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Development of a Facial Recognition-Based Access Control System for Scientific Research Laboratories

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INTRODUCTION & AIM

Facial detection and recognition, although natural for humans, still represent a computational challenge due to factors such as lighting and color variations. With advances in computer vision, they have become viable systems capable of interpreting images with greater resolution, expanding their use in security solutions [1]. In this scenario, access control becomes fundamental, especially in laboratories and research institutions, which require protection of equipment, sensitive materials, and traceability of users.

In this context, access control systems become essential to ensure security in various environments, allowing for efficient management of the entry and exit of authorized users. Traditional methods, such as keys and cards, have limitations, while facial recognition stands out for offering greater practicality, security, and resistance to human error. In addition, this technology favors compliance with privacy and data protection standards, aligning with the LGPD [2].

This work presents the development of a facial recognition-based access control system, specifically designed for research laboratories. The system performs identification directly on the embedded device, triggering an electromechanical release mechanism only when a previously registered face is recognized. The proposal aims to increase security, optimize access monitoring, and reduce dependence on traditional authentication methods.

METHOD

This work adopted an applied research methodology, combining literature review and testing in a controlled environment to develop and validate a prototype access control system based on facial recognition.

- **Definition of Requirements**

The functional needs of the system were identified, including facial recognition for authentication, automatic lock activation, Wi-Fi communication, and event logging.

- **Component Selection**

Based on the requirements, the most suitable hardware and software components were selected, including ESP32, ESP32-CAM, relay module, power supply, DC-DC converter, Arduino IDE, local server, and Telegram.

- **Hardware Development**

The hardware was designed by defining the functions of each microcontroller. The ESP32-CAM was responsible for facial capture and recognition, while the ESP32 was responsible for displaying the images on the TFT display and activating the relay. Communication between the two occurred via UART, complemented by voltage regulators and auxiliary modules.

- **Firmware Development**

The firmware was structured in a modular way. The ESP32-CAM performs facial detection and recognition and sends an image and a byte of information to the ESP32, which displays a reduced image via SPI and activates the relay when necessary. Event logging and transmission to Telegram were also implemented.

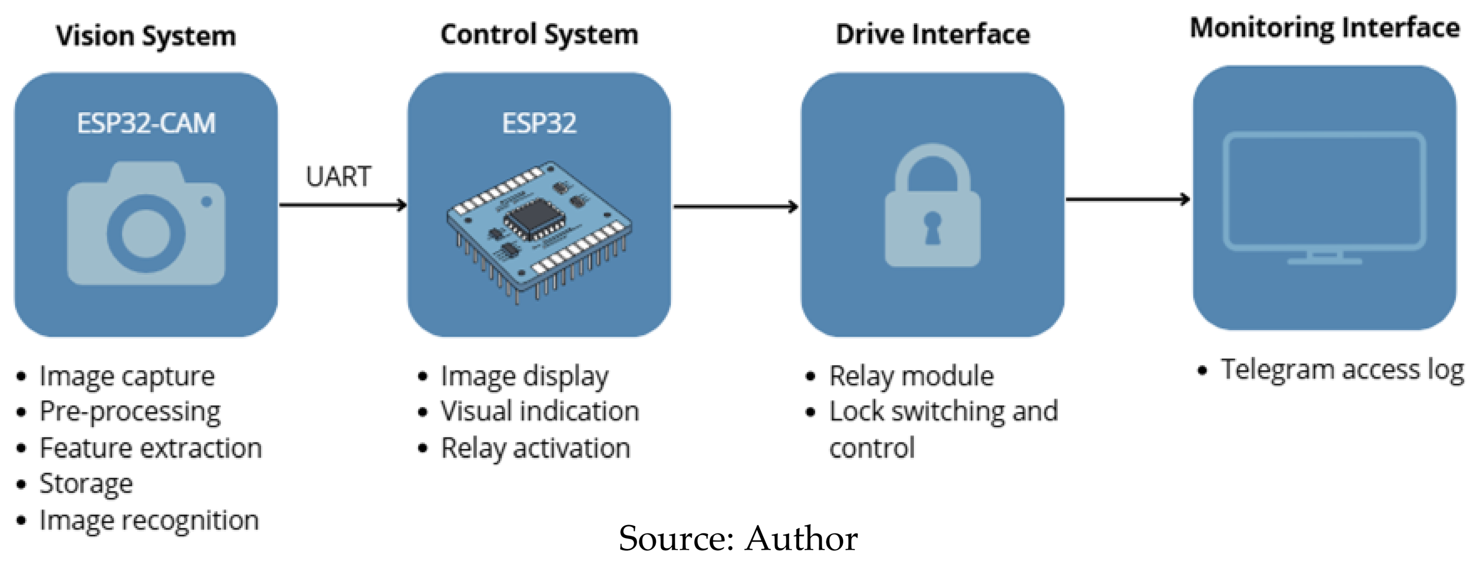
- **Monitoring Interface**

The interface was developed as a web page hosted on the ESP32 itself. Through the dashboard, the user monitors the system status and registers faces, processed directly on the device without the need for external servers.

RESULTS & DISCUSSION

The tests evaluated the joint operation of the ESP32-CAM and the ESP32, verifying image capture, communication, processing, and access release. Figure 1 illustrates the system architecture.

