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Original Research Article

Research on the Design of an Electric Fan Control System Using AI and IoT Technologies

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Abstract: Artificial Intelligence (AI) and the Internet of Things (IoT) are key drivers of today's digital transformation; therefore, engineering training programmes need practical learning tools that reflect these technologies. This paper presents the design and implementation of an electric fan control system that integrates AI-based speech recognition with IoT technology. The system uses an ESP32-S3 Yolo Uno board as the central controller, combined with a DHT20 temperature–humidity sensor, a light sensor, an I2C LCD and a relay module that switches the fan on and off. Sensor data are transmitted via the MQTT protocol to a cloud-based dashboard, allowing users to monitor the environment and turn the fan on and off remotely from a smartphone or computer. Functional tests on the prototype showed that 10 of 10 voice commands and 9 of 10 dashboard commands were executed correctly. Beyond its potential application in smart homes, the model also serves as a practical training kit for students of Electrical and Electronic Engineering, integrating sensors, embedded programming, electrical switching, IoT communication and applied artificial intelligence into learning activities. In this way, the model helps students develop the digital competencies that are widely applied in today's practice.

Keywords: Artificial Intelligence, Internet of Things, Speech Recognition, ESP32-S3, Digital Transformation.

1. INTRODUCTION

The electric fan is the most common household appliance in homes, dormitories and classrooms in Vietnam, especially given the hot and humid climate. However, most fans in use are still operated manually with push buttons, or with infrared remote controls at close range. Users have to walk up to the fan to switch it on or off; fans are often left running when no one is present, wasting electricity; and elderly people, people with mobility impairments, or those with their hands full find them difficult to operate. Smart fans with DC inverter motors, smartphone app connectivity and voice assistants have appeared on the market, but they are expensive and their closed systems make it impossible to explore their internal structure for learning purposes.

The Internet of Things (IoT) allows sensors, microcontrollers and software to connect over the Internet to collect, process and share data and to control devices remotely [1-7]. Artificial intelligence (AI), and speech recognition based on deep neural networks in particular, has reached a level of accuracy high enough to serve as a natural human–machine interface. The combination of AI and IoT is being studied in many fields, such as healthcare [9], agriculture [10], and logistics [8]. Low-cost microcontrollers with built-in Wi-Fi, such as the ESP32 [5], make it feasible to build such systems within the scope of a student project.

From a training perspective, programmes in Electrical and Electronic Engineering Technology require students not only to master individual courses (sensors, microcontrollers, electrical apparatus, communication networks) but also to be able to integrate them into a complete product. Low-cost, "open" practical models built around familiar everyday devices are suitable learning materials for developing this competence. Against this background, this paper reports the results of a study on the design of an electric fan control system using AI and IoT technologies. The aim is to build a controller that can switch an electric fan on and off by Vietnamese voice commands and over the Internet, while also monitoring ambient

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temperature, humidity and light, and, on that basis, to propose ways of using the model as a practical learning resource for students of Electrical and Electronic Engineering Technology.

2. Research Content

2.1. Design Requirements and Overall System Structure

The system was designed to meet five requirements: (i) safely switching the power supply to the fan through a relay, with the control circuit isolated from the power circuit; (ii) measuring and locally displaying the ambient temperature, humidity and light level; (iii) monitoring the parameters and controlling the fan remotely over the Internet; (iv) controlling the fan with Vietnamese voice commands; and (v) low cost and a modular, easy-to-assemble structure suitable for use in training.

Based on these requirements, the system is organised into the following functional blocks: power supply, sensors, central controller, display, actuator, IoT and AI (Figure 1). The ESP32-S3 microcontroller plays the central role: it reads sensor data, shows it on the LCD, sends data to the MQTT server, and receives commands to open or close the relay. Users have two ways to issue commands: pressing a button on the IoT dashboard, or speaking a voice command into a microphone. Both channels are reduced to the same MQTT message, so the microcontroller program does not depend on how the user issues the command.

