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VISIÓN ELECTRÓNICA

A RESEARCH VISION

Performance evaluation of the Over-the-Air Update protocol for remote device programming

Evaluación del rendimiento del protocolo Over-the-Air Update para la programación remota de dispositivos

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INFORMACIÓN DEL ARTÍCULO

Historia del artículo:
Enviado: 10/03/2024
Recibido: 29/03/2024
Aceptado: 16/05/2024

Keywords:
STEAM
Embedded Systems
Technology Platform
Over-the-air

Palabras clave:
STEAM
Sistemas Embebidos
Plataforma Tecnológica,
Por el Aire

ABSTRACT

This document is the result of the development of the extension project: Unillanos Technological Club 2021. Its main objective was to design and implement a technological platform for communication with embedded systems (ESP32), allowing the programming and updating of the sketch through the "over-the-air" (OTA) function. To achieve this, knowledge in web development was used and languages such as HTML, CSS, JavaScript and Python were used. In addition, the Django framework was integrated, which facilitates the support of different scale models for the development of STEAM (Science, Technology, Engineering, Art and Mathematics) educational activities, all accessible from areas with an internet connection.

By implementing this platform, students enrolled in the electronic engineering program were able to participate in various types of practical activities in different fields of knowledge, all done remotely. The inspiration for this idea arose from the impact of the COVID-19 pandemic, which highlighted the need for virtual education tools that efficiently address practical components without requiring students to assume additional expenses to acquire devices.

This platform contributes significantly to improving the quality of virtual education by fostering an enriched approach that complements the theoretical knowledge acquired through practical exercises within the educational platform. In addition, it increases the installed capacity of the laboratory services offered by the Faculty of Basic Sciences and Engineering, thus promoting innovation and the application of new technologies within the region.

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Citar este artículo como: J. A. Bonilla-Bonilla, D. A. Martínez-Quevedo, L. A. Rodríguez-Umaña, "Performance evaluation of the Over-the-Air Update protocol for remote device programming" , Visión electrónica, vol. 18, no. 1, pp. 32-42, january-june 2024, https://doi.org/10.14483/22484728.22761

RESUMEN

Este documento es el resultado del desarrollo del proyecto de extensión: Club Tecnológico Unillanos 2021. Su objetivo principal fue diseñar e implementar una plataforma tecnológica para la comunicación con sistemas embebidos (ESP32), *plataforma tecnológica para la comunicación con sistemas embebidos (ESP32),* permitiendo la programación y actualización del sketch a través de la función "over-the-air" (OTA). Para lograrlo se utilizaron conocimientos en desarrollo web y se emplearon lenguajes como HTML, CSS, JavaScript y Python. Además, se integró el framework Django, que facilita el soporte de diferentes modelos a escala para el desarrollo de actividades educativas STEAM (Ciencia, Tecnología, Ingeniería, Arte y Matemáticas), todo accesible desde áreas con conexión a internet.

Al implementar esta plataforma, los estudiantes inscritos en el programa de ingeniería electrónica puedieron participar en varios tipos de actividades prácticas en diferentes campos del conocimiento, todo realizado de manera remota. La inspiración para esta idea surgió del impacto de la pandemia COVID-19, que resaltó la necesidad de herramientas de educación virtual que aborden eficientemente los componentes prácticos sin requerir que los estudiantes asuman gastos adicionales para adquirir dispositivos.

Esta plataforma contribuye significativamente a mejorar la calidad de la educación virtual al fomentar un enfoque enriquecido que complementa el conocimiento teórico adquirido a través de ejercicios prácticos dentro de la plataforma educativa. Además, aumenta la capacidad instalada de los servicios de laboratorio ofrecidos por la Facultad de Ciencias Básicas e Ingeniería, promoviendo así la innovación y aplicación de nuevas tecnologías dentro de la región.