Figure 1 - General system architecture

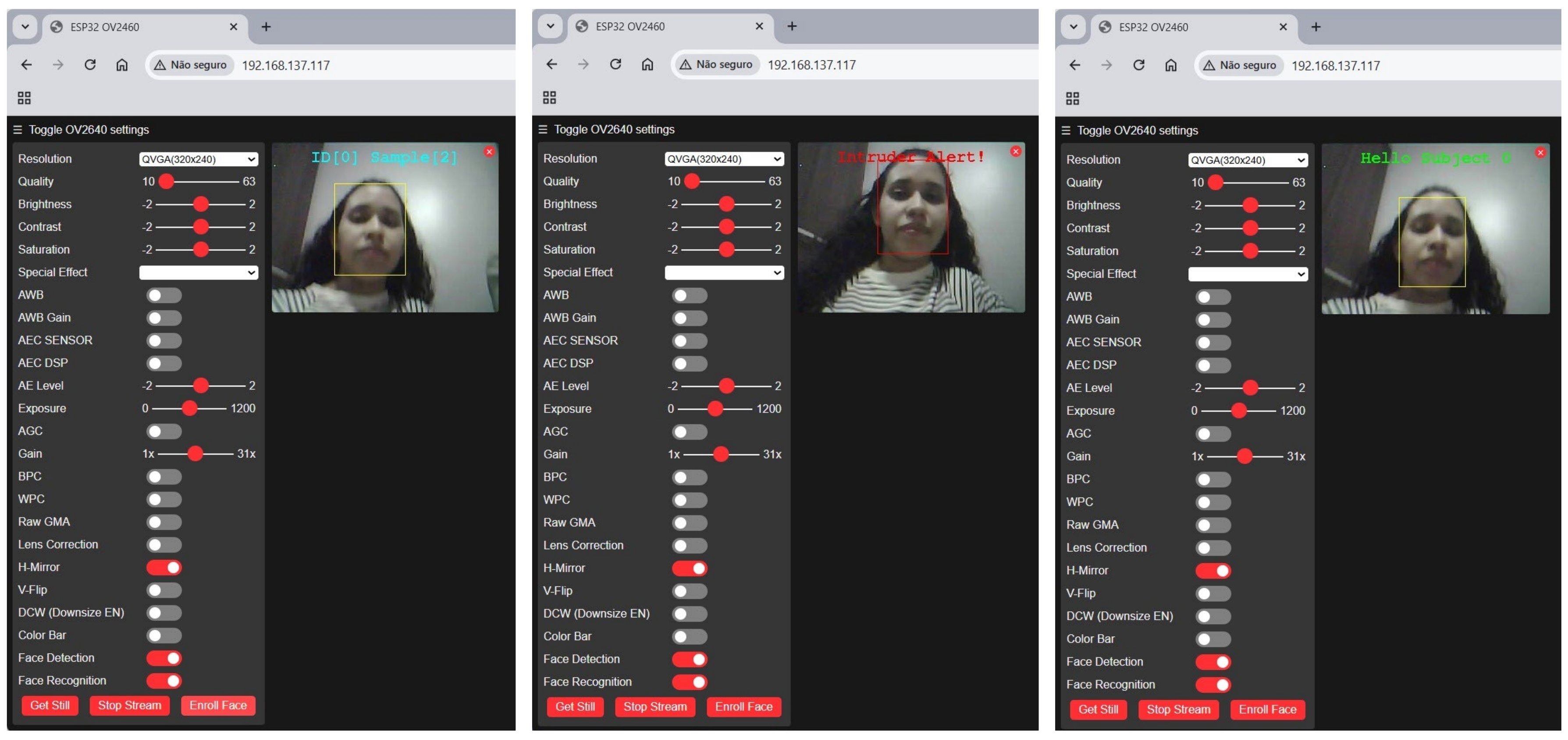


Source: Author

UART communication between the modules proved to be stable, with the ESP32-CAM sending 240×260-pixel images, resized by the ESP32 to 180×160 pixels and displayed on the TFT display via SPI.

Using five samples per user registered in the dashboard as illustrated in Figure 2-a, the facial recognition showed good accuracy as illustrated in Figure 2-b,c. The average time for capture, processing, and authorization varied between 4 and 6 seconds, influenced by lighting and distance.

Figure 2 – (a) Training for facial recognition; (b) Unauthorized face; (c) Face authorized after registration



Source: Author

Furthermore, the "Telegram" platform was used for access logging, where, with each authentication, the ESP32 sends a message to the Telegram bot containing the date and time of access and the result of the attempt, whether it was authorized or denied.

Finally, the main limitation of the ESP32-CAM was identified as the reduced availability of buses, which prevents the simultaneous use of peripherals necessary for the system, especially for future improvements.

Thus, the results confirm the viability of the solution and the good performance of the adopted architecture.

CONCLUSION & FUTURE WORK

The system met its objectives, performing facial recognition and activating the door lock only for registered users. The memory limitations of the ESP32-CAM justified the use of a second microcontroller, responsible for the interface, dashboard, and relay control. As a future improvement, it is recommended to integrate an SD card via SPI to the ESP32-CAM, expanding the storage capacity and autonomy of the system.

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