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COMPUTERIZATION OF ACTIVITIES PERFORMED BY ELECTRONIC GATE CONTROLS

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Alex Silva[1], Jackson Henrique da Silva Bezerra[2] and Jefferson Antônio dos Santos[3]

ABSTRACT

Electronic gates have become fundamental elements in the security and privacy of homes and businesses. This work proposes the development of a technological solution for the management of electronic sliding gates, integrating Internet of Things (IoT) and home automation concepts. The main objective was to create an accessible and functional system that allows remote control of the gates using mobile devices, with operation via both the internet and Bluetooth, even in adverse connectivity conditions. The methodology was based on the case study, using a descriptive qualitative perspective and the agile Scrum methodology for system development. The results demonstrated the viability of the solution, with features such as efficient remote control, recording of operations history, dynamic partial opening and simplified user inclusion. The solution overcomes limitations of existing systems, offering greater accessibility, control and security for users.

Keywords: Electronic Gate. Development. Home Automation. Iot. Innovation. Remote Control.

[1] Systems Analysis and Development Technologist - Federal Institute of Rondônia.
E-mail: alexro.kcoal@gmail.com
[2] PhD in Regional Development - Federal Institute of Rondônia.
E-mail: Jackson.henrique@ifro.edu.br
[3] Specialist in Software Engineering - Federal Institute of Rondônia.
E-mail: jefferson.santos@ifro.edu.br

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INTRODUCTION

With the advancement of technology today, society is witnessing the rapid evolution of devices and systems that significantly shape our daily lives (CARVALHO and LORENA, 2017). In this context, electronic sliding gates, fundamental elements in residential security and practicality, are subject to improvements that reflect contemporary innovations. There is a need to integrate the benefits provided by home automation and the Internet of Things (IoT) into these devices (FERRARI et al., 2021).

This research aims to explore and develop an innovative application for managing sliding electronic gates, allowing control through mobile devices. By identifying the limitations of currently available systems, this proposal seeks to overcome existing obstacles. The introduction of a specific electronic device connected to the gate's central unit enables efficient and wireless communication with mobile devices, thus providing a more accessible solution.

In modern times, the emergence of new technologies constantly opens up a range of ideas and opportunities that foster significant advances in our way of life (MORAES, 2018). By analyzing the functionality of current electronic gates, it is evident that improvements can be achieved through the addition of new features and popular technologies.

This study focuses on developing and presenting a novel application and device for managing the activities of sliding electronic gates, ensuring their control via mobile devices using home automation and IoT concepts. Currently, some devices with similar functionality exist but do not operate without an internet connection (ROCHA JÚNIOR, 2014). To enable direct control of the gate through mobile devices, an electronic device was developed to mediate communication between the gate's central unit and mobile devices. The device is physically connected to the gate's central unit, while commands from the mobile device, through the application, are sent and received wirelessly.

The choice of the ESP32 microcontroller for hardware development was based on its low cost and, primarily, its support for multiple wireless connections such as Wi-Fi and Bluetooth (SANTOS and LARA JUNIOR, 2019). This allows the user to operate the electronic gate even without an internet connection, utilizing Bluetooth for gate configuration and as a secondary control option. The distance from the gate will no longer be a limitation, as connected devices will function from any location with internet connectivity. As the control and use of the electronic gate are carried out through the user's mobile devices, the process

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of configuring and including new users is simplified, eliminating the need to purchase additional gate controls.

By employing the technology developed in this project, users will be able to control their electronic gates via their smartphones. Adding new users for gate access will become easier, avoiding additional costs for purchasing and configuring new controls. Furthermore, the system will log gate operation history, indicating the gate, the user responsible, and the date and time of operation. The gate can also be operated via smartphone even without an internet connection.

The general objective of the project is to develop a system for the computerization of activities performed by electronic gate controls. To achieve this objective, the following specific objectives were established: review the state of the art regarding IoT resources and technologies necessary for the development of the project; develop a hardware prototype to integrate into the electronic gate motor control board; analyze, design, develop and test a firmware to enable communication between the hardware prototype and the electronic gate; analyze, design, develop and test a mobile application to open the electronic gate; and analyze, design, develop and test the application server.

METHODOLOGY

In order to achieve the proposed objectives, it is essential to understand the methods applied in this study, as they provide, in an organized manner, the direction and focus necessary to find solutions to the problems highlighted in the object of study. The concepts of methodology are decisive in the development of the research, and, therefore, the researcher's perspectives must follow their foundations. The case study, widely used in the scientific community, can be applied in different areas of knowledge. However, to use this approach, it is essential to understand its definitions (CASTRO FILHO, FREIRE and MAIA, 2021, p. 3-4).

Proetti (2017, p. 3) describes the types of research that can be adopted: quantitative research, characterized by objectivity and precision, uses measurable data; while qualitative research seeks to understand, analyze and describe events related to the research. Both approaches can be combined, depending on the object of study. It is important to highlight that the case study, because it involves a more in-depth analysis, often uses the qualitative approach. This approach allows the exploration of phenomena and circumstances of interest to the researcher.

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According to Castro Filho et al. (2021, p. 8), the case study presents three distinct perspectives: descriptive, exploratory and explanatory. In this work, a qualitative investigation was carried out with a descriptive approach, through a case study. This choice makes it possible to detail the processes necessary to solve the problems raised, allowing the reader to understand each stage of the solution process.

PROJECT DEVELOPMENT METHODOLOGY

Software development is a complex activity that requires structured planning and the adoption of appropriate methodologies to ensure efficiency and quality. For this project, the Scrum agile methodology was used, which organizes work into iterative and incremental cycles, called Sprints. The main Scrum events include Sprint Planning, Daily Scrum, Sprint Review, and Sprint Retrospective, which structure the process and promote continuous improvement. The methodology uses artifacts such as the Product Backlog, Sprint Backlog, and Increment, which organize and monitor the project's progress in a clear and objective manner. The choice of Scrum is justified by its flexibility and applicability in different contexts, enabling the integration of lean teams and the constant delivery of functionalities aligned with customer needs (SCHWABER, 2020).

Tools such as Jira Software were used to facilitate the implementation of the methodology, guaranteeing greater efficiency in project management and reducing costs and rework. Thus, Scrum offers a practical and agile approach to achieving the proposed objectives with quality and efficiency. At the end of the project, 15 Sprints were carried out in total.

RESULTS AND DISCUSSIONS

The application was developed using the client-server architecture for communication between all its components. The application works as a client, while the server-side layer, composed of the Application Server and the MQTT Broker, acts as a server. The application hardware operates as both a client and a server: in Internet communications with the server-side layer, it acts as a client; in Bluetooth communications directly with the application, it acts as a server.