1. Introduction

During the conditions generated by the Covid-19 pandemic, it was essential to adapt to new teaching methods mediated by technology, an example of this is STEAM education (by its acronym in English), which integrates knowledge in the fields of: Science, Technology, Engineering, Arts and Mathematics, due to these circumstances, it is necessary to find alternative ways to continue carrying knowledge efficiently both in the theoretical and practical part. [1]

Currently, the planet is facing the consequences left by the pandemic, and Colombia is a country where the economic and social impact was affected by confinement measures and biosecurity regulations. Since the beginning of the confinement in the country, different activities that involve contact with people were suspended, among which educational activities stand out, bringing consequences. Virtual classes do not allow for practical work, having the disadvantage that knowledge cannot be assimilated in the same way as a face-to-face class. [2]

Embedded systems with an Internet connection are an economical alternative for carrying out laboratory practices. Using a virtual platform that allows these systems to be reprogrammed, the ESP32 from Expressif Systems is a low-cost, low-power embedded system on a series of microcontrollers with Wi -Fi and Bluetooth capabilities and a highly integrated structure powered by a Tensilica microprocessor. Xtensa LX6 Dual Core. [3]

In recent years there has been talk about programming methods that allow us to remotely program low-cost embedded systems. One of the most talked about alternatives is Over-the-Air Programming (OAT), which is a new alternative to reprogram systems so that they can update their sketch and resolve software errors. This technology was born due to the limitations of IOT devices. [4]

To carry out this project, it is essential to have basic knowledge of web design and the languages that compose it, such as HTML, CSS, JS and Python. To facilitate the process, tools called framework are used. Python is a platform-independent, object-oriented scripting language, prepared to create any type of program, from Windows applications to network servers or even web pages. It is an interpreted language, which means that the source code does not need to be compiled in order to run it, which offers advantages such as speed of development and disadvantages such as slower speed. [5]

Django is a high-level web framework that enables rapid development of secure, maintainable websites. Developed by experienced programmers, Django takes care of much of the hassle of web development, so you can focus on writing your application without reinventing the wheel. It is free and open source, has a thriving and active community, great documentation, and many free and paid support options. [6]

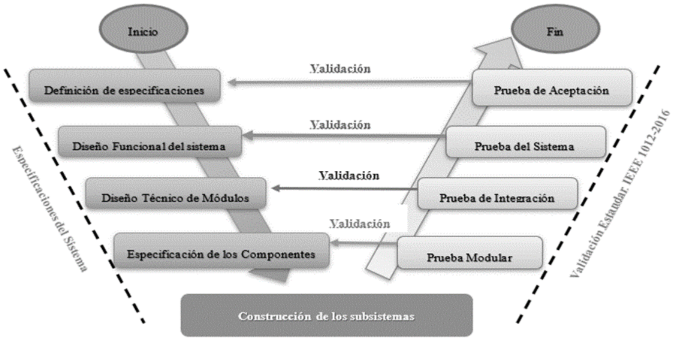
It is necessary to know about internet protocols such as http defines a set of request methods to indicate the action you want to perform for a given resource. Although these can also be nouns, these request methods are sometimes called HTTP verbs. Each of them implements a different semantics, but some similar characteristics are shared by a group of them: GET, POST, PUT and DELETE among others which make requests to the server which sends them a response according to what is indicated can send from text to files. [7].

Regarding the developments generated for remote teaching, we can highlight the distance teaching platform created by [8], the robots for teaching mechatronics implemented by [9], the remote educational IoT laboratory of [10]. The techniques used have contributed to both the dynamics and the evolution of autonomous learning, as demonstrated by the contributions made by [11-14], the centralization of data through cloud computing techniques, have in turn allowed to efficiently manage data [15], reducing the gap between the limitations that arise when there are huge distances between the teacher and the student [16], supported by Steam tools such as those used by [17], the software engineering used in [18], taking us to the digital age through sizing and routing of wireless sensor networks for applications in smart cities [19], supported by electrical connections between different devices, without an undefined connection diagram and remotely throughout the world [20], with the possibility of assuming its own architecture such as the one proposed in [21], expanding the control capabilities over various variables [22].

