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Design and Implementation of an IoT-Based Smart Office Automation System

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Abstract — This paper presents the design and implementation of an Internet of Things (IoT)-based smart office automation system developed to improve energy efficiency, security, comfort, and real-time office monitoring. The proposed system integrates an ESP32 controller with IR, LDR, DHT11, MQ-2 and R307 fingerprint sensors, together with relay modules, an L298N motor driver, a DC motor, a 16×2 LCD and a P10 LED display. Occupancy information is used to automate lights and fans, while environmental information supports temperature, humidity, light and air-quality monitoring. Biometric authentication is used to update office availability, which is displayed outside the office. ESP-NOW/Wi-Fi communication supports wireless exchange of status information between controller and display modules. The supplied project report documents successful hardware and integration testing, including motion detection, environmental sensing, biometric authentication, appliance control, curtain operation, sensor integration and failure handling. The system provides a practical prototype for smart-office and future smart-campus applications.

Keywords— IoT, Smart Office, ESP32, Automation, Energy Efficiency, Biometric Authentication, Sensors, ESP-NOW.

I. INTRODUCTION

The Internet of Things enables physical devices to sense, communicate and respond to changing conditions. In an office environment, routine activities such as switching lights and fans, checking environmental conditions, managing access and communicating staff availability can be automated through connected sensors and embedded controllers. The supplied project report identifies unnecessary energy consumption, manual operation of electrical appliances, limited security and lack of real-time occupancy information as key motivations for the smart-office solution.[1]

The proposed system combines sensing, decision-making, actuation, biometric authentication and visual status display in a single embedded platform. An ESP32 is used as the central controller. IR sensing provides occupancy information; LDR sensing supports light-based control; DHT11 measures temperature and humidity; MQ-2 is used for gas/smoke monitoring; and an R307 fingerprint sensor provides authorized-user authentication. Relay modules control electrical appliances, while an L298N driver and DC motor support automated curtain operation. A 16×2 LCD provides local information and a P10 LED display communicates availability status.[2]

The work aims to demonstrate a practical, modular and expandable smart-office prototype. The design is also positioned as a foundation for future integration of cloud services, artificial intelligence, mobile control, voice interfaces and smart-campus deployment.

II. RELATED WORK AND RESEARCH GAP

The report reviews IoT-based office automation, environmental monitoring, energy management, biometric access control, smart curtain control and smart-campus systems. Earlier systems commonly automate lighting, fans or air-conditioning according to occupancy and environmental conditions. Other studies emphasize air-quality monitoring, energy conservation, cloud dashboards, or fingerprint-based access control.

The reviewed approaches demonstrate that IoT can reduce manual effort and support energy-aware operation. However, the report observes that many existing implementations emphasize one or two functions rather than combining automation, environmental monitoring, security and staff-availability communication in one platform. The proposed work addresses this integration gap by bringing these functions together around an ESP32-based controller.

The research contribution is therefore an integrated prototype in which occupancy and environmental inputs drive appliance control, biometric authentication supports authorized status updates, and wireless communication transfers office availability to an external display. This integrated design is particularly relevant to educational offices and small institutional workplaces where a low-cost embedded solution is desirable.[3]

Objectives

The major objectives are: (i) automate lights, fans and curtains using sensor information; (ii) monitor temperature, humidity, light intensity, occupancy and air quality in real time; (iii) provide biometric authentication for authorized access and status updating; (iv) reduce unnecessary energy use through occupancy- and environment-driven control; and (v) display environmental information and office availability through local visual interfaces.

III. SYSTEM ARCHITECTURE AND METHODOLOGY

The architecture follows a sensing–processing–actuation model. Input sensors acquire physical conditions and send signals to the ESP32 controller. The controller applies predefined decision logic and produces control commands for relays, the motor driver and displays. The supplied architecture diagram shows IR, LDR, DHT11, MQ-6/MQ-2 gas sensing and fingerprint input connected to the controller, with relay outputs, motor control, LCD and P10 display forming the principal outputs.