The architecture consists of several components that interact physically or wirelessly. Communication between the hardware and the electronic gate occurs through wires, sensors and actuators. Communication between the application and the hardware is wireless and can

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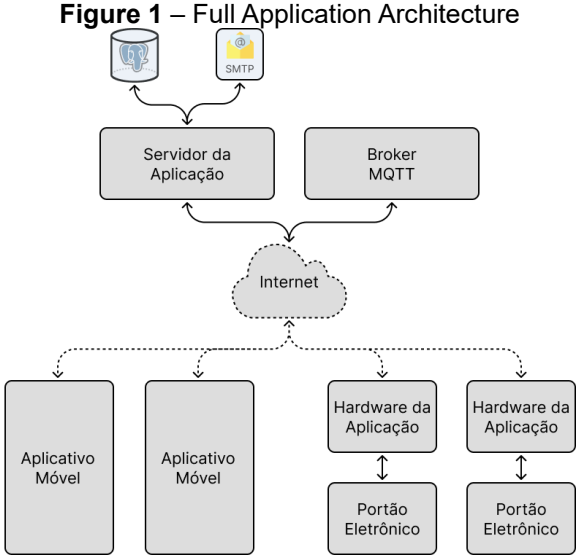
occur via Bluetooth or the Internet, which is the default mode (Figure 1). The Bluetooth connection is used during the initial configuration of the gate or in situations where the Internet is not available. Even so, operations performed via Bluetooth are synchronized with the server as soon as the Internet connection is reestablished. When connected to the internet, the application sends activation commands to the server-side layer, which passes them on to the electronic gate.

Figure 1 – Full Application Architecture



Source: Author's own.

After being activated, the hardware records the operation performed on the server. The information recorded includes the type of operation (opening, closing, stopping, activation), the gate activated, the user responsible and the date and time of activation. This history can later be accessed by the application, which queries the data directly on the server.

The application was designed to be intuitive and functional, allowing users to configure the gate, access operating information and perform opening and closing operations. Connected to an API hosted on the Internet, the application uses the HTTP protocol and JSON format to exchange data. This integration guarantees secure authentication, login support and detailed recording of the operations carried out.

The API also offers features for managing information, such as registering, consulting, updating and deleting users, gates and locations. An additional feature is the automatic sending of emails to new invited users, simplifying the integration process and providing clear instructions for accessing the application and controlling the electronic gate. All data is securely stored in a database, ensuring integrity and high availability.

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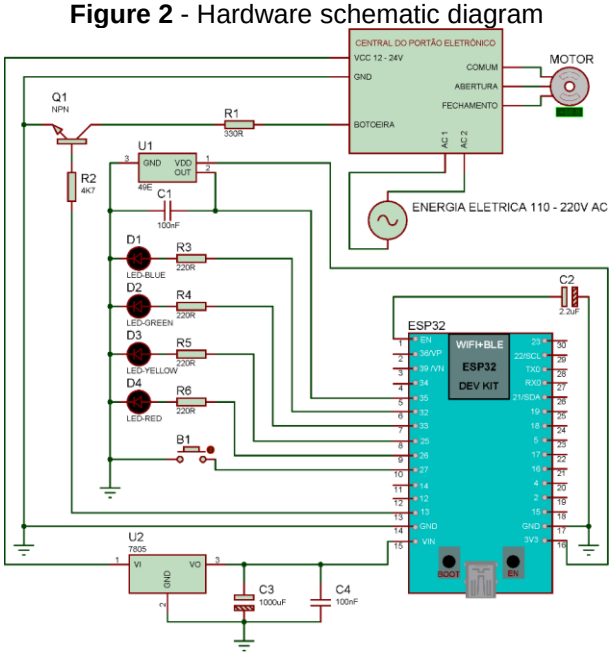
Furthermore, an MQTT Broker, hosted on the internet, acts as an intermediary between the application and the gate hardware, using the publish-subscribe communication model. This model, widely adopted in Internet of Things (IoT) applications, enables efficient transmission of messages between devices, supporting features such as security, quality of service (QoS), and message retention.

HARDWARE PROTOTYPE

Initially, a prototype was developed to perform tests, with the aim of identifying the best arrangement of components and determining the most appropriate values for the electronic components of each hardware function. After defining the ideal arrangement, the schematic diagram of the electronic board was drawn up.

This diagram played a fundamental role in guiding the process of building the final electronic board. Through standardized symbols, it represents how the electronic circuit components are interconnected, their values and their characteristics. Furthermore, the diagram serves as a reference for analysis and future optimizations, constituting a valuable guide throughout the entire life cycle of the electronic project. Figure 2 shows the developed schematic diagram.

Figure 2 - Hardware schematic diagram



Source: Author's own.

The main hardware component is the ESP32 microcontroller, on which the developed firmware is recorded. For power supply, a voltage regulator (U2) was integrated into the

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circuit, responsible for adjusting the voltage received from the electronic gate control unit or another external source to 5 volts, the value required for the ESP32 to operate. This voltage is stabilized by capacitors C3 and C4. In addition, a button (B1) was included to reset the settings. The current state of the gate is read by means of a linear Hall effect sensor (U1), together with capacitor C1. The indication of the hardware's operating status is carried out by four indicator LEDs (D1, D2, D3 and D4), each accompanied by a current limiting resistor (R3, R4, R5 and R6). To activate the control unit button, a transistor (Q1) connected to resistors R1 and R2 was used.

Hardware assembly was a crucial step in the completion of this project. The process began with the careful selection of materials and components, as detailed in the previously prepared list, ensuring alignment with the needs and requirements of the project. Each component was integrated into the circuit following the previously defined arrangement, ensuring desired functionality and performance. Attention to detail during the assembly process not only ensured the integrity of the hardware, but also established the ideal conditions for system efficiency and reliability. The electronic components were fixed to the board by electronic soldering, using a soldering iron heated to approximately 300 ºC and solder wire composed of an alloy of tin and lead.

Initially, the electronic component terminals were inserted into the holes on the board. Then, the soldering iron was placed next to the soldering wire, positioned between the component terminal and the copper hole on the board, to ensure the union. After fixing all the components on the board, the tracks that connect the components to each other were created, following the schematic model design. Finally, the wires and the magnetic sensor were soldered, completing the assembly of the electronic board (see Figure 3).