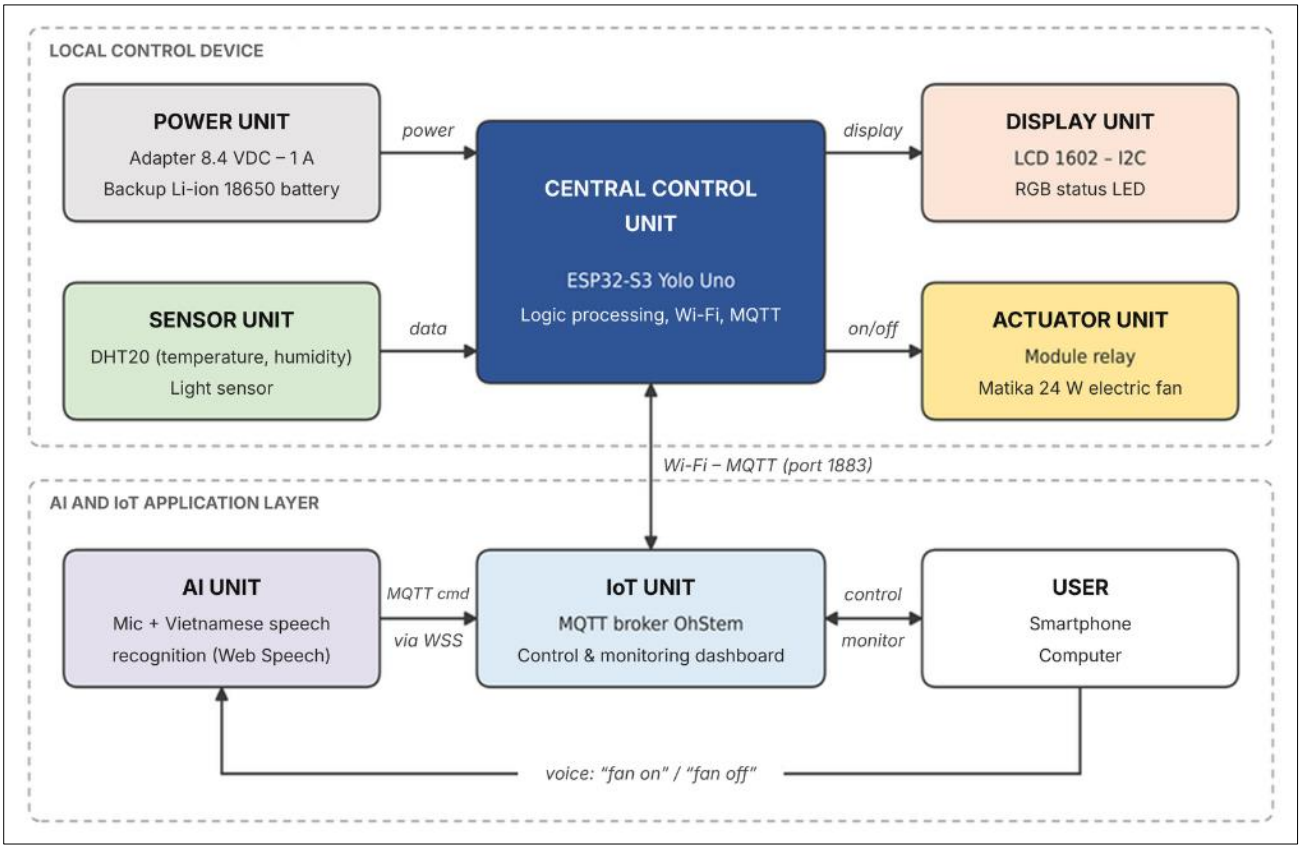


Figure 1: Overall structure of the electric fan control system using AI and IoT

2.2. Central Control Device

The system uses OhStem's Yolo Uno board with an ESP32-S3 chip as the central controller (Figure 2). The ESP32-S3 has a 32-bit dual-core Xtensa processor running at up to 240 MHz, integrated 2.4 GHz Wi-Fi (802.11 b/g/n), Bluetooth 5 (BLE + Mesh), native USB, and vector instructions that accelerate computation for AI applications [5]. The board has 4 MB of flash and 8 MB of PSRAM; its dimensions and pinout are compatible with Arduino Uno; it provides 12 Grove ports (4 analog, 4 digital, 4 I2C) and an on-board NeoPixel RGB LED; it can be powered through USB Type-C or a 5521 DC jack (12 V maximum); and it can be programmed with Arduino, MicroPython, ESP-IDF or block-based programming in the OhStem App. The Grove ports greatly reduce wiring errors, which is very convenient when first- and second-year students assemble the model.

