del Valle-Salado, Andrea Paulina, Castillo Valverde Bruno Diego and Domínguez-Romero, Francisco Javier. [2025]. Design and development of a biometric electronic instrument with gel dispenser, based on IoT using ESP32, for access control in private spaces oriented toward health and hygiene. Journal of Engineering Applications. 12[33]1-14: e11233114.

Introduction

The implementation of an access control system with automated antibacterial gel dispensing, based on IoT technologies, requires the integration of sensors, transistors, and an ESP32 microcontroller to automate identity verification, presence detection, temperature measurement, and stable power supply.

This project emerged as a response to the health emergency caused by the SARS-CoV-2 virus, whose first case in Mexico was reported in February 2020, leading to actions such as the "Jornada Nacional de Sana Distancia," implemented on March 23 of that year [Cervera, 2021]. Campo [2020] mentions that since the onset of the pandemic, museums, galleries, and other cultural venues had to adapt to new and diverse forms of creation, implementing various measures to avoid contagion.

This aligns with Archivo General de la Nación [2021], which states that the virus responsible for COVID-19 is transmitted through three mechanisms: droplets, aerosols, and contact. However, because not all public and private spaces can provide handwashing stations with soap and water which is the most effective practice for preventing COVID-19 transmission according to the Pan American Health Organization OPS [2020], one of the main preventive measures was the strategic placement of dispensers to encourage use and reduce infections [Castañeda & Hernández, 2016]. Deploying automated gel dispensers in high-traffic areas helps reduce infection risks while ensuring compliance with sanitary regulations in such environments [Aguilar, 2021].

The proposed dispenser addresses three main areas of application for automation technologies as defined by Ayón y Maldonado [2023], management, efficiency, and prevention. These are fulfilled through access logging, accurate equipment measurements, and the prevention of disease transmission in private spaces. People often forget to sanitize their hands in critical situations, such as returning home after being out, entering school classrooms, or accessing their workplaces [Samyoun et al., 2021].

Devices like these can be highly useful when placed at building entrances to reduce the risk of spreading viruses indoors.

According to Lupión et al., [2014], healthcare-associated infections are a significant public health issue worldwide, and proper hand hygiene, along with correct glove use, are key preventive measures. Factors contributing to poor hygiene include long working hours and lack of access to sanitizing tools, such as gel dispensers and sinks [Costa & Braga, 2024]. Thus, offering a compact device with gel dispensing capability proves to be a valuable solution. Automated dispensers are used in various public-facing spaces such as offices [Ortiz, 2023].

Due to their small size, these devices can be installed in numerous locations, including public transportation services. In the event of a future pandemic, they could be deployed in transport cabins, helping to curb the rapid spread of disease while supporting the continuity of essential sectors like logistics [Aguagallo, 2021]. Such devices promote hand hygiene and help develop the habit of hand sanitization without wasting water, making hand cleaning more accessible. According to Tejada et al., [2021], a large portion of the global population lacks the habit of washing hands after using the restroom. Many people also do not know the correct technique for efficient handwashing or lack basic resources such as clean water. These challenges could be alleviated by the use of antibacterial gel. These technologies can benefit private companies in areas such as healthcare, research, and security purposes [Burgueño, 2025].

As Robalino-Tibán [2025] points out, in Latin America, small and medium-sized enterprises face a significant failure rate within their first five years. This phenomenon is attributed to the limited adoption of technological innovations and the lack of a reference framework for process management, among other factors. IoT-based solutions can enhance the early detection of COVID-19 and other illnesses with fever as a symptom, while reducing the workload on healthcare workers and minimizing their exposure risk [Leng et al., 2024]. Since the beginning of the pandemic, significant resources have been invested in IoT technologies to mitigate its effects. This includes systems for remote work and education, activity monitoring, employee tracking, and collaborative work platforms—many of which are still in use five years later [Umair et al., 2021].

ISSN: 2410-3454.
RENIECYT: 1702902

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Using IoT technologies, Palma y Rojas [2025] suggest that, through digital evolution, there has been an increase in the use of technological tools for data capture, validation, storage, and transfer. These tools can enable significant advancements in the monitoring of patients with illnesses or comorbidities, allowing for the collection of essential data so that physicians can assess a patient's health status without exposing them to the risks of leaving home, spreading infections, or worsening their own condition [Corso, 2021]. In this project, the ESP32 microcontroller coordinates input and output signals and provides wireless connectivity [Wi-Fi and Bluetooth] for data transmission and remote communication with other devices. The growing demand for IoT devices is due to increasing user reliance on such technologies, especially in work environments, leveraging connectivity and internet access to monitor, control, store, and visualize data remotely [Lozada et al., 2024]. Since the onset of the COVID-19 pandemic, global research communities have worked to develop a wide range of technologies aimed at addressing future pandemic threats through IoT [Nasajpour et al., 2020]. Additionally, developing IoT-based devices contributes to scientific knowledge and supports the creation of new and innovative systems and equipment [Flores et al., 2023].

This particular project features a device that captures fingerprints and measures body temperature without physical contact using the MLX90614 sensor, which detects infrared radiation from the body and transmits the data via I2C communication [SDA/SCL]. This information, along with the activation of the gel dispenser, is shown on a 16x2 I2C LCD, which simplifies connections using only four pins. To switch loads like the motor and protect the ESP32, TIP31C and 2N2222A transistors are used, while an LM7805 voltage regulator stabilizes the power supply to 5V from a 12V source. This system provides an integrated, automated solution for access control, hygiene, and thermal monitoring, ideal for settings that require sanitary safety and electronic security.