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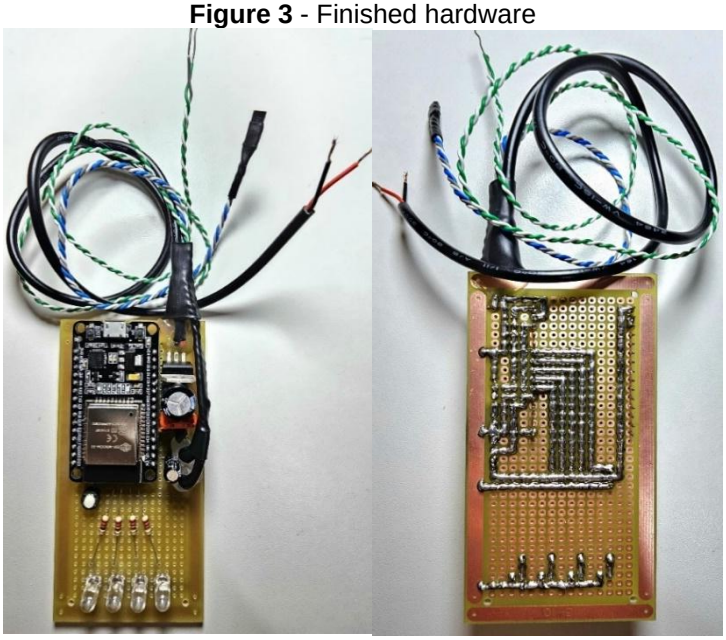
Figure 3 - Finished hardware



Source: Author's own.

Once this process is complete, the electronic board is solid and ready to meet the project demands in a consistent and reliable manner. The efficiency, quality and precision employed in each stage of its construction confirm the viability and success of this electronic project. However, it is still necessary to write the developed firmware to the board's microcontroller, which constitutes the intelligence responsible for the board's operation. This step is essential for the hardware to carry out the planned tasks according to the specifications defined in the project.

HARDWARE *FIRMWARE*

The firmware was developed using the ESP-IDF framework, provided by the ESP32 microcontroller manufacturer. Initially, it was necessary to set up the development environment by installing ESP-IDF and integrating it with VS Code. With the environment properly configured, coding began in C/C++, taking advantage of the libraries and APIs provided by ESP-IDF. This step was essential for configuring the chip's input and output pins and integrating the system's essential components.

The control logic was implemented to interpret the interactions with the reset button, establishing the board's reset functionality. However, the button was initially tested in a simplified way: an LED was connected to the gate's drive wires, making it possible to check both the operation of the button and the sending of the drive signal to the electronic gate control unit.

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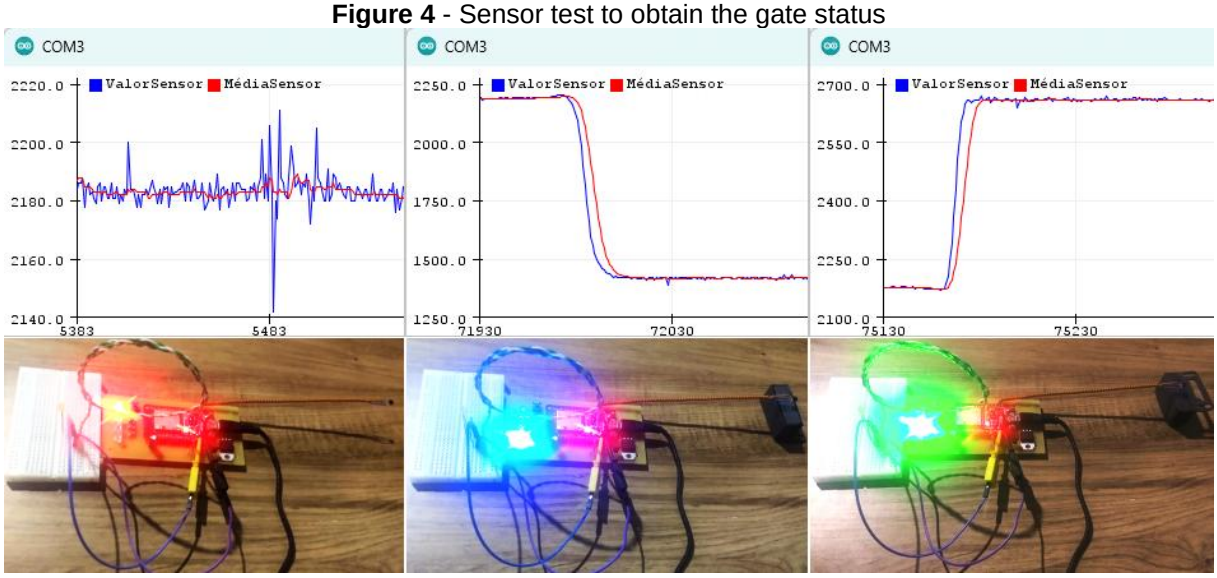
Subsequently, the algorithm responsible for interpreting the magnetic sensor data was developed, allowing accurate detection of the gate state. To validate this algorithm, simulated situations were created that represented different positions of the gate. The simulation was performed using an end-of-stroke magnet, reproducing three different scenarios: magnet far from the sensor, one pole of the magnet close to the sensor and the other pole of the magnet close to the sensor (see Figure 4).

Figure 4 - Sensor test to obtain the gate status



Source: Author's own.

As noted, for each of the three magnetic sensor test scenarios, there is a graphical representation of the reading obtained from the sensor and visual signaling of each gate state through an LED of a different color on the board. In the graphs, the legend presents two line colors: the blue one represents the value obtained at the time of the sensor reading, while the red one indicates the average of a fixed sampling of the last recorded values.

These graphs demonstrate that direct sensor readings, without the application of filters, are susceptible to noise, a common problem in electronic devices that can result in improper firmware operation. However, applying the average of the readings effectively solved this issue. The microcontroller was configured to interpret sensor inputs in a range of 0 to 4096, the ESP32's default value for analog voltage readings. In the first scenario, with the magnet absent, the gate is in a partially open state, the red LED lights up, and the sensor value approaches 2048, approximately half of the allowed range. In the second scenario, the magnet is positioned on one of the poles, representing the gate completely open or closed, depending on the configuration defined, the blue LED lights up, and the sensor value is below