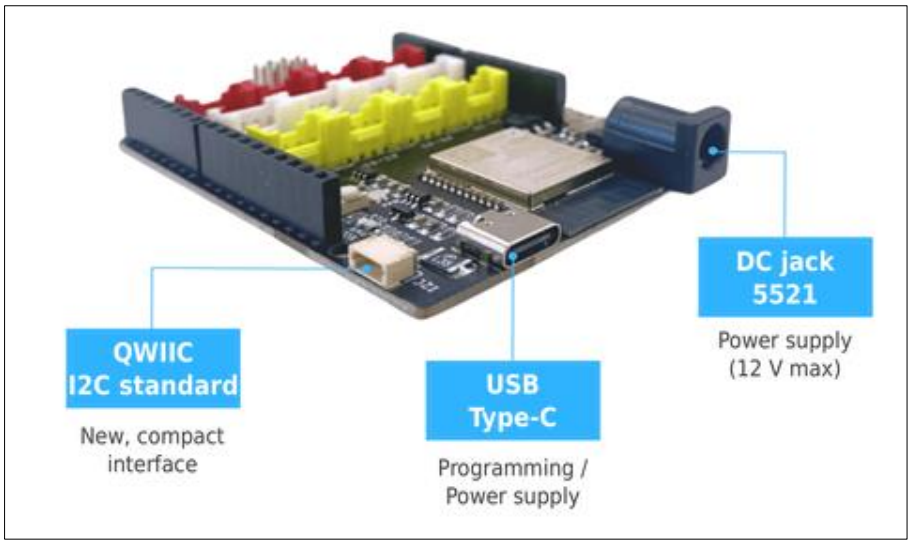


Figure 2: The ESP32-S3 Yolo Uno board and its main connection ports

2.3. Sensors, Display Device and Actuator

The DHT20 temperature–humidity sensor communicates over I2C and operates at 3.3 V. Its temperature range is −40 to +80 °C (accuracy ±0.5 °C), and its humidity range is 0 to 100 %RH (accuracy ±3 %RH at 25 °C). The light sensor is a photoresistor that outputs an analog signal; it is read through the ESP32-S3's ADC and converted to a percentage scale (0–100 %) to distinguish bright from dark environments [3]. The 1602 LCD (2 rows × 16 characters) communicates over I2C at address 0x27 and shares the I2C bus with the DHT20, so it occupies only two signal lines, SDA and SCL.

The relay module is the actuator, switching the power supply to the fan on and off. Its coil is driven by a digital pin of the microcontroller, and the COM–NO contacts are wired in series with the fan's power supply line, so the fan receives power only when the relay is energised. This wiring completely isolates the low-voltage control circuit from the 220 V power circuit and keeps the fan off when the controller loses power. The fan used in the model is a Matika MTK-6311 rechargeable fan: 24 W, 220 V, 8-inch blades, three speed settings, with automatic cut-off on overheating. The power block consists of an 8.4 VDC, 1 A adapter and an 18650 Li-ion battery as a backup supply for the control circuit.

2.4. Wiring Diagram of the System

The devices are connected to the ESP32-S3 Yolo Uno board according to the diagram in Figure 3 and Table 1. The power circuit (220 V plug, relay contacts, fan) is laid out separately from the control circuit, and the high-voltage wires are insulated and firmly secured to ensure safety when students handle the model.