The device developed here registers fingerprints and measures temperature without physical contact, using the MLX90614 infrared sensor. It communicates via I2C [SDA/SCL], and displays system information on a 16x2 I2C LCD, reducing pin usage and simplifying connections.

To safely drive the motor and protect the ESP32, TIP31C and 2N2222A transistors are used, while a LM7805 voltage regulator ensures a stable 5 V output from a 12 V power source. Altogether, this design delivers an effective and automated solution for access control, hygiene promotion, and temperature monitoring, ideal for educational and workplace settings.

Objective

Development and implementation of a gel dispenser with biometric access control via fingerprint sensor and IoT integration, aimed at preventing the spread of infections in public and private spaces. This system also supports the creation of digital learning materials in the Electrical and Electronic Engineering Program at FES Aragón, UNAM, by enabling students to apply programming skills and work with sensors and actuators in Electronic Instrumentation courses. Additionally, the device contributes to early fever detection, facilitates access control for the academic community, and enhances hands-on learning through the practical application of IoT technologies.

Hypothesis

If an electronic device is implemented to record temperature, monitor attendance, and dispense antibacterial gel, it will enable the timely detection of potential infectious diseases such as COVID-19, H1N1, H5N1, among others, thereby reducing the spread of infections in academic and workplace settings. Additionally, it will encourage students at FES Aragón to develop socially impactful projects through the use of IoT technologies.

Methodology and Development

The project was developed at the Centro Tecnológico Aragón [FES Aragón, UNAM], beginning with the individual functional verification of the sensors, with emphasis on the MLX90614, which was configured to detect only human body temperatures with high accuracy in the range of 0 °C to 50 °C. An LCD display was then integrated for local data visualization, and communication with the Blynk platform was established, enabling remote system control through a graphical interface.

ISSN: 2410-3454.
RENIECYT: 1702902

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Widgets were configured with virtual pins to switch between operational modes: “Verify” [main mode], “Register user” [V0], “Show users” [V1], and data entry [V3], all managed via the ESP32 board connected through Wi-Fi, as shown in Figure 1.

Box 1

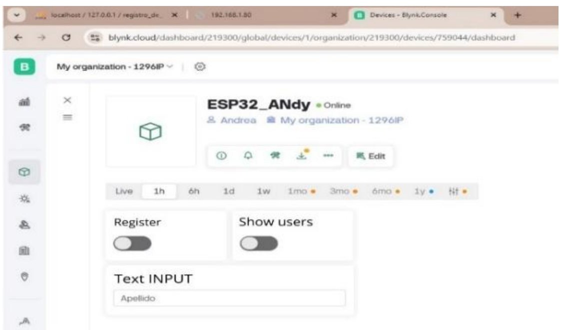

Figure 1
Blynk Control Panel configured for the gel dispenser's fingerprint sensor

The system’s sensors were integrated and validated, starting with the FC-51, adapted for short-range object detection, and the AS608, capable of storing up to 127 fingerprint records. The LCD display and I2C interface shared the SDA/SCL lines with the MLX90614 sensor. The ESP32’s Wi-Fi connection was established, and transistors were implemented as external interrupts to ensure stable communication with Blynk. Subsequently, a microSD module was added for data storage, the power stage was configured to activate the motor for 3 seconds, and all components were integrated on a breadboard, following a validated schematic design, as shown in Figure 2.

Box 2

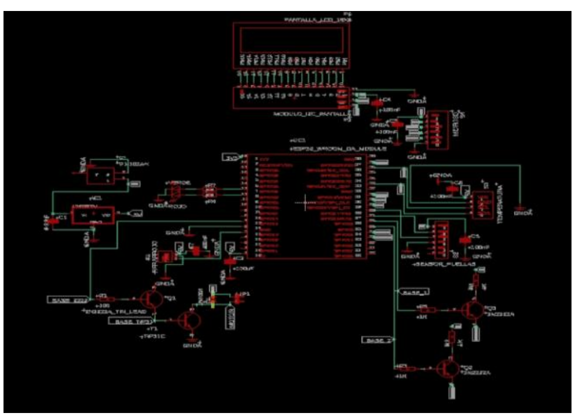

Figure 2
Digital schematic of the sensors and electronic components integrated into the gel dispenser system.

As shown in Figure 3, the MLX90614 and FC-51 sensors were connected, and their readings were verified through the serial monitor to ensure they were accurate and appropriate for infection prevention. Subsequently, the LCD display was integrated to visualize the data both locally and through the serial monitor.

Box 3

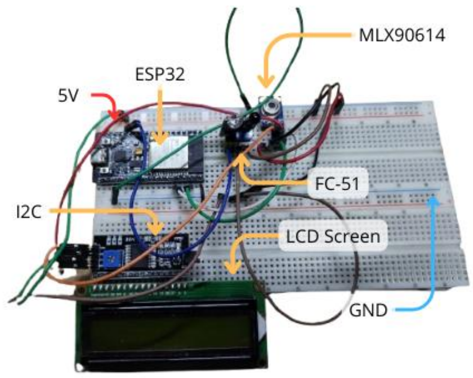

Figure 3
Breadboard testing using an ESP32 connected to the MLX90614 infrared temperature sensor, FC-51 infrared module, I2C interface, and a 16x2 LCD screen

The AS608 fingerprint sensor was integrated, validating accurate fingerprint registration, storage, and recognition. External interrupts were configured, and a microSD module was added to back up the data in case of power failures. A daily log of verifications was also implemented. Figure 4 shows the components added during this stage.

