System for personnel access control based on image processing

Sistema para control de acceso de personal basado en procesamiento de imágenes

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Abstract

Access control in organizations has been an important logistic process that allows verifying the identity of those who transit in a company. It gives security management certainty, but it is also a control point for additional information, for example, the health status of those who access it. This study proposes a software and hardware prototype to implement access control to an institution using various technologies within the framework of industry 4.0. It consists of an image processing system for validating QR codes, through an Arduino hardware module, as well as a web application for managing the information generated during the logistics process.

Resumen

El control de acceso en las organizaciones ha sido un proceso logístico de importancia que permite verificar la identidad de aquellos quienes transitan en una empresa. Da certeza a la gestión de la seguridad, pero también es un punto de control de información adicional, por ejemplo, el estado de salud de quienes acceden. El presente estudio propone un prototipo de software y hardware para implementar un control de acceso a una institución usando diversas tecnologías dentro del marco de la industria 4.0. Consiste en un sistema de procesamiento de imágenes para validación de códigos QR, a través de un módulo de hardware Arduino, además de una aplicación web para la gestión de la información que se genera durante el proceso logístico.

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Introduction

Globalization has made the logistics sector a very important part of business processes given the need to comply with the required organizational models, for example, the entry and exit of personnel or merchandise (Lora & Garcés, 2020). Access control for personnel helps to manage compliance with regulations imposed by an organization such as: the security of the facilities, maintaining adequate capacity in the face of the health emergency caused by the covid-19 pandemic, or restricting access to sensitive areas of a hospital or a student space, to mention a few (Tapia, 2020). Another application of access verification mechanisms is in the area of product logistics. Throughout the supply chain, it is necessary to know a sufficient amount of information about each merchandise to ensure its storage, transportation, distribution, and acquisition (Guedes, 2021).

For its part, industry 4.0 has been a catalyst for access control to play a relevant role within the organization, since it gives certainty to the safety management of personnel and/or products, but it is also a point of generation of information that can be used to build statistical models that support decision-making (Guerra & Ortiz, 2020). Currently there are technologies dedicated to access control based on biometrics such as facial recognition or fingerprint, however, these mechanisms are limited to personnel control. Another technology widely used in this sector is called Quick Response (QR), unlike the previous ones, it can be used in other industrial fields by storing encrypted information, in addition to reducing operating costs by not requiring highly specialized equipment (Henríquez, 2021).

There are many possibilities offered by the QR code, not only as access control but also to provide more information about the personnel or product that is verified. The advantages of using this technology are extensive: it is possible to generate a URL, a smartphone or tablet can be used to read it, it facilitates the construction of SMS messages, making calls or writing emails, among others, (Sánchez, 2021). In addition to cards, the QR code can be present on many other surfaces, such as a smartphone or tablet touch screen.

As an access verification control, it can be read by a device such as those mentioned above, recover the encrypted information and thus determine the entry or exit, generating a precise record of the movement of personnel, dates, times or any sensitive data for the organization (Chung et al. to, 2022).

The technology that offers benefits similar to those of QR are those based on cards with a built-in magnetic stripe, they have an integrated circuit that connects to an antenna and is inserted into a plastic. They use RFID (Radio Frequency Identification) which is a wireless technology for communication between electronic devices. A card reader is necessary, which detects the integrated card at a certain distance, recovering the information it stores (Baque, 2020). Unlike the QR that only needs to be printed or in image format, these cards normally use plastic, vinyl and polycarbonate, so a specialized printer should be considered for the design on the chosen material, as well as the information stored within the circuit. . These factors raise the cost of operating an access control system based on electromagnetic cards (Lluen, 2022).

Therefore, this study proposes a software and hardware prototype to implement access control to an organization or institution, using various information and communication technologies within the framework of industry 4.0. The main idea consists in the construction of an artificial vision system for reading and validation of QR codes, in addition to implementing a web application for the management of the information that is generated during the logistics process. The use of open source technology allows reducing manufacturing costs, making this solution accessible to small organizations, promoting growth and adherence to industry 4.0 paradigms. As a consequence of the global events caused by COVID-19 where organizations monitor access to their facilities with greater caution, this prototype proposes to validate two aspects of interest, the vaccination status in addition to verifying the identity of the personnel, their functions main are:

- Streamline the input-output process avoiding crowds.

- Reduce investment in security personnel.

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-   Reduce investment in expensive equipment for access control operation.

-   Avoid printing certificates, identification copies, CURPs or other documents that were required.

-   Propose a more sustainable solution avoiding the use of plastics and RFID chips.