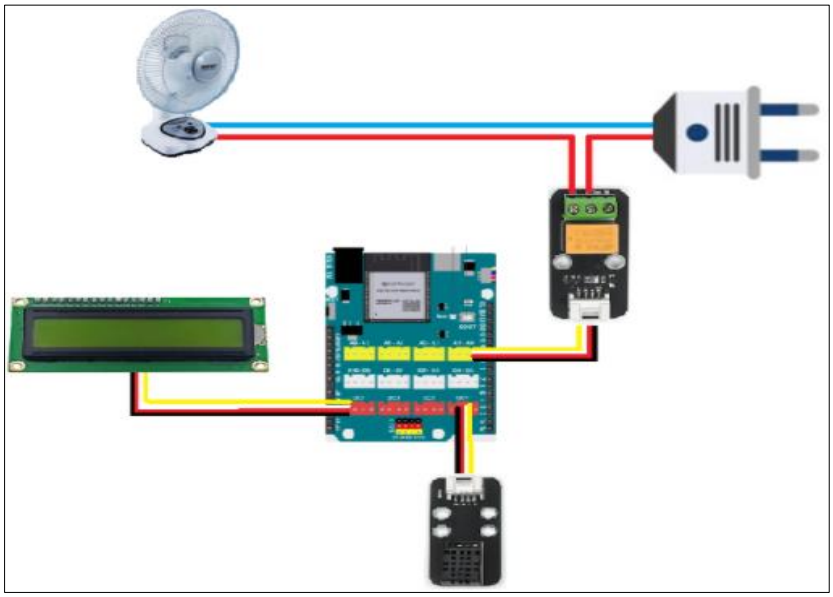


Figure 3: Wiring diagram of the system's devices

Table 1: Pin assignments of the devices

Device	Pin / interface	Function
DHT20 sensor	I2C (SDA, SCL)	Measures temperature and humidity
1602 LCD	I2C, address 0x27	Displays temperature, humidity, light level and date
Light sensor	A0 (analog)	Measures light level (0–100 %)
Relay module	D3 (digital)	Switches the fan's power supply on and off
NeoPixel RGB LED	Built into the board	Status indicator: red – connecting; green – ready
Power supply	5521 DC jack	8.4 VDC, 1 A; 18650 battery as backup

2.5. Mechanical design of the Controller Enclosure

The controller enclosure was designed in AutoCAD, measuring 19 × 9 × 6 cm, with a 7 × 2.5 cm window in the front panel for the LCD (Figure 4a). It is made of Formex sheet (foamed PVC) because the material is lightweight, easy to cut and drill with hand tools, non-conductive and resistant to warping in humid conditions. The finished enclosure is shown in Figure 4b; the board, relay and modules are fixed inside with M3 screws.

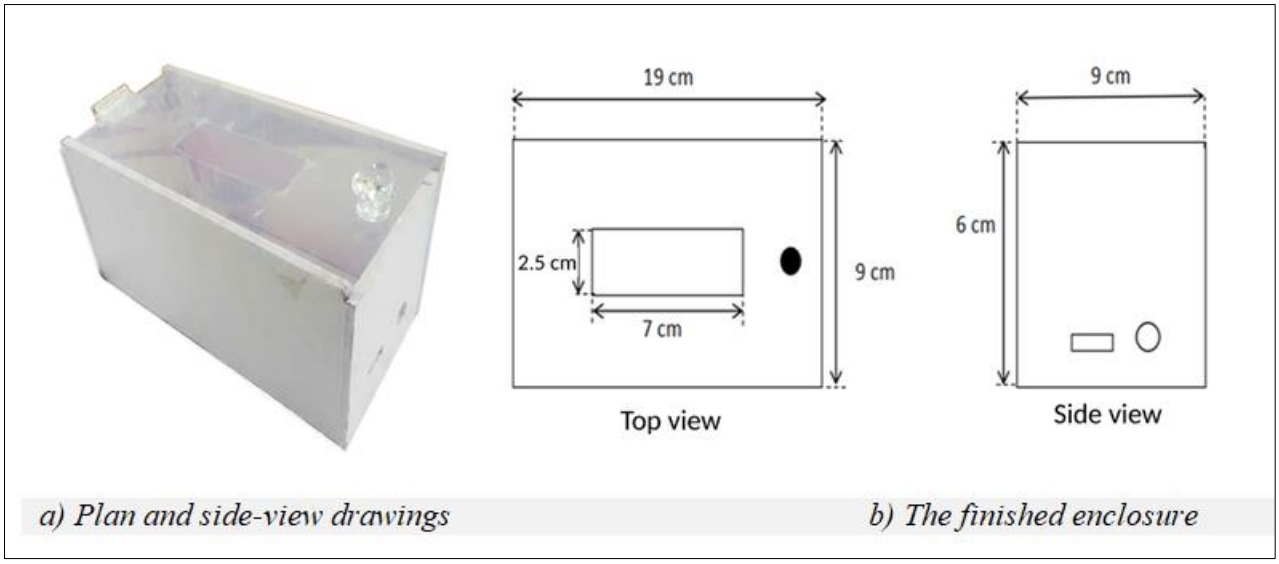


Figure 4: Design and fabrication of the fan controller enclosure

2.6. IoT Communication Architecture

The system uses the MQTT protocol, a lightweight publish–subscribe messaging protocol that works through an intermediary server and is well suited to resource-constrained devices and unreliable networks [1-6]. The ESP32-S3 connects to the broker mqtt.ohstem.vn over TCP port 1883 and exchanges data on the topics listed in Table 2.