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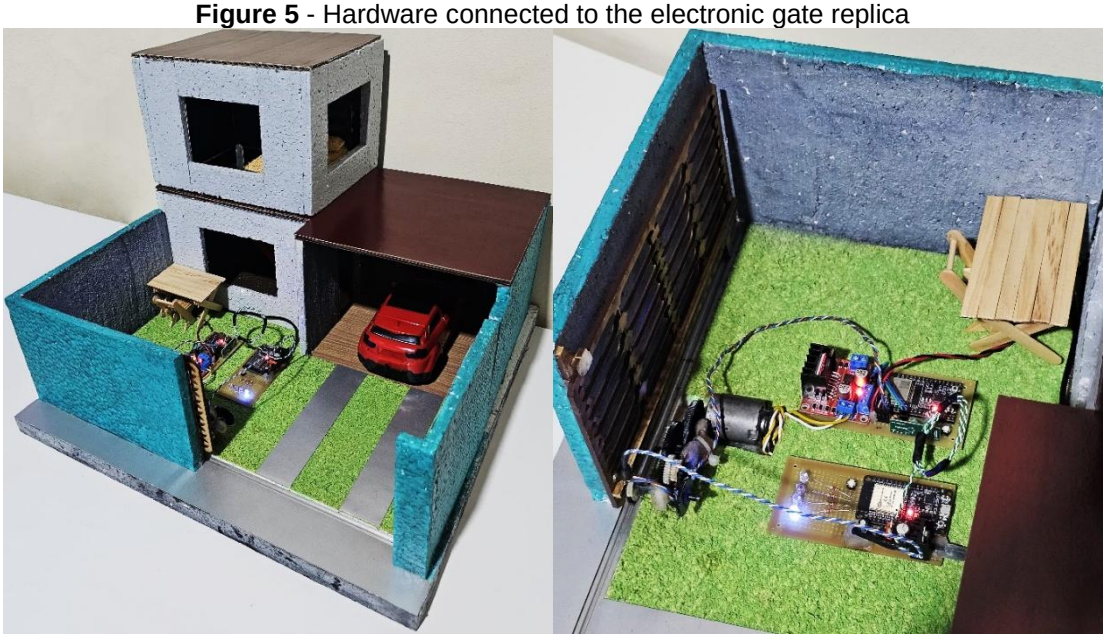
2048. In the third scenario, the magnet is on the pole opposite, indicating the reverse state of the gate, the green LED lights up, and the sensor value exceeds 2048. These fundamental functionalities — identifying the gate state, triggering and resetting the firmware — have been successfully implemented.

To enable information exchange with other devices, it was necessary to develop communication modules, including Bluetooth, Wi-Fi, HTTP and MQTT. Additionally, modules were created for security management, data synchronization and persistent storage, among other essential features.

During the development process, the need arose to create a tool that would facilitate testing. The constant activation of a real physical gate for adjustments and refinements could cause risks and accelerate wear. To mitigate this situation, a model was developed that faithfully reproduces the operation of an electronic sliding gate, allowing safe and accurate testing (see Figure 5).

Figure 5 - Hardware connected to the electronic gate replica



Source: Author's own.

The model played a crucial role in making it possible to carry out tests safely and accurately. By replicating the operation of a real electronic gate, it allowed the simulation of different scenarios, which were essential for the necessary refinements to the firmware logic and for bug fixes. However, although it was valuable in the intermediate steps, the final validation of the firmware functionalities was carried out on a real electronic gate, ensuring that the system met practical operating conditions.

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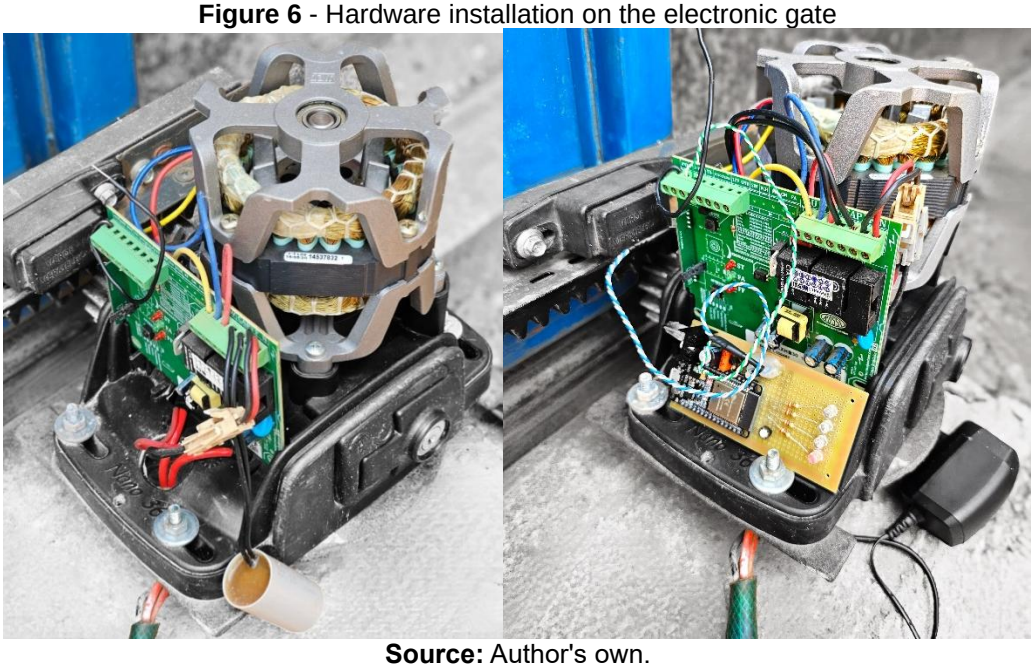
After the firmware development was completed, the process of writing the definitive version to the hardware microcontroller began. This procedure marked the end of an intensive phase of work, characterized by care for the stability and correct functioning of the system. With the version finalized and tested, the recording represented a transition point for the practical implementation of the firmware, incorporating the innovations and adjustments made during development.

HARDWARE CONNECTION TO THE ELECTRONIC GATE

After completing the development of the hardware and firmware, the hardware was installed on the electronic gate. Figure 6 clearly illustrates the difference between the original system and the result after integration. On the left side, you can see the gate motor in its standard configuration, connected via wires to its control board, known as the electronic control unit. On the right side, the updated system stands out, with the hardware developed in this project integrated into the gate's electronic control unit.

Figure 6 - Hardware installation on the electronic gate



Source: Author's own.

The hardware magnetic sensor was positioned next to the electronic gate's original magnetic sensor, allowing both to share the same operational status of the gate. The actuation wires of the control panel button were connected to the electronic control panel terminal, interconnecting the negative terminal and the actuation terminal of both boards.

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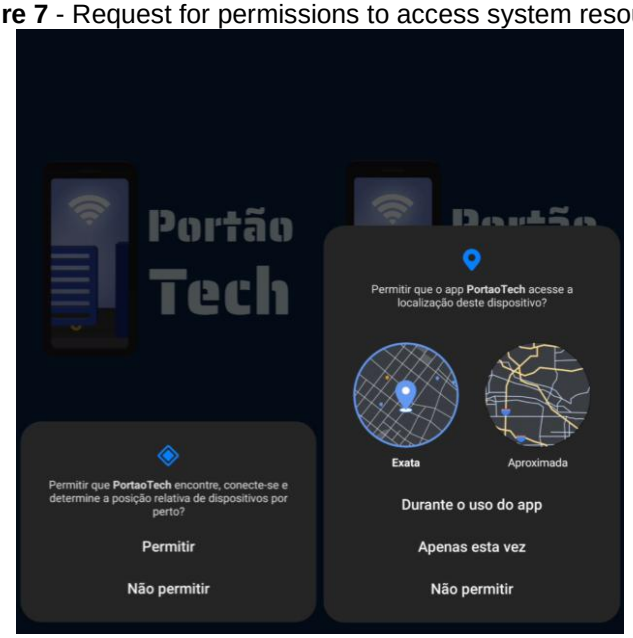
Typically, gate electronic control units have terminals that provide power supply voltage to external components. However, not all of them are capable of supplying sufficient current to operate new components, especially those with greater energy demands. In the specific case of the electronic gate used in this project, it was identified that its electronic control unit might not provide the current required for the proper functioning of the hardware developed.