Box 4

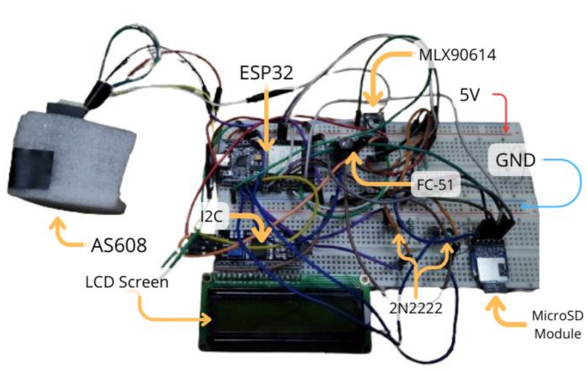

Figure 4
Prototype testing on a breadboard using an ESP32 microcontroller connected to an MLX90614 temperature sensor, FC-51 infrared module, I2C interface, and 16x2 LCD display, with the integration of the AS608 fingerprint sensor, microSD module, and interrupt transistors.

ISSN: 2410-3454.
RENIECYT: 1702902

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The connection between the motor and the ESP32 was established using an LM7805 voltage regulator and a Darlington configuration with 2N2222A and TIP31C transistors, controlled by the FC-51 sensor. The motor is activated for three seconds to dispense gel and is protected by a 1N4004 diode. LEDs were added to indicate access status: green for authorized and red for denied. Finally, communication with the database was verified, confirming the successful logging of events. Figure 5 illustrates this stage

Box 5

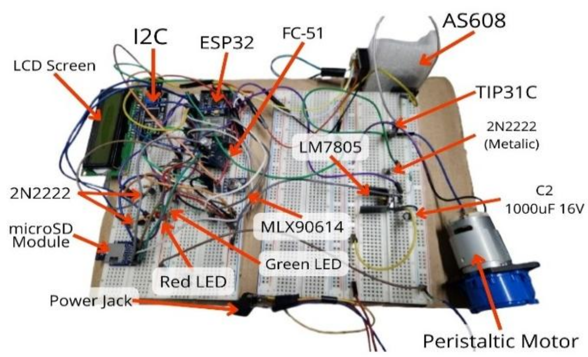

Figure 5

Prototype testing on a breadboard using an ESP32 connected to all sensors, the peristaltic pump motor, and a traffic light-style LED indicator.

The database was configured using the XAMPP platform. This software package enables the installation of a local server that includes Apache, MySQL [used in this project], and PHP support, facilitating the development and management of local databases. Thanks to this integration, it was possible to store and efficiently retrieve the records generated by the system. Figure 6 shows the general structure of the working environment configured with XAMPP.

Box 6

Figure 6

XAMPP control panel with Apache and MySQL services succesfully initialized.

For this particular project, an ESP32 board is used to register device usage by identifying the user through an AS608 fingerprint reader and measuring their body temperature with the MLX90614 sensor. Both pieces of data are sent and stored in a MySQL database hosted locally on a server implemented using XAMPP.

The system's workflow consists of several stages. In the first stage, Identification and Measurement, the fingerprint reader verifies the user's identity by retrieving their name from a preloaded list stored on the microSD card. Then, the temperature sensor measures the user’s body temperature before allowing access to the gel.

In the second stage, Data Transmission via HTTP, the ESP32 sends the captured data [name and temperature] through a POST HTTP request to a PHP file hosted on the Apache server [XAMPP], using the local URL: http://192.168.1.80/Dispensador_project/info_huellas.php. In the third stage, PHP Processing, the PHP file receives the request and establishes a connection to the MySQL database using the appropriate parameters. In the fourth stage, Database Insertion, the processed data is inserted into the defined project table through an SQL query.

In the fifth stage, Storage and Query, the information is recorded in the database, allowing future viewing or analysis via phpMyAdmin, a web application, or even from the ESP32 itself through new HTTP requests. For database management, phpMyAdmin was used to create a database named “registro_de_huellas” and a table named “registro”, which includes four columns: ID [an auto-incremented primary key], Name [identified user], Temperature [value in °C], and Datetime [exact date and time of registration].

The structure and functionality of this table can be seen in Figure 7. Thanks to the use of XAMPP, the system operates completely locally, without relying on cloud servers, making it an efficient, secure, and flexible solution for educational environments.

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Box 7

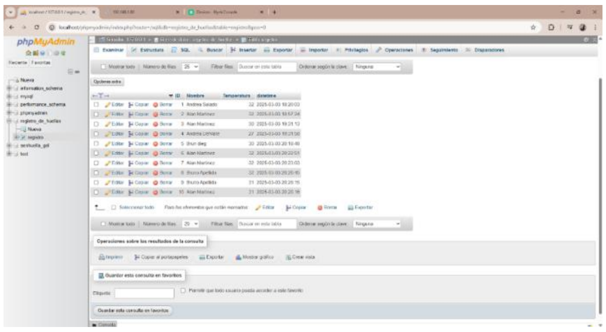

Figure 7

phpMyAdmin interface displaying the designated project database, with sample entries from the access log table.

The PCB wiring was designed with an emphasis on orderly and functional component layout. The power ports and the microSD module were positioned at one end, while the power stage, ESP32, and sensors were primarily arranged on the bottom layer of the board.

Specifically, the FC-51 and MLX90614 sensors were placed on the lower side to facilitate front-facing detection of presence and temperature. On the top layer, visual output elements were placed, with the LCD screen centered as much as possible. The I2C adapter was located at the top, and the indicator LEDs were positioned beside the screen to make system status easier to read.