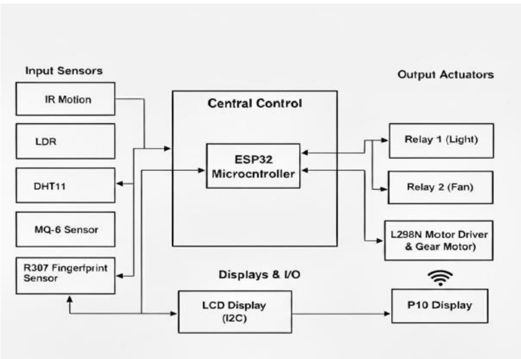

Fig. 1. System architecture adapted from the supplied project report.

For occupancy control, an IR sensor detects a person in the sensing range. The controller can then switch lights and fans according to the occupancy state. LDR information is used to distinguish bright and dark conditions for automatic lighting. DHT11 values provide temperature and humidity information, while the gas sensor supports air-quality detection. The fingerprint module authenticates registered users and allows the availability state to be updated. The P10 display communicates this state outside the office.[4]

IV. SYSTEM ARCHITECTURE AND METHODOLOGY (CONTINUED)

The software is developed in Embedded C/C++ using Arduino IDE. The ESP32 provides Wi-Fi capability and ESP-NOW is used for wireless exchange between ESP32 modules. UART is used for the R307 fingerprint module and I2C is used for the LCD interface. The report also identifies HTTP/MQTT as possible interfaces for remote monitoring.[5]

Hardware and Software Implementation

The implementation uses an ESP32 controller operating at 3.3 V with Wi-Fi and Bluetooth support. An Arduino Nano (ATmega328) is also listed in the technical specification for sensor processing and control operations. The sensing layer consists of DHT11, MQ-2, IR and LDR modules.

The actuation layer contains relay modules for lights and fans and an L298N motor driver with a DC motor for curtain control. The R307 fingerprint module provides biometric access control. A 16×2 LCD and P10 LED matrix provide local and external information display, respectively.[6]

The report specifies DHT11 measurement ranges of 0–50 °C for temperature and 20–90% for humidity, with stated accuracy of ±2 °C and ±5%. The MQ-2 is described for LPG, smoke and methane detection over a stated 200–10000 ppm range. The L298N is listed for 5–35 V motor control. An LM2596 regulator is used for adjustable voltage regulation. These specifications are taken directly from the supplied project report.[7]

The system is designed with modularity and maintainability in mind. Hardware components can be replaced individually, while the software is organized so that future features can be added without redesigning the complete platform.

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Module	Component	Role
Controller	ESP32	Central processing and Wi-Fi/ESP-NOW
Sensors	IR, LDR, DHT11, MQ-2	Occupancy and environmental sensing
Security	R307 fingerprint	Authorized-user authentication
Actuation	Relay + L298N + DC motor	Lights/fans and curtain control
Display	16×2 LCD + P10 LED	Local data and availability status

V. CONTROL ALGORITHM

The control logic continuously initializes the sensors and wireless interface, reads environmental and occupancy data, checks authentication information, applies automation rules and updates the displays. A simplified operational sequence is: 1) initialize ESP32, sensors and communication; 2) read IR, LDR, DHT11 and MQ-2 values; 3) check fingerprint authentication; 4) determine occupancy and office availability; 5) control lights and fans according to occupancy and environmental conditions; 6) operate the curtain motor according to light conditions; 7) update the LCD and P10 display; 8) transmit relevant status through ESP-NOW; and 9) repeat the cycle.[8]

This rule-based embedded approach is appropriate for a prototype because it is deterministic, computationally lightweight and easy to debug. The report uses a Waterfall development model with phases covering requirement analysis, system design, implementation, integration and testing, deployment and maintenance.

Algorithm 1: Smart Office Control Cycle

- Start and initialize ESP32, sensors, display and wireless communication.
- Read occupancy, light, temperature/humidity and air-quality inputs.
- Check registered fingerprint and update authorized-user availability.
- Apply appliance-control rules for lights, fans and curtains.
- Update LCD and P10 display with current system information.
- Transmit availability/status data through ESP-NOW where configured.
- Repeat the sensing and control cycle continuously.