Table 2: MQTT topics used in the system

Topic	Direction	Content
V2	Dashboard/AI → ESP32	Fan control command: "1" – on, "0" – off
V13	ESP32 → Dashboard	Temperature (°C)
V14	ESP32 → Dashboard	Humidity (%RH)
V15	ESP32 → Dashboard	Light level (%)
V18	AI → Dashboard	Response message after a voice command is executed
V1	Dashboard → ESP32	LED on/off command (extension channel)

2.7. AI-Based Voice Control Module

Automatic speech recognition is a typical AI problem: features are extracted from the audio signal and passed through an acoustic model and a language model (today mostly deep neural networks) to produce a text string. Because the ESP32-S3 does not have enough resources to run a general-purpose Vietnamese recognition model, the authors adopted a distributed architecture: recognition is performed in the browser of a smartphone or computer through a web interface, with the recognition language set to "vi-VN", and the microcontroller receives only the processed command message via MQTT (Figure 5).

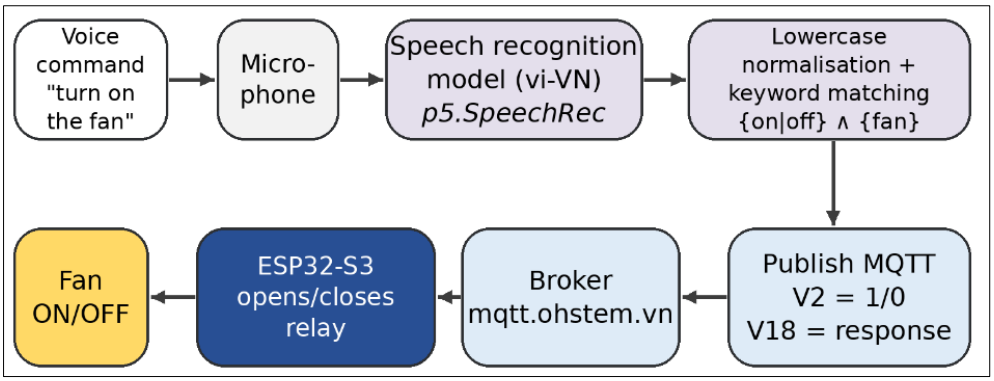


Figure 5: Processing flow for voice control of the fan

The process consists of the following steps: (1) the program turns on continuous listening and automatically starts a new session whenever a recognition session ends; (2) the returned text is normalised to lowercase and displayed on screen so the user can check it; (3) a rule-based intent detector checks two conditions at the same time: the string contains the word "bật" (on) or "tắt" (off), and it contains the word "quạt" (fan); (4) if both are satisfied, the program publishes the value "1" (or "0") to topic V2 and the reply "Dạ quạt đã được bật (tắt), xin cảm ơn!" ("Yes, the fan has been turned on (off), thank you!") to topic V18. Requiring both keywords at once reduces false activations when the user merely says "on" or "off" in ordinary conversation.

2.8. Control Algorithm and Program

The microcontroller program was built in the OhStem App using block-based programming and then converted to MicroPython for finalisation. It uses asynchronous programming with tasks running in parallel, so that periodic sensor reading does not slow down the response to control commands. The algorithm flowchart is shown in Figure 6.