Once the final layout was defined, the connection traces were generated with varying widths depending on the type of signal. Power traces [12 V, 5 V, and 3.3 V] were designed with a thickness of approximately 32 mil to withstand possible current spikes and prevent structural damage from overheating. Additionally, ground planes were created on both the top and bottom layers to facilitate current return paths and reduce electromagnetic noise.

To improve electromagnetic immunity, stitching vias were incorporated, acting as decoupling elements between layers, especially along data and communication lines. Furthermore, ceramic SMD capacitors were added to help attenuate noise generated during system operation. Figure 8 shows the final component layout and trace distribution on the PCB.

Box 8

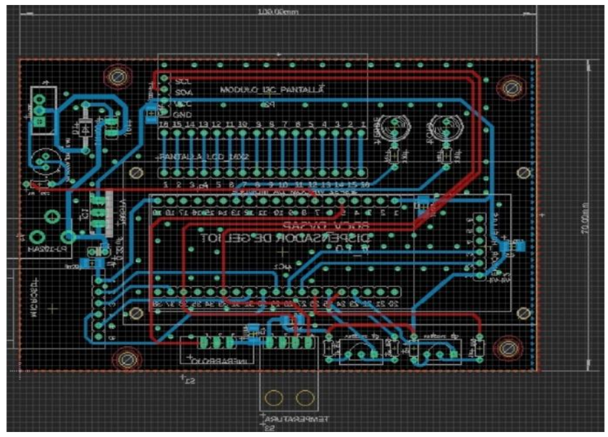

Figure 8

Overview of the PCB layout design, including the routing of tracks and signal paths.

After verifying the correct placement of components, the proper routing of traces, the positioning of vias, and the absence of interference between drill holes and traces, a 3D model of the PCB was generated. This step aimed to visually validate the physical layout of all elements in the design, using Autodesk Eagle for the schematic and trace design, and Autodesk Fusion 360 for the three-dimensional modeling. The dimensions of the components were carefully reviewed to ensure accurate representation and to prevent errors during the manufacturing stage. Once the virtual assembly of components and sensors was completed, the final visualization of both sides of the board was obtained, as shown in Figure 9.

Box 9

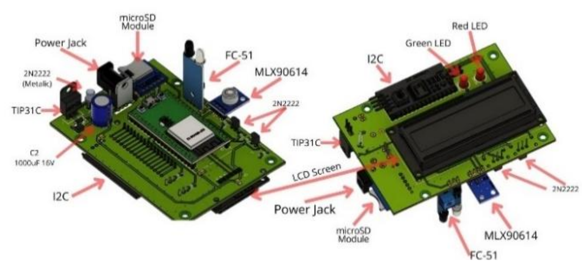

Figure 9

The project's PCB design featuring 3D models of all integrated components.

When designing the PCB, the enclosure was modeled using its exact dimensions to ensure a precise fit and mechanical stability. Considerations were made for motor vibration absorption and the alignment of visual elements such as the LCD. In the final design, the top side of the PCB aligns with the front face of the enclosure, ensuring both functionality and ergonomic usability, as shown in Figure 10.

ISSN: 2410-3454.
RENIECYT: 1702902

Box 10

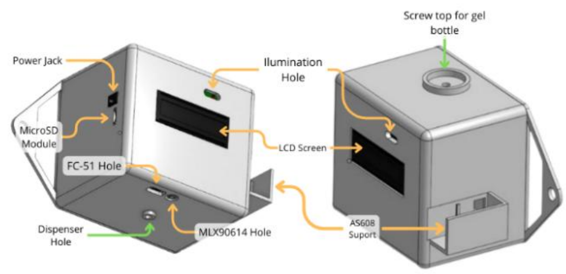

Figure 10

Enclosure designed in OnShape, displayed from a three-quarter perspective showing both lateral sides.

To secure the PCB to the enclosure, a mounting system was implemented using support posts equipped with M3 threaded metal inserts, complemented by side rails that allow for the insertion of a plastic separation plate. This plate serves as both an additional support structure and an insulator between the electronics and the gel dispensing system.

The decision to incorporate this isolation was made to protect the PCB from potential gel spills, which could cause short circuits and irreversible damage to the circuit. Moreover, the structure provides a secondary mechanical safeguard in case the posts give way due to the weight of the board and its components. The implementation of this system is shown in Figure 11.

Box 11

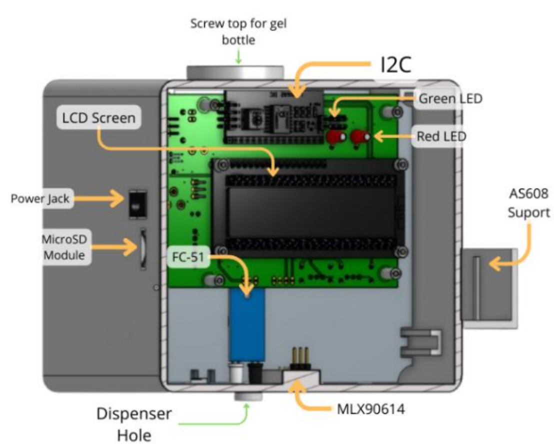

Figure 11

Front internal view of the enclosure designed based on the PCB layout as a structural reference

An M-type thread for plastics was implemented at the top of the enclosure to allow the placement of various antibacterial gel containers. This solution facilitates the refilling process by enabling the user to easily replace or refill the bottle without requiring additional tools. For the thread design, precision measuring instruments such as a vernier caliper were used to determine the pitch, crest depth, and total length. Additionally, technical reference information [Envases Pepsa, 2024] was consulted to establish the proper thread profile angles. The thread was modeled in OnShape using the "sweep" tool, which requires a path and a cross-sectional profile. A helical path was defined along with a reference plane, as shown in Figure 12, generating the necessary thread to ensure secure fastening of the bottle to the dispenser body.