Given this limitation, it was decided to use an external power supply. This adaptation was essential to ensure the stable and safe operation of the system. Thus, a synergy was established between the new hardware and the existing electronic control unit, adding the functionalities designed in this project and expanding the capabilities of the electronic gate.

MOBILE APPLICATION

When opening the app for the first time, you are asked for essential permissions to access Bluetooth and the device's location. These permissions are essential for the app to work with all its features.

Figure 7 - Request for permissions to access system resources



Source: Author's own.

Bluetooth is required to set up a gate for the first time and is also used when there is no internet connection, either on the user's smartphone or on the gate. In situations where the board connected to the electronic gate loses its connection to the internet, it will not be

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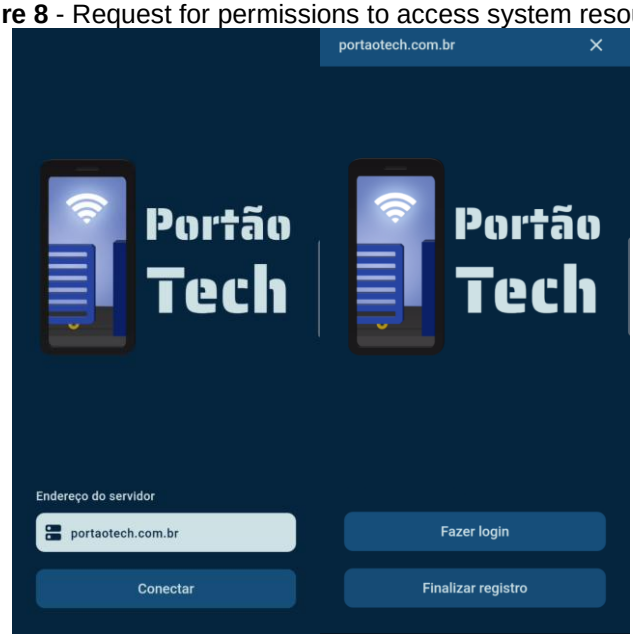
able to receive commands or communicate with the server. After the initial step, a screen is displayed for the user to enter the server address.

For the application to work, it must be connected to a machine that hosts the PortãoTech back-end server. The server is responsible for authenticating users and managing data that can be inserted, searched, changed or deleted through HTTP requests. By default, the address "portaotech.com.br" is already filled in, but it is possible to use another address if necessary. After entering the server address, the user must tap the "Connect" button to establish the connection.

Figure 8 - Request for permissions to access system resources



Source: Author's own.

If the application is not being opened for the first time, it automatically checks whether there is an active login session. If the session is active, the main screen is displayed to the user. If there is no active session, the application checks whether the server address was previously entered. If the address exists, a screen is displayed with the options "Log in" and "Finish registration", allowing the user to log in, if they are already registered, or to finish the registration, if they were invited and are accessing for the first time.

Finalizing registration is part of the process of adding new users. In order for a user to be able to control the gates, they must be previously invited. The invitation is sent via email, containing access instructions and a verification code. When accessing the registration completion screen, a modal is displayed asking for the registration code to be entered. The user must enter the six-digit code received in the email and tap the "Validate" button.

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Figure 9 - User Registration Finalization Screens

Source: Author's own.

If the provided code is invalid, an error message will be displayed. If it is valid, the modal will close and the user will be able to fill in their information. The requested fields are "Full name", "Password" and "Password confirmation". After filling in the fields, the user must tap the "Finish" button. If all the information is registered successfully, the login screen will be displayed, allowing the user to access the system.

Access to the application is via the login screen, where the user must enter the registered email and password defined when completing registration. For greater convenience during filling out the form, the password field has the functionality to display or hide the text entered, activated by a button located on the right side of the field. In situations of login errors, such as lack of internet connection, server unavailability or incorrect provision of credentials, the system displays informative messages to the user. Once the login is successful, the user is automatically redirected to the application's main screen.

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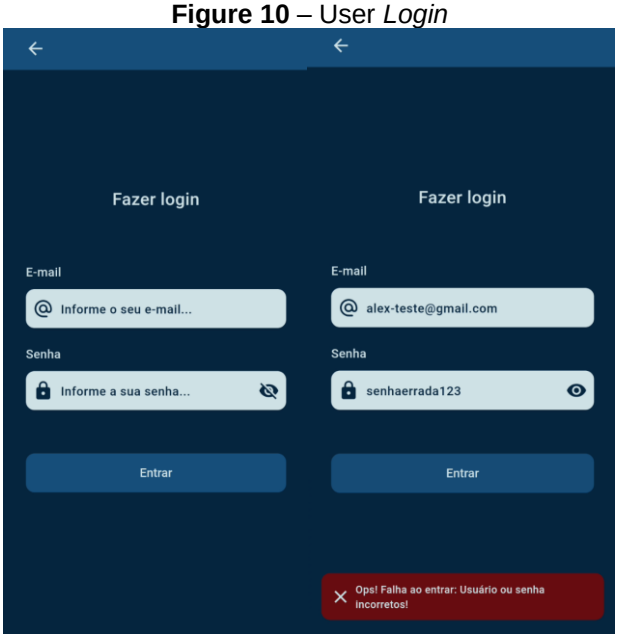
Figure 10 – User *Login*



Source: Author's own.

The main screen is the central operating point of the application and serves as the primary interface for controlling the electronic gate. When accessed, the application checks whether there were any gates being controlled when last used. If so, the application automatically attempts to reestablish the connection with the same gate, using the type of connection previously used, whether Internet or Bluetooth. If the initial attempt is unsuccessful, the application switches to the other type of connection available. When the automatic connection is successfully established, the gate control buttons are displayed on the interface, allowing the user to perform opening, closing or stopping actions. However, in scenarios where the connection is not possible or no gate was previously controlled, the system displays a notification message next to a button called “Connect”. This button, when pressed, presents the user with a modal dialog that allows the selection of the gate to be controlled. Additionally, the main menu, accessible through an icon in the upper left corner of the screen, offers options for other application features.

The choice of gate is made through a modal that can be accessed in different ways, allowing the user flexibility. Among the available methods, the modal can be activated by the “Connect” button on the main screen, when no gate is active; through an option located on the main menu; or by touching the name and location of the gate that is currently in use. This approach provides agility in the selection, especially in scenarios where several gates are registered in the application.