2. Materials and methods

The methodology implemented in this project is the V-type model, using as a verification model for the development of embedded systems in which there are some items to carry out systems and applications to work with electronic devices, obtaining as a result a web platform to program embedded systems. This is summarized in Figure 1.

Figure 1. Diagram of the methodology used. Taken and adapted from [21]


Inicio
Fin
Definición de especificaciones
Validación
Prueba de Aceptación
Diseño Funcional del sistema
Validación
Prueba del Sistema
Diseño Técnico de Módulos
Validación
Prueba de Integración
Especificación de los Componentes
Validación
Prueba Modular
Construcción de los subsistemas
Especificaciones del Sistema
Validación Estandar IEEE 1012-2016

2.1. VPS architecture implementation

It is essential to install a series of programs to carry out the implementation of the VPS architecture, these software and hardware are listed in Table 1.

Table 1. Implemented software and hardware.

Software		Hardware
Name	Version	Esp 32
Visual studio code	1.69	50 megabyte internet network
Django	4.0	Computer (4Ram, 500Gb, intel core i5)
Python	3.9	
DigitalOcean	N/A	
PuTTY	0.76	

Source: own.

To configure the VPS server, it is necessary to have previously created it in Digital Ocean, once the previous step is completed, communication with the server is started through ssh. When the communication is successful, the server is configured, in order to automate the application deployment process, in addition to providing security and thus avoiding possible attacks by malicious people. For this reason, a series of steps were carried out, which are described below:

- Change ssh port.
- Activate the firewall.
- Install and configure the supervisor.
- Assign DNS to the server IP.
- Install and configure the wsgi server Gunicorn.
- Install and configure the Nginx web server.

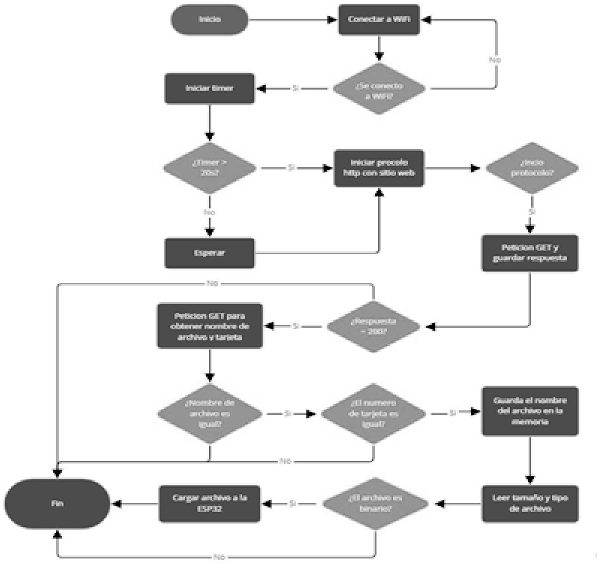
2.2. Web platform implementation

This was done with the help of the Django framework and using basic web development languages such as HTML, CSS, JS and Python. For this, various components were created such as navigation bars, forms, views, URLs, tables for the database, HTML templates, CSS style sheets, JS logic and the HTTP protocol was used to send documents with the GET command.

2.3. Implementation of Unillanos OTA library

For its implementation, the Arduino IDE was used and a flow chart was made with the procedure carried out as shown in Figure 2.

Figure 2. OTA library flowchart.


Inicio
Conectar a WiFi
No
¿Se conecto a WiFi?
Si
Iniciar timer
¿Timer > 20s?
Si
Iniciar procolo http con sitio web
¿Inicio protocolo?
No
Si
Esperar
Peticion GET y guardar respuesta
No
Peticion GET para obtener nombre de archivo y tarjeta
Si
¿Respuesta = 200?
¿Nombre de archivo es igual?
Si
¿El numero de tarjeta es igual?
Si
Guarda el nombre del archivo en la memoria
No
Fin
Cargar archivo a la ESP32
Si
¿El archivo es binario?
Leer tamaño y tipo de archivo
No

Source: own.