Methodology

The Tecnológico Nacional de México Campus Ciudad Valles, located in the state of San Luis Potosí with a student population of more than 2,000 and more than 120 workers, was considered as the subject of the case study. The campus requirements for access control consisted of:

-   Expedite admission to the Institute.

-   Do not use physical documentation such as: vaccination certificate and official identification.

-   Have a process as independent as possible from human supervisión.

-   Determine the following with the information generated in the access validation process:

-   Time when more students enter the institution.

-   Average entrance to the Institution of the students.

-   Number of students who enter the Institution per day, week or month.

-   Students with updated COVID-19 vaccination status

Hardware module

For the construction of the physical part of the prototype, various components are required that are described below:

Web camera as a data entry device, which remains active while the equipment is running. This camera will be programmed to enter a power saving mode as long as it does not detect a QR code, when it detects one it will return to its active state to read the QR code (Coronado et al., 2021). See figure 1.

Figure 1 Logitech c920 webcam Fountain
Source: https://resource.logitech.com/w_692

PCB ("Printed Circuit Board", "Placa de Circuito Impreso" in Spanish) is the most compact and stable way to build an electronic circuit. The Arduino board is nothing more than a PCB that implements a certain internal circuitry design. You should not worry about the electrical connections that the microcontroller needs to work (González, 2021). Manages the electronic components used such as the ethernet module, leds, horn, etc. figure 2.

Figure 2 Arduino Uno
Source: https://arduino.cl/wp-content/uploads/2019/01/Arduino-UNO-1.png

Ethernet module, complements the Arduino board, designed to facilitate internet connectivity without the need for an operating system. It incorporates Jack RJ45, reset button and microSD memory reader, where it is possible to store the files to use or share them as if it were a server, figure 3.

Figure 3 Network module (Ethernet) Ard-351. Fountain
Source: https://m.media-amazon.com/images/I/51D4V-aLRdS._AC_SX522_.jpg

LEDs, used to notify the user of access to the institution, as a reference the green color allows access, the red access denied and the yellow as a warning that something has not gone well during the process, figure 4.

Figure 4 10mm LEDs. Fountain
Source: https://uelectronics.com/wp-content/uploads/2018/10/Led-10mm-Grande-V1-550x550.jpg

Speaker, is a horn whose function is to produce a sound indicating that the QR code was read, accepted or denied. The sounds will be programmed on the Arduino board, figure 5.

Figure 5 Horn 8 ohm 0.5w Diameter 3.5 cm. Fountain
Source: https://http2.mlstatic.com/D_NQ_NP_987976-MLM43431820224_092020-W.jpg

Necessary box to protect the electronic equipment from blows, humidity or direct sunlight. It will have inside the Arduino and ethernet module, with holes for the exit of the cables that will carry the necessary connections, figure 6.

Figure 6 Safe. Fountain
Source: https://http2.mlstatic.com/D_NQ_NP_816836-MLM49214783006_022022-V.jpg

Software module

There are two software components developed for this module, the artificial vision system implemented in the Python programming language, embedded in the Arduino integrated whose function is the decoding by image processing of the QR code captured through the webcam. This information is temporarily stored in the integrated circuit to later be sent to a database on a remote server, in this way, access to information in real time and be used for statistical analysis, which support the decision. organizational decisions (Carrillo & Ronny, 2022).

The second software component is a web application implemented under client-server architecture with technologies such as JavaScript and PHP, where there are two submodules, one for users and the other for the person responsible for the system. While users access the QR verification module, the administrator has access to the application settings (Tircio, 2022).

Results

Hardware module

The integration of the hardware elements takes the Arduino integrated circuit as its core. The webcam that allows the reading of the QR image, whether printed or in digital format, is a visible element of the prototype with which the user interacts directly. This device remains active waiting to receive new information, however, when it does not process a QR for a certain time, it enters a suspended state to avoid unnecessary processing.

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Once the personnel identification number is obtained, the Arduino through the ethernet board that has been configured to establish a connection to the institution's network and thus be able to execute http requests, sends the identification information to the remote server which maintains Communication with the system database.

Finally, the application designed to verify the status determines the condition of the personnel, sending a signal back to the Arduino to allow access (green light), or deny it (red light), in case of any anomaly during the process it lights up. yellow light, figure 7.
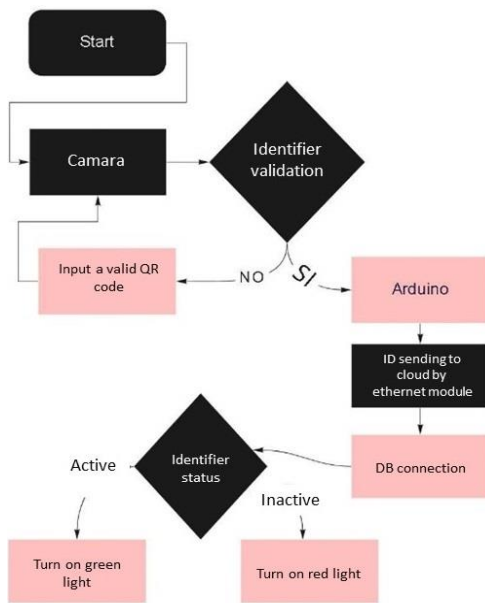
Figure 7 Hardware module operation flow
Source: Own elaboration