Box 12

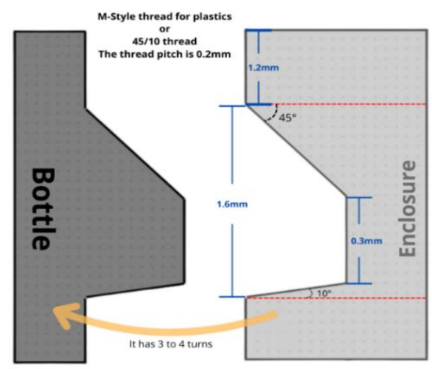

Figure 12

'M'-type profile designed for bottle fittings, including the parameters used in the creation of the threaded connection for the gel reservoir.

A specific support for the fingerprint sensor was also required. A simple structure was designed based on the sensor's negative volume, utilizing the lateral channels present in its casing to create a sliding guide that improves fixation and facilitates assembly within the enclosure. On the other hand, the peristaltic pump could not be integrated directly into the main body of the enclosure because it obstructed the insertion of the plastic isolating plate, complicating assembly. As a solution, a removable and slidable internal base was designed, taking advantage of the rails previously incorporated into the device's interior. This base consists of two parts [upper and lower] which, combined with a pair of M3 screws and fastening nuts, ensure the motor's stability against the vibrations generated during its operation, as shown in Figure 13.

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Box 13

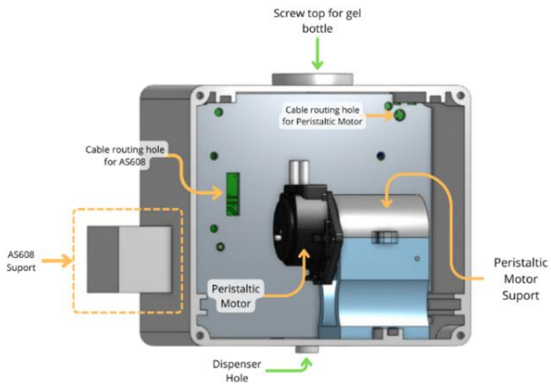

Figure 13

Rear perspective of the enclosure highlighting the allocated mounting area for the peristaltic pump motor

Figure 14 shows the final assembly result, with all components correctly placed on their respective sides of the PCB, as planned during the design phase.

The front side features the LCD display, its I2C module, and on the side, the indicator LEDs [green and red]. On the back side, the temperature, presence, and fingerprint sensors were integrated, along with the microSD module, power components, and decoupling capacitors.

Box 14

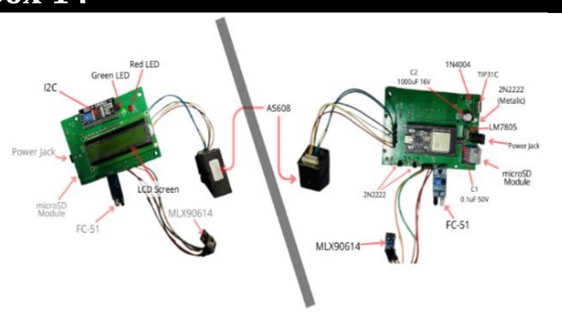

Figure 14

Final outcome of the fully assembled PCB, with all components soldered in place — front and rear views included.

Figure 15 confirms that the PCB design and manufacturing were successful, as all components function correctly with no failures in the sensors or in the connection with the Blynk platform or the database. This validates the integrity of the assembly and the reliability of the system.

Box 15

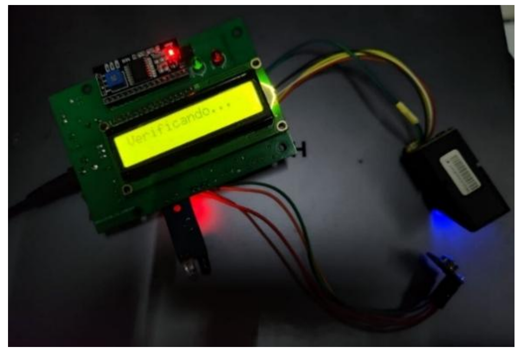

Figure 15

Verification test confirming proper soldering of sensors and components, ensuring the PCB is free of faults or errors.

Due to its complexity and size, the printing sequence began with the enclosure, considering critical features such as the bottle thread. As shown in Figure 16, the enclosure was fabricated using an Ender 3 V2 Neo 3D printer, with an estimated 16 hours of continuous printing and approximately 200 g of PLA filament. A layer height of 0.28 mm was used to optimize print time without compromising the design's functionality.

Box 16

Figure 16

Enclosure 3D printed with the Ender 3 V2 Neo printer

After printing the enclosure, the support base for the peristaltic pump was manufactured, designed to absorb the vibrations generated during operation and prevent disconnections or unexpected failures. Subsequently, the isolating plate was printed, serving to electrically separate the electronic section from the gel dispensing area, providing greater structural stability and protection against potential spills. Finally, the rear cover was produced, intended to protect the internal components from external contact and to allow the dispenser to be mounted on a wall. The result of each of these elements can be seen in Figure 17.