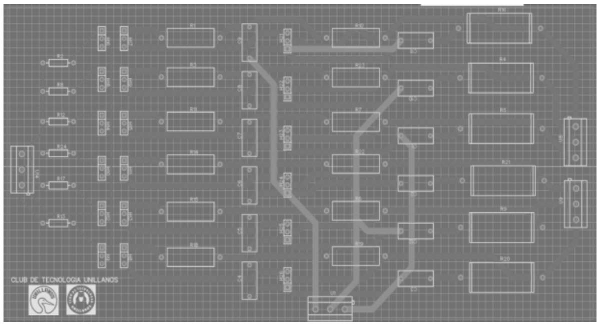
2.4. Scale models

For this project, scale models were built to help carry out the tests.

2.4.1 Starting and reversing the engine.

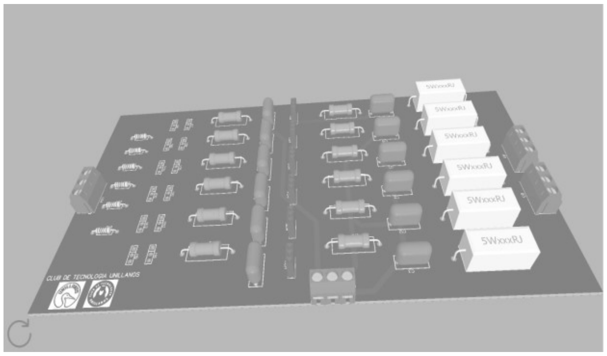
The following steps were carried out, first the PCB design and schematic circuit were made as seen below:

Figure 3. PCB start and reverse rotation.



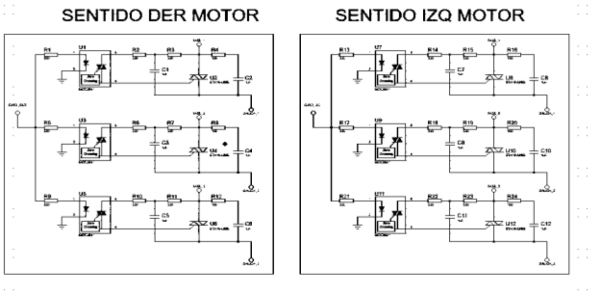
Source: own.

Figure 4. 3D model.



Source: own.

Figure 5. Schematic model.



Source: own.

It was separated into 3 stages which are the power stage, the control stage and its inputs and outputs.

2.4.2. Power stage

The power part is isolated using an optocoupler (MOC3041). The signal sent by this reaches the gate of the triacs (bta16-600). When this is activated, it allows the passage of the three-phase lines. As can be seen in the schematic (figure 5). After the capacitors, an RC filter is made which prevents stray currents from activating the optocouplers and generating a short circuit, since two high voltage lines can be joined.

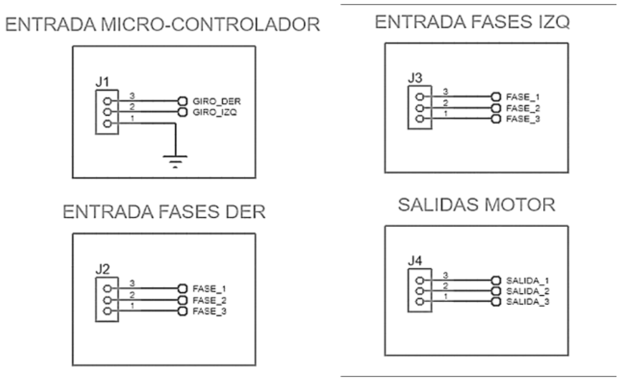
2.4.3. Control stage

For the control part, the ESP32 was used, where several functionalities can be done through code in this practice, such as starting the motor, reversing the motor and a three-phase motor timer. This can be carried out by varying the code to suit the teacher or the planned activity. It should be noted that in this part, each of the ESP32 outputs will be connected to 3 optocouplers; this signal activates them.