Implementation and Development Process

The project follows a Waterfall development model. The report maps the work through requirement analysis, system design, implementation, integration and testing, deployment and maintenance. The detailed implementation plan includes topic finalization, requirement specification, technology study, architecture design, sensor integration, automation logic, biometric security, web-interface development, hardware/software integration, display implementation, testing and documentation.[9]

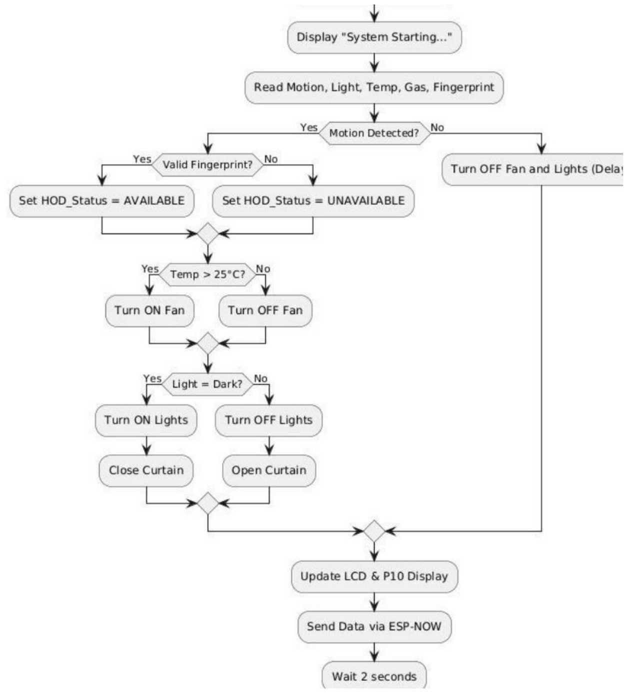

Fig. 2. Activity flow of the smart-office automation process.

VI. TESTING AND RESULTS

Hardware testing was conducted for individual modules and integrated operation. The report documents ten test cases covering sensors, authentication, actuation, integration and failure handling. The first five documented tests verify IR motion detection, DHT11 temperature/humidity detection, LDR-based lighting control, fingerprint authentication and relay-based appliance control. All five are recorded as Pass.[10] Further tests verify MQ-2 air-quality detection, LCD output, DC-motor curtain control, complete sensor integration with the ESP32 and operation under a sensor-disconnection condition. These tests are also recorded as Pass. The integration test reports that the system worked properly with all components,

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while the failure-handling test reports continued operation with remaining components when one sensor was disconnected.[11] The reported outcome is therefore functional rather than a quantified energy-performance evaluation. The report does not provide a measured percentage reduction in electricity consumption or a statistical accuracy study; accordingly, this paper does not invent such numerical performance claims.[12]

Table 1. Summary of documented hardware and integration tests.

ID	Test	Actual Result	Status
TC001	IR motion detection	Motion detected successfully	Pass
TC002	DHT11 temperature/humidity	Values displayed correctly	Pass
TC003	LDR light detection	Lights controlled correctly	Pass
TC004	Fingerprint authentication	Authentication works correctly	Pass
TC005	Relay appliance control	Devices controlled successfully	Pass
TC006	MQ-2 air-quality detection	Air quality displayed correctly	Pass
TC007	LCD display output	Display working properly	Pass
TC008	DC-motor curtain control	Curtain operates correctly	Pass
TC009	All-sensor integration	System works properly with all components	Pass
TC010	Sensor-failure handling	System runs with remaining components	Pass

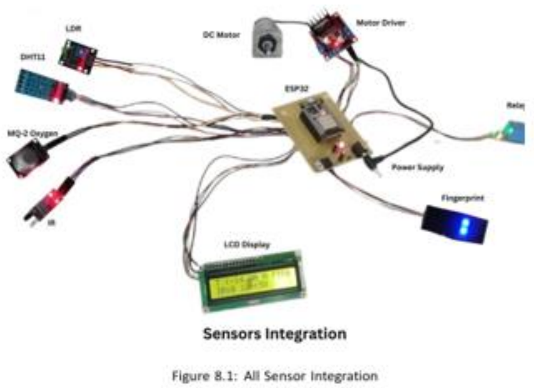

Fig. 3. Integrated sensor/controller prototype shown in the supplied report.