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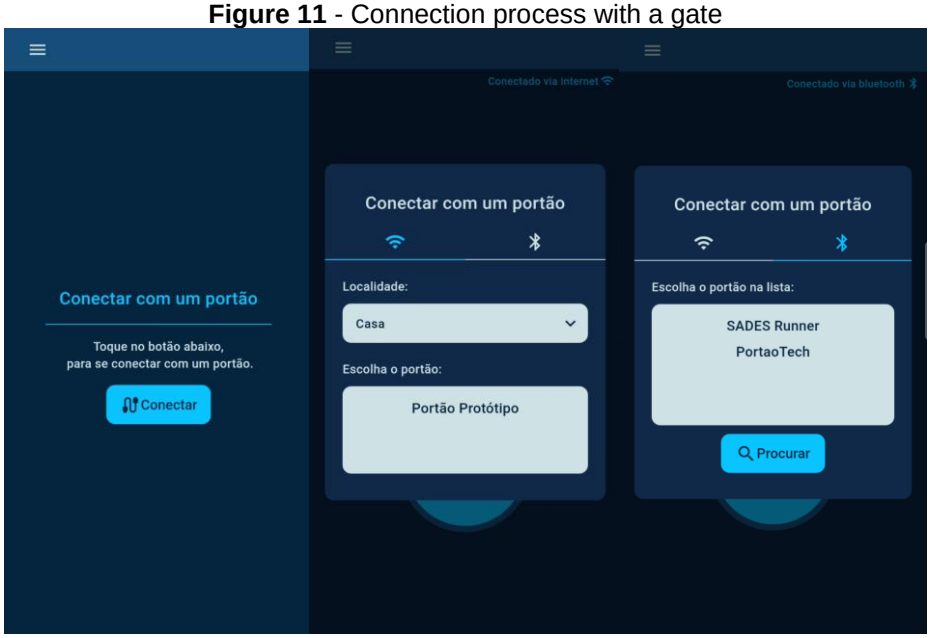
Figure 11 - Connection process with a gate



Source: Author's own.

The application supports two connection methods: internet and Bluetooth. The internet connection is prioritized by default, and is presented as the initial option to the user due to its stability and range. The Bluetooth connection is recommended as an alternative in situations where the internet is unavailable, either on the user's device or at the electronic gate. To select the desired connection type, the user must navigate between tabs represented by specific icons in the interface before choosing the gate.

The internet connection process requires the user to first select the location where the gate is located. After selection, a list of gates associated with the location is displayed, allowing the user to choose the desired gate to establish the connection. On the other hand, connecting via Bluetooth requires physical proximity to the electronic gate. In this mode, the interface initially displays a list of already paired Bluetooth devices. If the desired gate is not among the listed devices, the user can press the “Search” button to start discovering new devices. After finding the gate in the list, the user selects the device, establishing the connection.

During the connection process, whether via the internet or Bluetooth, the system displays an informative message along with a circular progress indicator, signaling the attempt to establish communication. In case of connection failure, the system notifies the user through detailed error messages. When the connection is successful, the selection mode is automatically closed, and the gate control buttons are displayed on the main screen, allowing full control of the system.

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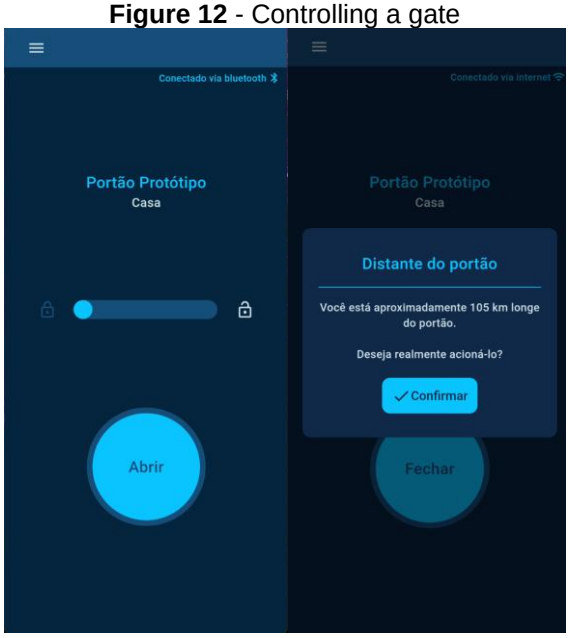
The electronic gate control screen is designed to provide users with an intuitive and efficient interface for managing gate access. The screen layout is divided into distinct sections, each with specific functionalities, providing a fluid and easy-to-navigate user experience. At the top of the screen, information about the type and status of the connection with the current gate is displayed, represented both in text and by graphic icons. The connection status indicates whether communication with the gate is active or if there has been a signal loss, providing the user with crucial information about the state of interaction with the gate control system.

Just below the connection status section, the "Gate Name" and the "Location" to which the gate belongs, such as "Home" or "Work", are displayed. This information is essential to help the user identify the correct gate, making it easier to select the device to be controlled.

Figure 12 - Controlling a gate



Source: Author's own.

After the initial connection with the gate, the system checks the distance between the user and the gate using geographic coordinates. If the distance between the two devices exceeds 100 meters, an informative message is displayed indicating the distance between them, as shown in the second screen of Figure 12. This mechanism aims to increase security by preventing accidental activations, such as when the cell phone is placed in an unlocked pocket or if the user forgets to choose the correct gate. To proceed with activating the gate, the user must confirm the operation by tapping the "Confirm" button.

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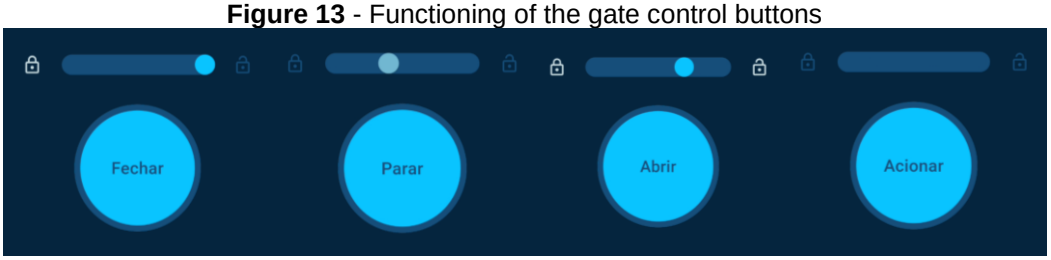
One of the gate's main controls is the slider button, which allows the user to precisely set the gate's stopping point. By holding the slider, the user can drag it to the desired position and release it to bring the gate to a stop exactly at that point. This control allows for proportional adjustment of the gate's opening, with the slider moving to the right opening the gate and to the left closing it. In intermediate positions, the gate stops proportionally, allowing for detailed control of the opening. At the ends of the slider, there are closed and open padlock icons. Touching the closed padlock icon triggers the gate to close, while the open padlock icon triggers the gate to open.

Figure 13 - Functioning of the gate control buttons



Source: Author's own.