2.4.4. Inputs and outputs

Coast of the inputs for the control part, as seen in Figure 6, this has 3 pins digital input 1, digital input 2 and ground or common, it also has the input for three-phase power supply and finally it has two outputs for the motor because each of them is to give it direction of rotation.

Figure 6. Schematic model.



Source: own.

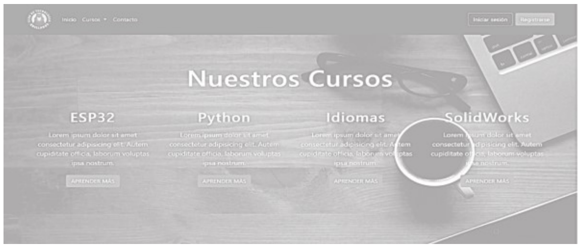
3. Results

The results obtained in the project allow for a technological contribution to the development and advancement of education with the STEAM methodology. This is thanks to the fact that, through the implemented system, students can carry out practices in various subjects such as robotics, instrumentation, programming, power electronics, control, among others, all this without having to go to the site where the plants or equipment are located**.**

3.1. Web platform

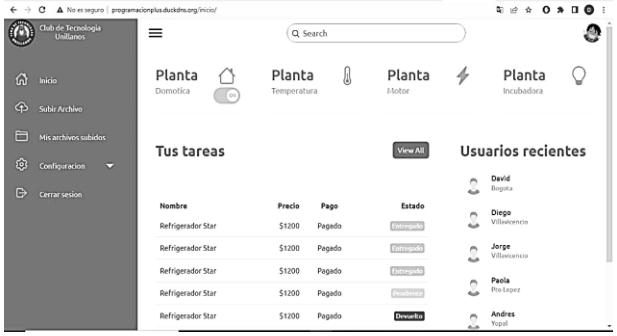
The various web pages that make up the web platform are now displayed.

Figure 7. Home page.



Source: own.

Figure 8. Dashboard.



Tus tareas

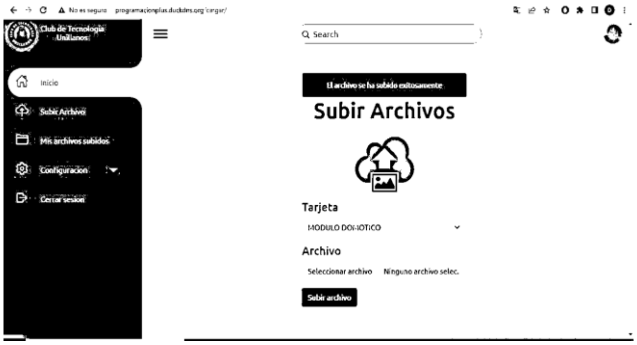
Nombre	Precio	Pago	Estado
Refrigerador Star	$1200	Pagado	Entregado
Refrigerador Star	$1200	Pagado	Entregado
Refrigerador Star	$1200	Pagado	Entregado
Refrigerador Star	$1200	Pagado	Pendiente
Refrigerador Star	$1200	Pagado	Devuelto

Usuarios recientes

David	Bogota
Diego	Villavicencio
Jorge	Villavicencio
Paola	Pto Lopez
Andres	Yopal

Source: own.

Figure 9. Uploading files.