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Box 17

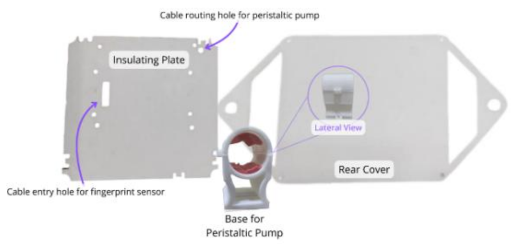

Figure 17
Peristaltic pump mount, insulation plate and rear panel of the enclosure

As shown in Figure 18, after removing the printing supports, M3 metal inserts were placed at the mounting points to ensure durable fastening. These were installed using heat and served as alignment guides. The PCB and rear cover were secured using M3 x 10 mm screws, and the isolating plate was mounted via rails, routing the cables from the peristaltic pump and the AS608 sensor. Both components were then fixed to the enclosure, with the hose directed toward the lower dispensing channel and the threaded bore for the bottle. Finally, the enclosure was closed and the gel bottle was screwed into place, completing the assembly.

Box 18

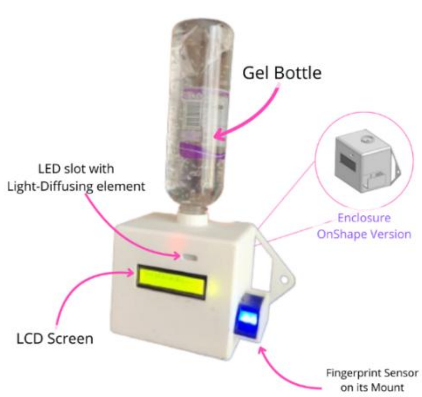

Figure 18
Fully assembled enclosure including the PCB, fingerprint sensor and gel reservoir, with the system powered up.

Results

Figure 19 presents the flowchart that summarizes the operation of the developed system. When the device is powered on, the configuration variables are initialized, and the LCD screen is activated, followed by an attempt to connect to the WiFi network.

If unsuccessful, the system enters a loop until the connection is established, at which point it displays "Connection successful" on the screen and prints the credentials via the serial port. Next, it links to the Blynk platform, initializes the AS608 fingerprint sensor [repeating the operation in case of failure], and proceeds with the verification of the MLX90614 temperature sensor, displaying "Sensor error" if unresponsive and "Temperature sensor OK" if operating correctly. The system then synchronizes the time with the NTP server, a requirement for timestamping events. Upon completion, it displays "NTP time synchronized successfully." Finally, the microSD module is initialized; in case of an error, a visual alert is issued, but this does not block program execution.

Once the hardware verification is complete, the system checks the selected operating mode via Blynk, which can be: Verify Mode, Register Mode, or Show Users Mode. In Register Mode, the user is prompted for an ID [1–127] and personal data via a text box, after which they are guided through instructions like "Place your finger," "Remove your finger," and "Place your finger again" to complete the biometric registration.

In Show Users Mode, registered IDs are displayed on the LCD screen in ascending order, repeating the sequence until the corresponding switch is deactivated. Verify Mode is the default setting; when a fingerprint is detected, if it matches a record, the system displays the message "Welcome + name," requests a temperature reading via the presence sensor, and based on the detected value, if it exceeds 37°C, the red LED is activated, "Fever detected" and "Access denied" messages are shown, and the flow returns to the beginning.

If the temperature is between 25°C and 37°C, the green LED lights up, "Dispensing gel" is displayed, the peristaltic pump activates for 3 seconds, and the message "Record OK" appears along with temperature, date, and time data. The data is then sent to the database via a PHP script and stored on the microSD card. If the fingerprint is not recognized, the system displays "Access denied" and returns to the scanning node, thus closing the dispenser's operating cycle.

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Box 19

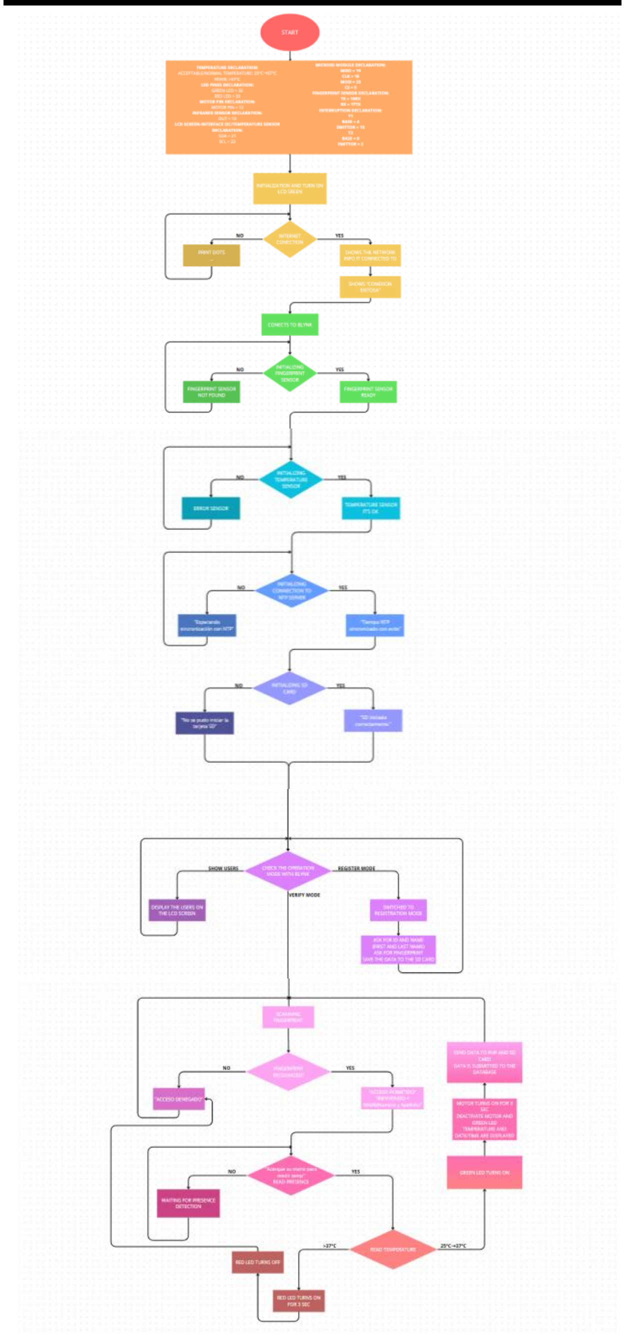

Figure 19

Flow diagram of the fingerprint-activated gel dispensing system.