Below the slider is the main button, a round button that is larger than the other controls. This button allows the user to perform immediate actions on the gate, with the description of the action to be performed clearly displayed in the center of the button. Available actions include "Open", "Close", "Stop" and "Activate". This main button offers a direct and convenient alternative to the gate control, allowing the user to perform functions with a single touch, without the need to drag the slider.

Overall, the gate control screen offers a user-friendly and efficient interface for users, allowing precise control of the opening, closing and stopping of the gate, as well as providing important information about the connection status and the gate in operation. With this interface, users can manage their electronic doors safely and with full control over the operational status of the system.

The application's main menu is accessed by tapping the three horizontal lines icon located in the top left corner of the main screen. This menu is designed to offer intuitive and organized navigation, allowing the user to quickly access the system's functionalities. At the top of the menu is the "Back" button, which allows you to close the menu and return to the application's main screen. This functionality aims to ensure a convenient transition between the menu and the main screen. Below the "Back" button, the name of the logged-in user is displayed, clearly identifying the currently active account.

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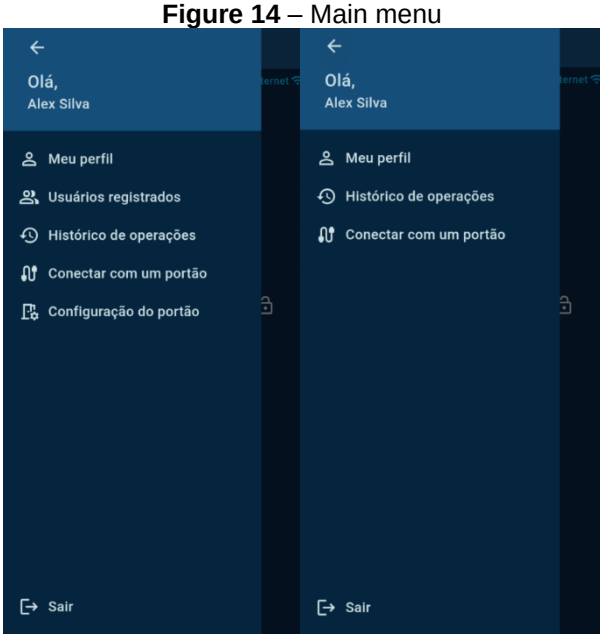
Figure 14 – Main menu



Source: Author's own.

In the central part of the menu, there is a list of features that varies according to the type of user. For regular users, classified as "Standard", the options include "My Profile", "Operation History" and "Connect with a Gate". For users with administrator privileges, in addition to the features available to the "Standard" user, additional options are presented, such as "Registered Users" and "Gate Configuration". At the bottom of the menu, there is the "Exit" button, which allows the user to end the active session safely and efficiently.

The user profile screen is accessible through the main menu and is designed to allow viewing and editing of personal information. From this screen, the user can manage data such as name, email and privileges, as well as choose to delete their account if desired. When opening the profile screen, the user data is displayed immediately, but the “Save” button remains disabled until some change is made to the available fields.

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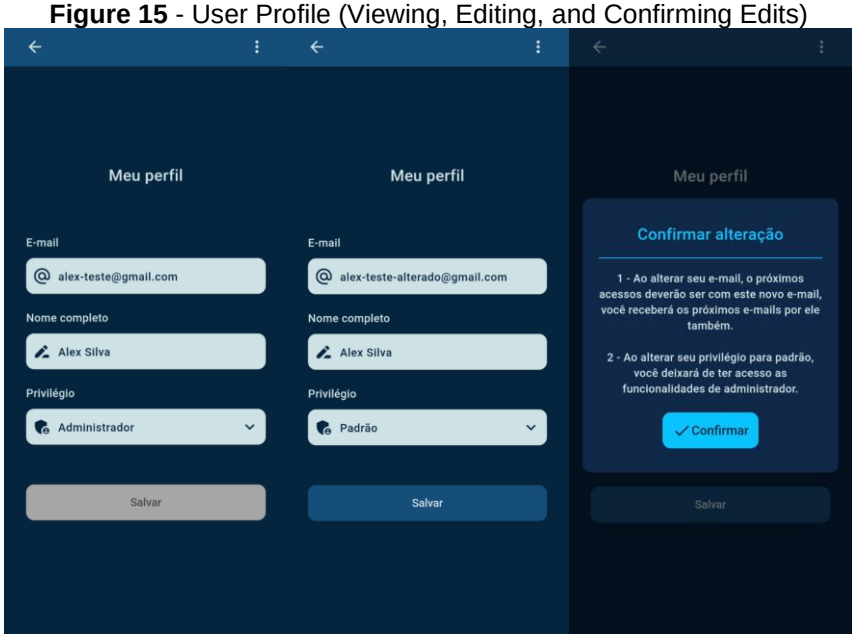
Figure 15 - User Profile (Viewing, Editing, and Confirming Edits)



Source: Author's own.

The fields available for editing include: “Email”, which corresponds to the email address used for registration and login, but which can be updated; “Full name”, which identifies the user in the application; and “Privilege”, which allows you to change the user’s access level between “Standard” and “Administrator”. When making changes to any of these fields, the “Save” button is enabled, allowing you to confirm the changes made. For changes to the email or privilege, the system displays an informative dialog with important instructions. If the email is changed, future emails from the application will be sent to the new address, and subsequent logins must be made with the updated email.

In addition to editing, the application offers profile deletion functionality, allowing the user to permanently close their account. To do so, the user must access the options icon in the upper right corner of the profile screen. When selecting the “Delete profile” option, a dialog box appears, warning about the consequences of the action, such as the loss of access to the application and associated data. If the user confirms the deletion by tapping “Confirm”, the application proceeds with the deletion of the profile and displays a success message. If the user decides not to proceed, simply tap outside the dialog box or use the device’s back button to cancel the operation.

The registered users screen offers features that allow you to view, invite new users to the application, and manage access for existing users. The list displayed on this screen contains users already registered in the system, with each item in the list displaying the following information: name, privilege, and status. The name identifies the user in the

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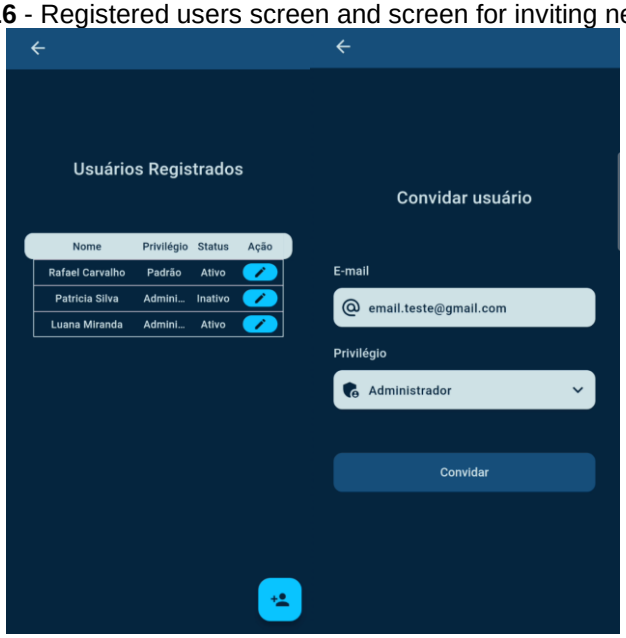
application, while the privilege can be "Standard" or "Administrator", the latter with additional permissions to manage gates and other users. The status indicates whether the user is authorized to use the application, and can be "Active" or "Inactive".