El archivo se ha subido exitosamente

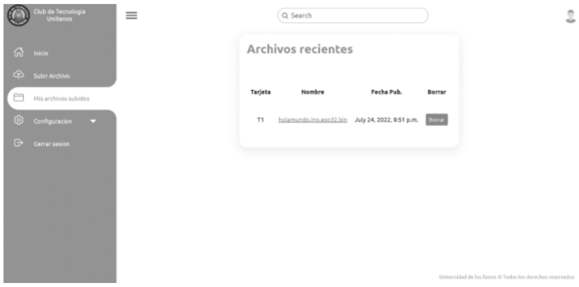
Subir Archivos

Tarjeta: MODULO DOMOTICO

Archivo: Seleccionar archivo Ninguno archivo selec.

Source: own.

Figure 10. My uploaded files.


Club de Tecnologia Unillanos
Inicio
Subir Archivo
Mis archivos subidos
Configuracion
Cerrar sesion
Search
Universidad de los llanos © Todos los derechos reservados

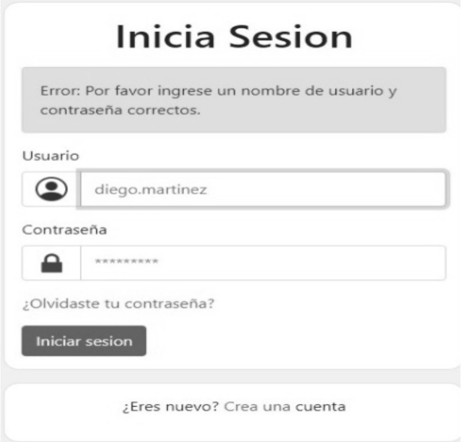
Archivos recientes

Tarjeta	Nombre	Fecha Pub.	Borrar
T1	holamundo.ino.esp32.bin	July 24, 2022, 9:51 p.m.	Borrar

Source: own.

On the other hand, the forms were tested as shown below.

Figure 11. Incorrect password or username.



Inicia Sesion

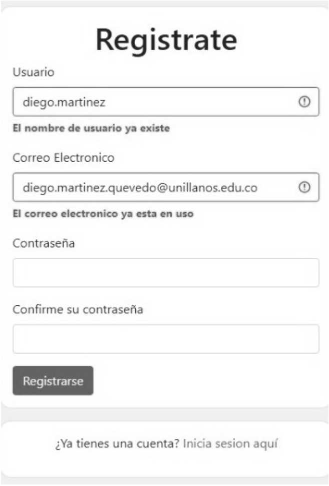
Error: Por favor ingrese un nombre de usuario y contraseña correctos.

Usuario: diego.martinez

Contraseña: *********

Source: own.

Figure 12. User and email validation.



Registrate

Usuario

diego.martinez

El nombre de usuario ya existe

Correo Electronico

diego.martinez.quevedo@unillanos.edu.co

El correo electronico ya esta en uso

Contraseña

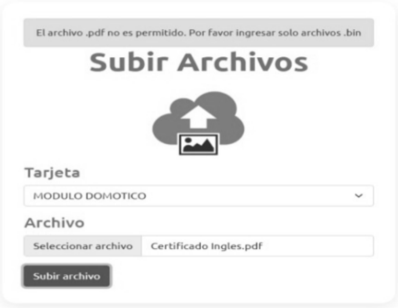
Confirme su contraseña

Registrarse

¿Ya tienes una cuenta? Inicia sesion aquí

Source: own.

Figure 13. Validating bin files.



El archivo .pdf no es permitido. Por favor ingresar solo archivos .bin

Subir Archivos

Tarjeta

MODULO DOMOTICO

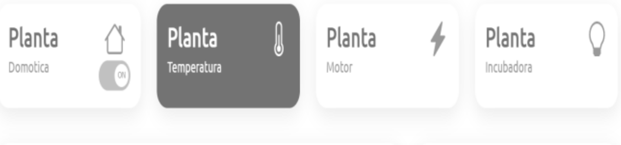
Archivo

Seleccionar archivo Certificado Ingles.pdf

Subir archivo

Source: own.

Figure 14. Validation of models at scales in use.