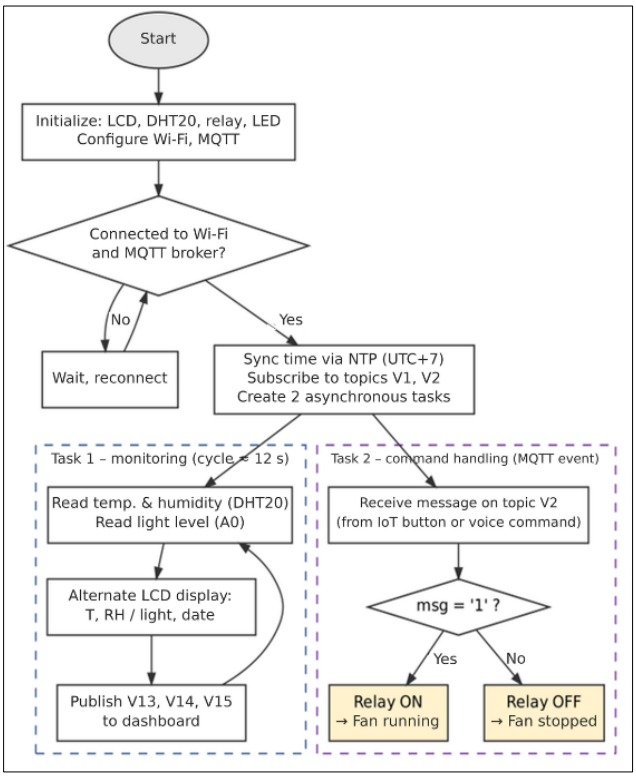


Figure 6: Flowchart of the control program on the ESP32-S3

At start-up, the program initialises the peripherals, connects to the broker, synchronises time via NTP (UTC+7) and subscribes to topics V1 and V2. The monitoring task repeats roughly every 12 s: it reads the temperature, humidity and light level, displays them on the LCD and publishes them to topics V13, V14 and V15. The command-handling task is triggered when a message arrives on topic V2: if the content is "1", it sets pin D3 high so that the relay engages (the fan runs); otherwise the fan stops.

3. RESULTS

a. The Completed Hardware Model

After design, fabrication and assembly, the fan controller was completed with all of its functional blocks (Figure 7). The LCD on the front of the enclosure alternately displays the temperature and humidity (for example, "NHIET DO: 22.1 C – DO AM: 86.1 %"), the light level, and the date; the fan is powered through the relay contacts inside the enclosure.

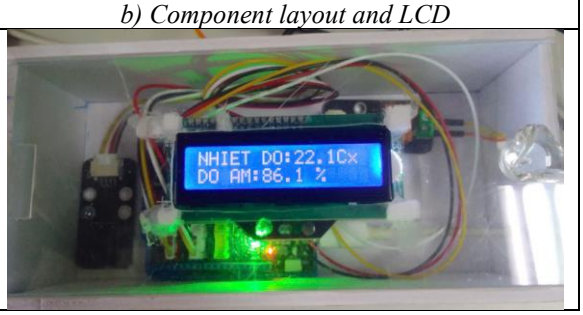
a) The controller connected to the fan	*b) Component layout and LCD*
	

Figure 7: The completed electric fan controller model

b. Monitoring and Control Results Via the IoT Dashboard

The "IoT electric fan control and monitoring" dashboard on the OhStem App (Figure 8) includes tiles showing temperature, humidity and light level; charts of temperature and humidity over time; a switch to control the fan; and a tile showing the AI module's responses. The dashboard can be accessed from both computers and phones. When the user issues a voice command, the switch state and the response message (for example, "Dạ quạt đã được tắt, xin cảm ơn!" – "Yes, the fan has been turned off, thank you!") are updated on the dashboard, allowing the user to verify that the command has been carried out.

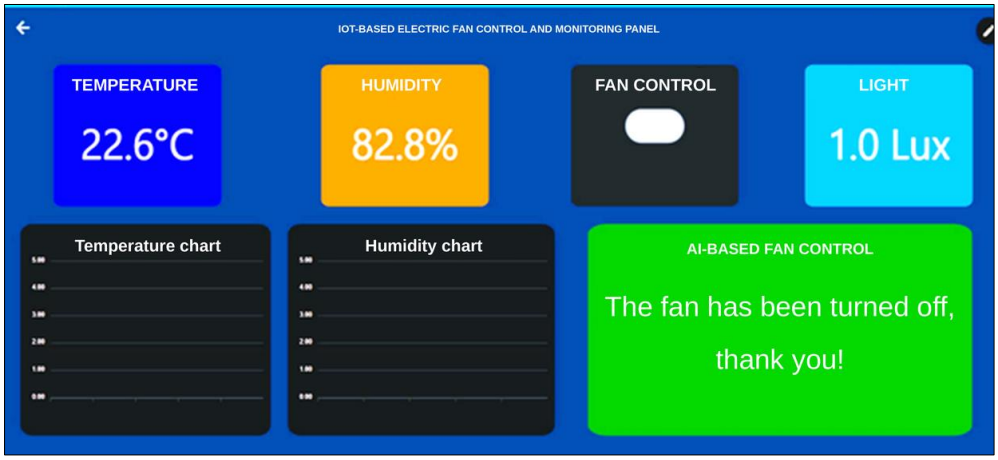


Figure 8: Interface for monitoring and controlling the electric fan on the IoT platform