Once the dispenser assembly was completed, functional tests were carried out to validate its proper performance. The evaluation protocol included user registration in various contexts: domestic, work, and educational, to verify both biometric identification and data transmission and storage in the MySQL database, as shown in Figure 20. For the tests, the MLX90614 [temperature] and FC-51 [presence] sensors were calibrated to operate effectively at a distance of 1.5 to 2 cm, while the AS608 fingerprint sensor performed best when the finger was placed centrally, firmly, and flat, fully covering the sensor surface.

The tests were conducted with a diverse group of users—men and women—across different environments, allowing for the collection of a broad range of data. All records were stored on both the microSD card and the database, making them available for future analysis or monitoring. Regarding environmental conditions, tests in domestic and educational settings were carried out in well-ventilated spaces, while workplace tests were conducted in more enclosed areas with less ventilation. Despite these variations, the temperature readings remained within a consistent range, with no significant deviations. A digital thermometer was used to validate the measurements.

Box 20

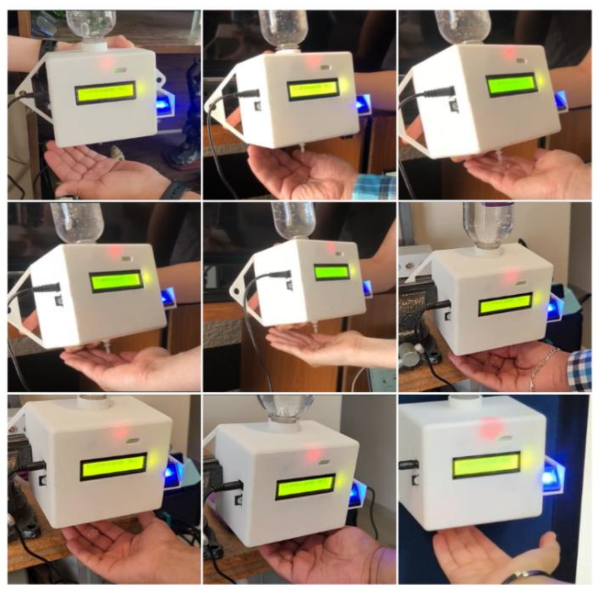

Figure 20

Test evidence captured in domestic, professional, and educational settings.

Figure 21 shows the distribution of temperatures obtained during the testing period. A clear concentration of values is observed between 28°C and 32°C, which corresponds to the expected range for the surface temperature of extremities such as the palm under normal environmental conditions. This behavior validates the use of the MLX90614 infrared sensor for non-invasive detection applications, as a preliminary mechanism before granting access to controlled spaces.

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Unlike core body temperatures [oral, axillary, or rectal], which range between 36.1°C and 37.2°C, extremities usually register lower values due to physiological processes like peripheral vasoconstriction and greater exposure to the environment [Kräuchi et al., 1997; Nadel et al., 1971]. Studies indicate that in temperate environments, hand temperature may range from 27°C to 34°C, with 32°C being a common value in resting, healthy hands [Togawa, 1985]. This distribution, along with the low standard deviation obtained [2.47°C], reflects high consistency in the sensor's behavior and proper implementation of the thermal system, aligning with the device's objectives. It also shows the relationship between the reading index and the recorded temperature. The red line represents the fitted linear regression, with a slope near zero [0.0021], confirming that there is no increasing or decreasing trend over time, indicating the sensor's stability and reliability. The coefficient $R^2 = 0.0213$ and its square root confirm very low correlation, as is desirable in measurements not influenced by time or registration order.

Box 21

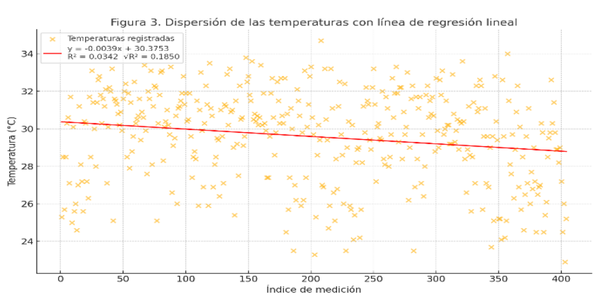

Figure 21

Scatter plot of recorded temperatures with linear regression line.

A simple linear regression model was fitted to analyze the temperature trend relative to the registration index, with the following equation:

$$y = 0.0021x + 29.2237$$

Coefficient of determination $R^2 = 0.0213$. The low correlation indicates no significant linear trend between the registration index and temperature. Square root of $\sqrt{R^2} = 0.1459$. This confirms a weak linear association, as expected from a stable sensor. The statistical summary shows: Mean = 29.58°C, Median = 30.10°C, Mode = 30.30°C, Standard deviation = 2.47°C, Variance = 6.12, Range = from 22.9°C to 34.7°C, Coefficient of variation [CV] = 8.37%.

Figure 22 shows the distribution of recorded temperatures throughout the testing period. A concentration of data is observed between 28°C and 32°C, indicating that most measurements fall within a healthy range. Vertical lines are included representing: Mean [dashed red]: 29.58°C, Median [dashed green]: 30.10°C, Mode [dashed purple]: 30.30°C. The KDE curve reinforces the notion of a near-normal distribution.