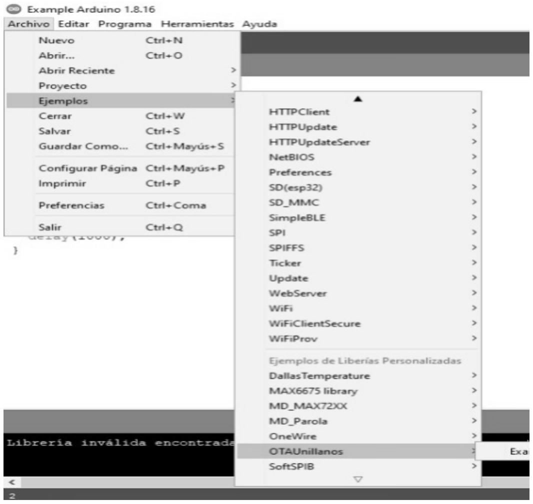


Source: own.

3.2. Unillanos OTA Library

In this section the library and its examples will be shown in the Arduino IDE.

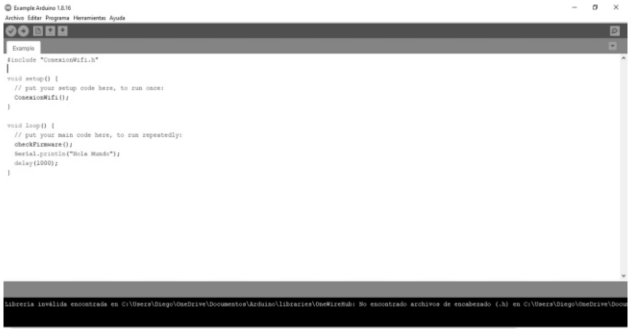
Figure 15. Installed library.



```
Libreria inválida encontrada
```

Source: own.

Figure 16. Example of plant operation at scale.



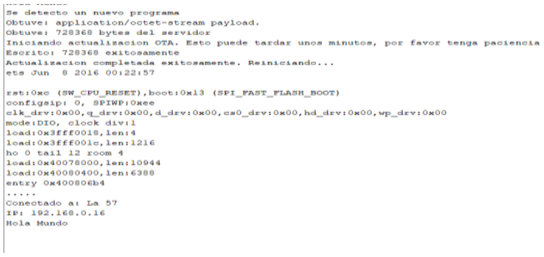
```
#include "ConexionWifi.h"

void setup() {
  // put your setup code here, to run once:
  ConexionWifi();
}

void loop() {
  // put your main code here, to run repeatedly:
  checkFirmware();
  Serial.println("Hola Mundo");
  delay(1000);
}
```

```
Libreria inválida encontrada en C:\Users\Diego\OneDrive\Documentos\Arduino\libraries\OneWireHub: No encontrado archivos de encabezado (.h) en C:\Users\Diego\OneDrive\Docu
```

Source: own.

When the ESP32 detects a new program through the requests it makes every 20 seconds to the website, the program is loaded and restarted as can be seen below in the script in Figure 17.

Figure 17. Detection of a new program on the platform.



```
Se detecto un nuevo programa
Obtuve: application/octet-stream payload.
Obtuve: 728368 bytes del servidor
Iniciando actualizacion OTA. Esto puede tardar unos minutos, por favor tenga paciencia
Escrito: 728368 exitosamente
Actualizacion completada exitosamente. Reiniciando...
ets Jun  8 2016 00:22:57

rst:0xc (SW_CPU_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configsip: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:1
load:0x3fff0018,len:4
load:0x3fff001c,len:1216
ho 0 tail 12 room 4
load:0x40078000,len:10944
load:0x40080400,len:6388
entry 0x400806b4
.....
Conectado a: La 57
IP: 192.168.0.16
Hola Mundo
```

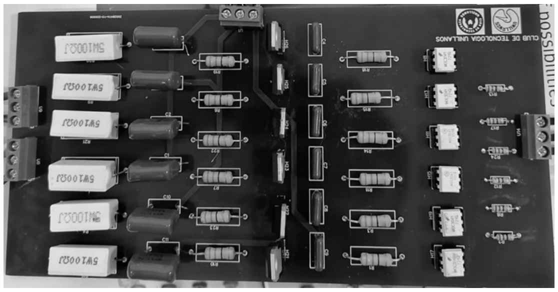
Source: own.