c. Functional Test Results

The model was tested indoors over a home Wi-Fi network. For each control method, 10 alternating on/off operations were performed (5 on, 5 off); a command was counted as successful when the fan switched to the intended state. Voice commands were spoken clearly in a low-noise environment. The results are summarised in Table 3.

Table 3: Test results for the fan control methods

Control method	Trials	Successes	Rate	Notes
Voice (AI)	10	10	100 %	All 5 "on" and 5 "off" commands recognised correctly
IoT dashboard	10	9	90 %	The 2nd attempt (an "off" command) responded unreliably because of a slow network connection
Monitoring of temperature, humidity and light	–	–	–	Displayed correctly on the LCD and dashboard throughout testing

The results show that both methods controlled the fan as designed. The voice method executed 10 out of 10 commands correctly, indicating that the Vietnamese recognition model combined with the two-keyword rule works reliably under the test conditions. The IoT method executed 9 out of 10 commands correctly; the one unreliable attempt was

attributed to the quality of the Internet connection. It should be noted that both channels pass through the same MQTT broker, so the reliability of the whole system depends directly on network quality; when the connection is lost, the fan can only be controlled with the mechanical buttons on the fan itself.

However, these results are only a functional evaluation with a small sample size: latency has not been measured, speech recognition has not been evaluated in noisy environments or with different regional accents, and the MQTT connection is not yet encrypted.

d. Potential for use in training Electrical and Electronic Engineering Technology Students

The model integrates, in one compact product, knowledge from many courses in the training programme, so it can be used as a practical learning resource within a project-based teaching approach. Table 4 proposes how the model can be used in each course.

Table 4: Proposed use of the model in different courses

Course	Practical content on the model	Intended learning outcomes
Sensor and measurement techniques	Read the DHT20 over I2C and the light sensor via ADC; compare with a reference instrument and determine the error	Understand the principles of sensors, and select and calibrate them
Microprocessors, microcontrollers and embedded systems	Program GPIO, ADC, I2C and LCD; block-based programming and MicroPython; asynchronous tasks	Be able to program multitasking embedded applications
Electrical apparatus and electrical safety	Wire the relay (COM, NO, NC); separate the control circuit from the 220 V power circuit	Design switching circuits correctly and safely
Internet of Things (IoT)	Configure the broker, topics and QoS; build a dashboard; analyse the effect of the network	Build remote monitoring and control systems
Applied artificial intelligence	Integrate speech recognition; extend the keyword set; evaluate recognition rate under noise	Apply existing AI models to a control problem
Projects and scientific research	Add an automatic temperature-based mode, speed control, and control of multiple devices	Competence in designing, integrating and evaluating systems

Teaching can be organised at three levels of increasing difficulty: (1) *Basic level*: students assemble and wire the model and upload a sample program, testing each block with a guided worksheet; (2) *Applied level*: students modify the program, for example by adding topics, adding voice commands ("fan number one", "fan number two"), or changing the data-sending interval; (3) *Creative level*: students work in groups to develop new functions and evaluate the system quantitatively. Thanks to its common, low-cost components, the model is easy to replicate into multiple kits for practical groups.

4. CONCLUSION

This paper has presented the design and construction of an electric fan control system using AI and IoT technologies, based on the ESP32-S3 microcontroller and the MQTT protocol. The system can switch the fan on and off in two ways: through an IoT dashboard on a phone or computer, and by Vietnamese voice commands via a speech recognition module. It also monitors temperature, humidity and light both locally and remotely. Test results show that the voice method executed 10 out of 10 commands correctly and the IoT method 9 out of 10, so the system meets the basic requirements set out. With its modular structure and low cost, the model can be used as a practical learning resource for courses in sensors, microcontrollers, electrical apparatus, IoT and applied AI in training students of Electrical and Electronic Engineering Technology.

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