Software module

The application developed in Python for image processing and which resides in the microcontroller, has as its first task the identification of a valid QR code through the webcam. This function requires the CV2 library used to perform operations on images, such as reading, segmentation, among others. The decoding of the information contained in the QR image is carried out by the Pyzbar library, whose interpretation function allows extracting the personnel identifier.

The developed web application provides two submodules: Administrator and Users. The tasks that each role will do both as the user and the administrator are shown in figure 8.
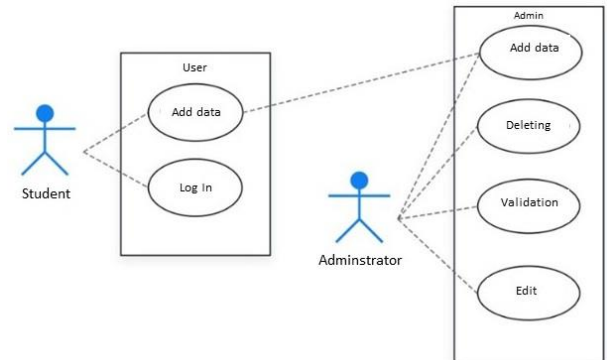

Figure 8 User/Student and Administrator module of the web application
Source: Own elaboration

The user module oriented to the personnel that accesses the institution and where it is possible to enter general information through a form on any device with an Internet connection, and thus, carry out the registration and generation of the QR code. All records will be stored in a database connected to the server.

The data flow in the software section is represented through figure 9, where it can be seen that the entry of correct data must be necessary for the generation of the QR, otherwise the user is notified to review and correct their information.
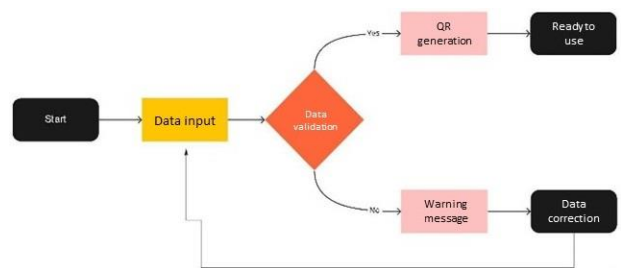

Figure 9 QR code generation operation flow
Source: Own elaboration

This module requires information such as: Name, Control Number, Specialty, Current Semester and Files in PDF format (Certificate of vaccination and official identification), figure 10.
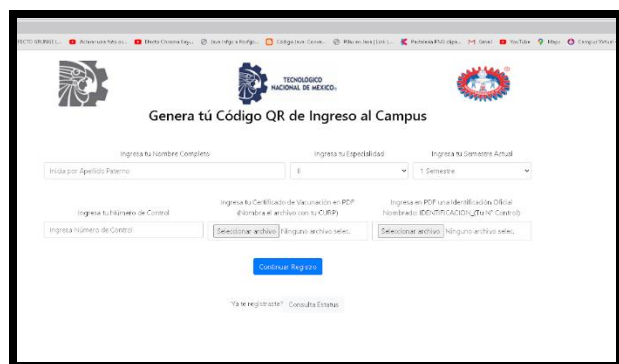
Figure 10 Interface for QR code generation
Source: Own elaboration

The QR code activation process does not end with the capture of the information, it is the responsibility of the System Administrator to validate the data and activate those requests that actually proceed, in this way the staff will be able to use the QR code to access the institution. To know the status of the request, a consultation module was designed where the user can continuously monitor if his request has been accepted, figure 11.