Figure 16 - Registered users screen and screen for inviting new users



Source: Author's own.

In the bottom right corner of the registered users screen, there is a button to open the new user invitation screen. On this screen, the administrator must enter the invited user's email address and the privileges they will have upon completing their registration. The system then sends an email to the invited user containing a registration code and instructions for completing their registration. After registering, the new user will be able to control and manage the gates available in the application.

Each item in the registered user list contains an action button, represented by a pencil icon, which allows access to the access control screen. On this screen, it is possible to modify the user's privilege between "Administrator" and "Standard", as well as change their status to "Active" or "Inactive". Any change made enables the "Save" button, and confirming it updates the user's access. To delete a user, simply access the options icon located in the upper right corner of the access control screen. The "Remove user" option displays a confirmation dialog, warning that the action is irreversible. Once confirmed, the profile is deleted, and a success message is displayed. After deletion, the system automatically returns to the registered users screen.

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Additionally, the application allows users to view operations performed by themselves or other users, such as opening, closing, partially opening, partially closing or activating the gate. The screen responsible for this functionality presents a filter and a list with details of the operations performed. The filter allows the user to choose between viewing only their own operations, using the "Only mine" option, or all operations, using the "From everyone" option.

Figure 17 - Screens with details of operations performed by the gate

Source: Author's own.

The list of operations is displayed in descending order, with the most recent operations displayed first. Each item in the list contains the name of the user who performed the operation, the type of operation, the date, time, location, and the name of the gate. This functionality contributes to monitoring and identifying possible problems or irregularities, such as gates that were not closed correctly, providing greater control and security.

The application's settings screen is designed to organize the gateway settings in an intuitive way, using specific tabs for each set of parameters. The "Connection" tab allows you to customize connection parameters, such as the server address, SSID and local network password, essential elements for the gateway to connect to the internet and the server.

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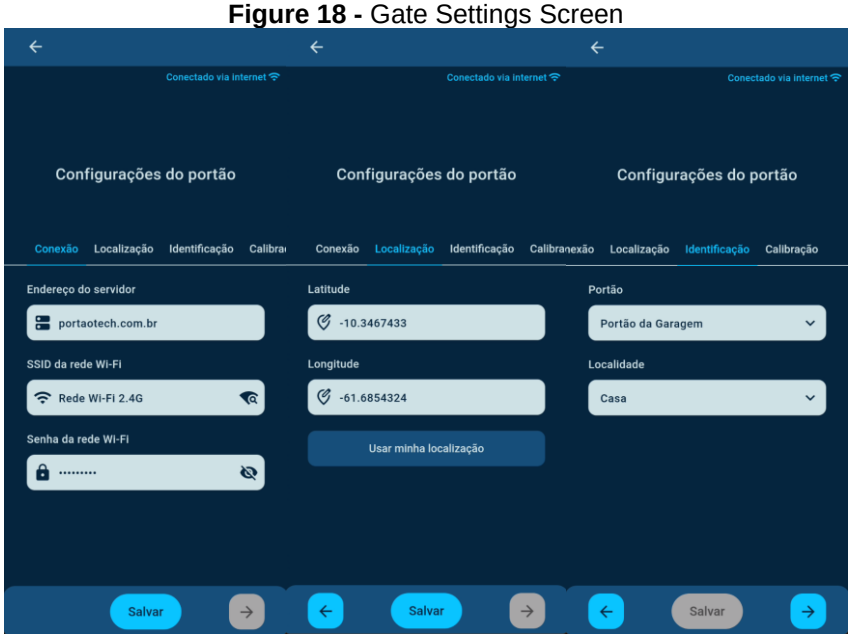
Figure 18 - Gate Settings Screen



Source: Author's own.

In the “Location” tab, the user can view and set the “Latitude” and “Longitude” coordinates of the gate. A button called “Use my location” allows these fields to be automatically filled in based on the current location of the device. The “Identification” tab allows the name and location of the gate to be customized, making it easier to identify in the system. Finally, the “Calibration” tab is dedicated to configuring internal parameters related to the operation of the gate, including measuring the time required to fully open or close, as well as associating the states of the gate with the sensor signals.

CONCLUSION

In summary, the research and development of this new application for the management of electronic sliding gates represents a significant advance in the modernization of access to residential technologies. The proposed objectives were fully achieved through a meticulous and continuous process, which involved everything from reviewing Internet of Things (IoT) technologies to the implementation of a functional system.

The project began with a review of IoT technologies, which provided the necessary foundations for the development of the proposed solutions. The development stage of the hardware prototype focused on integration with the electronic gate control board, aiming to improve its functionality. Simultaneously, the firmware was developed to establish efficient communication between the hardware and the gate system. The mobile application was designed and tested in detail, ensuring its functionality and ease of use. Lastly, the application

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server was designed to guarantee robust communication between mobile devices and the electronic gate system.

The complete process, which involved everything from design to implementation, resulted in notable improvements in accessibility and control of the electronic gates. The choice of the ESP32 microcontroller, based on its cost-efficiency and support for multiple wireless connections, proved to be a resilient solution, capable of operating in adverse connectivity conditions. By overcoming the limitations of pre-existing systems, the proposed solution not only enhances the functionality of the electronic gates, but also introduces new features, including dynamic partial opening, access control, real-time status and detailed operation history.

By aligning operational efficiency, accessibility and ease of use, the developed application not only optimizes the management of electronic gates, but also redefines the user experience. Intuitive control via mobile devices eliminates the need to purchase additional physical controls, simplifying configuration and user management. In this context, this work represents an innovative paradigm in the daily interaction with residential technologies.

Future prospects include the implementation of new functionalities to further enhance the user experience and increase the versatility of the system. A relevant extension would be the integration of an alert system into the application, informing users about the regular functioning of the gate and immediately notifying them of possible defects. This functionality would increase the safety and reliability of the system, allowing rapid intervention in the event of problems.

Another possibility for expansion would be the inclusion of an interface for presenting the gate's operational statistics, with graphs that facilitate detailed analyses, such as peak times, frequency of use and performance metrics. Furthermore, creating a functionality to configure the automatic opening and closing of the gate, adjusted to specific days and times, would allow for greater convenience and automation. These improvements would add substantial value to the project, raising its functionality and usability to even more practical and comprehensive levels.

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