Interactions are made for the designed instrumentation elements by blueprints programming, the interactive programming code that allows the measurement of the voltage in the circuit and generates the DC voltage, up to 30 volts to power the series circuits.

3.3. Scale models

Below is how the board looked after being soldered with the components specified in the schematic design.

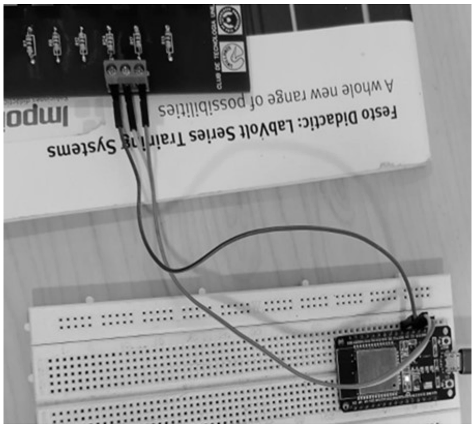
Figure 18. PCB board with components and soldered.



Source: own.

Now it will be shown in Figure 19, how the ESP32 is connected to the motherboard input.

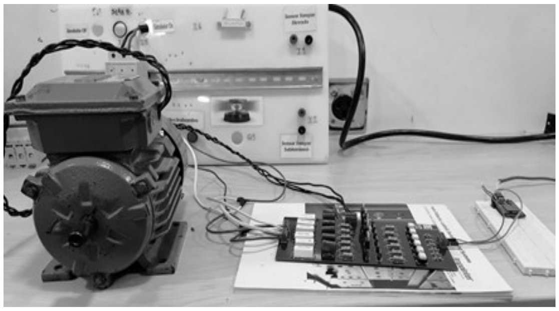
Figure 19. Control stage.



Source: own.

Finally, it shows how the entire plant is assembled and how it works; this can be seen in Figure 20.

Figure 20. Control stage.



Source: own.

4. Conclusions

Currently, there is no technological platform in the country that allows programming low-cost embedded systems from anywhere in the world, to carry out laboratory practices of subjects focused on STEAM education for this purpose. The architecture of a technological platform was designed and implemented that allows communication with the ESP32, and thus programming its sketch using OTA, to support the development and monitoring of educational activities with a STEAM focus.

It was clearly identified that the http protocol is necessary for the remote control and monitoring of embedded systems for STEAM teaching, since through it the files of the practices that can be carried out on the technological platform where the monitoring of the activities proposed by the teacher will be carried out are uploaded.

On the other hand, we will talk about the hardware and software used in this project, most of them were free software, regarding the hardware, low-cost embedded systems were used such as the ESP32 which has a WiFi and Bluetooth connection. The architecture was designed using internet protocols and base languages such as HTML, CSS, JS in addition to the use of a framework called Django, all this in order to be able to save these files in a database and be loaded into the respective ESP32.

To conclude, support material was created for the proper use of the technological platform, such as its user manual and its technical manual, as well as examples that can be used by both students and teachers to understand the structure of the code and make good use of digital twins.

To conclude the proposal, efficiency tests and recommendations for the proper use of the platform were carried out using visual methods to detect which digital twin is in use and thus avoid problems of several users using the same plant at the same time.

Acknowledgments

The authors would like to thank the Macrypt research group of the School of Engineering of the Faculty of Basic Sciences and Engineering of the Universidad de los Llanos for funding the costs associated with the development of the project and its teachers for their guidance throughout our training stage and while we were still students in the Electronic Engineering program.

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