Figure 11 Interface for QR code generation
Source: Own elaboration

The result of the query generates two types of messages, when the request has not been accepted by the administrator, inactive status, figure 12.
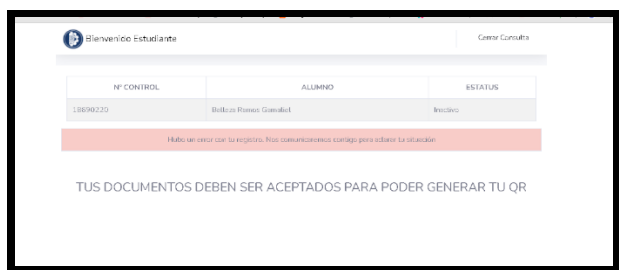

Figure 12 Request inactive message
Source: Own elaboration

When the administrator has validated the user's information and has accepted the request, the option to generate their code will be enabled, figure 13.
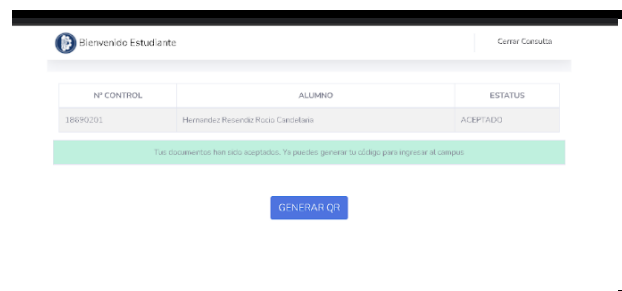

Figure 13 Request accepted message
Source: Own elaboration

To finish the QR code generation process, a security system is established that consists of checking the user's identification number, once this is done, the QR is created available to download and store in the desired format, figure 14.

Figure 14 QR code generation
Source: Own elaboration

The module for the Administrator provides an interface to review the requests made by users, consult and edit said records.

The status of the requests is easily identified by the assigned color, yellow for PENDING users, green for ACCEPTED users, red for INACTIVE users, figure 15.
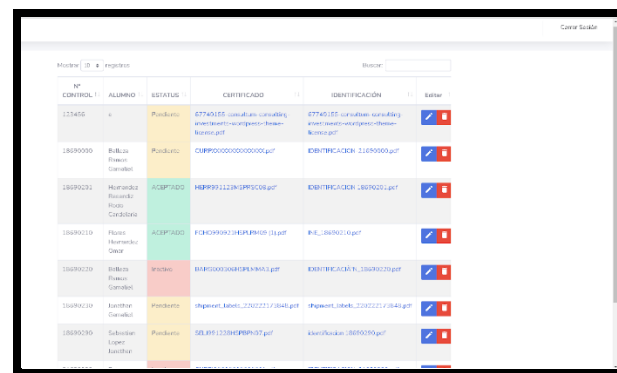

Figure 15 Web application administrator module
Source: Own elaboration

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The data dictionary is integrated by the student table, which stores the data that each user entered in the registration module. For its part, the Admin table stores the data of the Administrator account to be able to log in and allow entry to the administrator module. The Income table keeps track of the QR and the time it was used, this table stores a large amount of data since it will be constantly growing, it is described in figure 16.
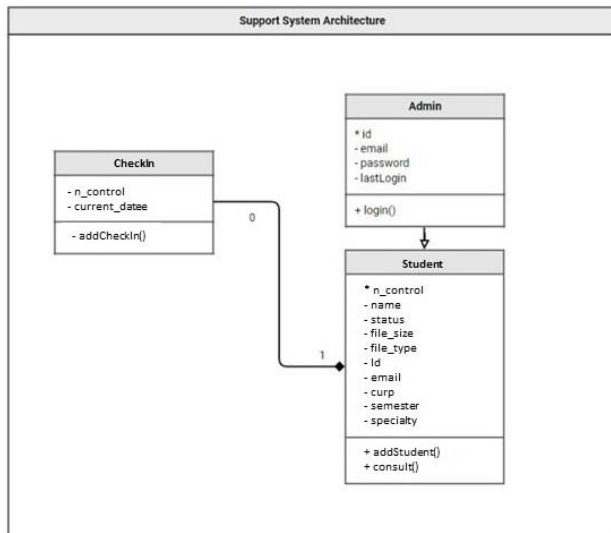

Figure 16 Access system data dictionary
Source: Own elaboration

The resulting prototype is shown in figure 17, it was tested in the access of the TecNM / Technological Institute of Ciudad Valles with a group of 185 students in a period of 5 business days, the operation of the device met the company's requirements.

Figure 17 Access control system
Source: Own elaboration

Conclusions

The proposed access control system solves the problem of entering a complex in an efficient and safe way, considering the global health contingency COVID-19 through the validation of the vaccination status of the personnel. Also, it significantly reduces the operational costs that would be generated with manual access protocols, or if compared to other similar access systems on the market. The benefits were:

- Promotes sustainability by avoiding the use of plastic material or magnetic tapes that are normally used in control systems based on radio frequency, additionally.

- Avoid printing physical documents by having everything stored in a digital BD.

- Reduces access control personnel in charge of verifying documentation.

- Avoid crowds at access points, through a continuous flow of entry-exit.

- Reduces the investment in the implementation, since it does not require high cost sophisticated hardware.

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