Box 22

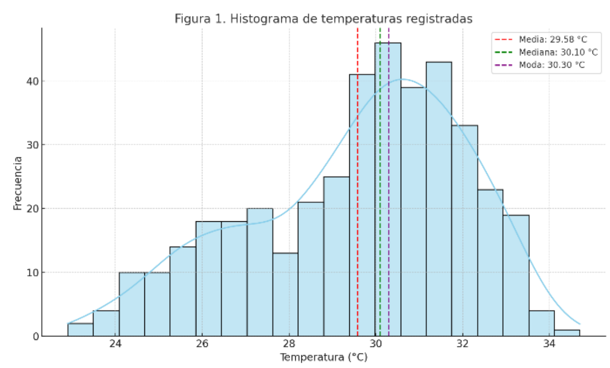

Figure 22

Histogram of recorded temperatures

The chart in Figure 23 compactly displays data dispersion and possible outliers. Vertical lines indicate: Mean [dashed blue], Minimum value [dotted black], Maximum value [dark red dotted]. A symmetric distribution with few outliers is evident, reflecting a stable sensor response and high-quality measurements.

Box 23

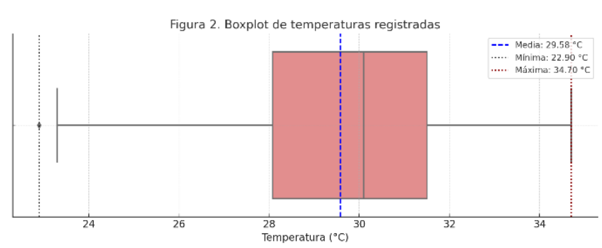

Figure 23

Boxplot of recorded temperatures, showing the outliers, which are observations that deviate significantly from the rest of the data

Conclusions

The project successfully met its objectives by developing an automated gel dispenser with biometric control and IoT integration, focused on disease prevention through peripheral temperature measurement and hand disinfection.

ISSN: 2410-3454.
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The MLX90614 sensor demonstrated high accuracy and stability, while the AS608 sensor enabled reliable user management, even after system resets, ensuring orderly and secure records. A hybrid storage system was implemented [microSD and local database], enhancing data integrity in case of failures.

During validation, 404 individual temperature measurements were collected, enabling a cross-sectional statistical analysis. The data reflected a distribution consistent with the thermal behavior of the extremities, showing low variability and no artificial trends, validating the use of the sensor for non-invasive thermal pre-screening. It is acknowledged that individual factors such as metabolism, diet, circulation, and blood conductivity influence thermal response, and should be considered in future system enhancements.

The automated gel dispensing following biometric verification promotes hygiene without reliance on water, making it particularly useful in resource-limited environments.

The device was successfully tested in educational contexts and is currently operating in the Measurement and Instrumentation Laboratory at FES Aragón, UNAM, receiving positive feedback for its functionality and sanitary impact. Its compact, easy-to-install enclosure makes it accessible for various environments. Inspired by the COVID-19 pandemic, the project aims to promote hygiene habits and sustainable preventive measures.

It is recommended to extend its application to high-traffic spaces and explore improvements such as touchscreen integration and dual-core processing with the ESP32, enhancing both performance and user experience, particularly for older adults.

Annexes

Acknowledgements

The authors would like to thank the Coordination of the Technology Centre and the Electrical and Electronic Engineering Department of the Facultad de Estudios Superiores Aragón of the Universidad Nacional Autónoma de México, for the facilities in the use of tools provided through agreements with different software companies.

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Author contribution

González-Galindo, Edgar Alfredo: Responsible for the conceptual design, he led the integration of sensors, PCB layout, mechanical modeling of the enclosure, and the implementation of the local database. He coordinated functional testing in real environments and conducted the statistical analysis for the development of digital documents aimed at teaching and learning in the Electronic Instrumentation course, supported by resources from the PAPIME project PE1088225.

Del-Valle-Salado, Andrea Paulina: Contributed to the technical documentation, assisted in the experimental validation phase within educational settings, collaborated in the design of the printed circuit board [PCB], and helped organize the data collected during field testing. She also participated in the writing and editing of the results and discussion sections.

Castillo-Valverde, Bruno Diego: Supported the design and fabrication of the enclosure through 3D printing and modeled the thread and mechanical interfaces in 3D. He assisted with the structural integration of the peristaltic pump, contributed to sensor programming—particularly the fingerprint sensor—and participated in the development and editing of the physical system test design.

Domínguez-Romero, Francisco Javier: Contributed to the design of the testing protocol, supervised compliance with technical requirements, and carried out a critical review of the manuscript. He also analyzed the potential impact of the device in application contexts that may yield substantial data in the medical field.

Availability of data and materials

The data for this research is available according to the sources consulted.

Funding

Work carried out with the support of the UNAM-DGAPA-PAPIME Program, project PE108225

Abbreviations

VCC	Positive supply voltage
LCD	Liquid Crystal Display
GND	Ground
SDA	Serial Data – data line in the I2C protocol
SCL	Serial Clock – clock line that synchronizes data transmission in the I2C protocol
V	Volts
3D	Three-Dimensional
PCB	Printed Circuit Board
M4	metric thread screw with a nominal diameter of 4 mm
M3	metric thread screw with a nominal diameter of 3 mm
PLA	Polylactic Acid filament used for 3D printing
CM	Centimeters
MM	Millimeters
PCB	Printed Circuit Board

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