Testing and Results (Continued)

The individual tests establish the functional behavior of the major modules. TC001 confirms that the IR sensor detects a person entering its range. TC002 confirms that temperature and humidity values are displayed on the LCD. TC003 verifies automatic lighting behavior under bright/dark conditions. TC004 confirms fingerprint authentication, and TC005 verifies relay-based device control.[13]

TC006 verifies air-quality display using the MQ-2 sensor, while TC007 verifies LCD output. TC008 confirms curtain operation using the DC motor. TC009 checks complete sensor integration with the ESP32 and records correct system operation with all components. TC010 evaluates a sensor-disconnection condition and records continued operation with the remaining components.

The testing evidence demonstrates functional integration of sensing, processing, actuation and display. However, the source report does not provide long-duration measurements such as kilowatt-hour savings, response-time distributions, false-acceptance/false-rejection rates for biometrics, or statistical sensor-accuracy validation. Therefore, the present study should be regarded as a functional prototype evaluation rather than a full quantitative benchmarking study.[14]

VII. DEPLOYMENT, MAINTENANCE AND DISCUSSION

Deployment involves assembling the ESP32, sensors, fingerprint module, relays, motor driver, display units and power supply, uploading the Arduino program, configuring Wi-Fi/ESP-NOW, enrolling authorized fingerprints, calibrating sensors and verifying automation rules. The final arrangement places the availability display at an appropriate location such as the office entrance.

Maintenance includes periodic sensor calibration, cleaning, inspection of power connections, software updates, security updates, backup of code/configuration, fingerprint database management and repeated functional testing. The report notes that environmental conditions can influence sensor accuracy and that stable power and wireless connectivity are important dependencies.[15]

From a system perspective, the main strength is integration: the same controller coordinates sensing, security, actuation and communication. The principal limitations are the use of low-cost sensors with limited accuracy, dependence on stable power, and the absence of a quantitative long-duration energy study. These limitations also define useful directions for the next research stage.

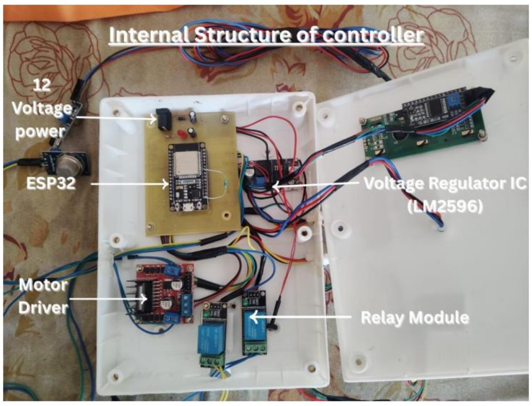

Figure 8.2: Main Controller

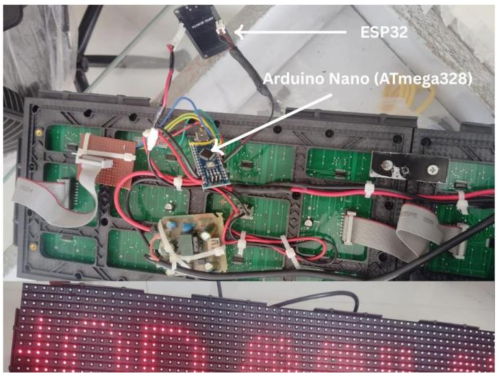

Fig. 4. Main controller and P10 display setup documented in the report.

Deployment, Maintenance and Discussion (Continued)
The deployment process begins with hardware assembly according to the circuit design. The ESP32 is configured as the central controller, the program is uploaded through Arduino IDE, wireless communication is configured, authorized fingerprints are enrolled, and sensor calibration is performed. Automation rules are then verified before the system is installed in the office environment. The external P10 display is positioned so that visitors can identify office availability.

Maintenance is an important part of the proposed system because low-cost sensors may drift and environmental factors can affect readings. The project report recommends periodic calibration of DHT11 and LDR sensors, cleaning, inspection of power connections, software updates, security updates, configuration backups and management of the fingerprint database. Regular functional testing is recommended to maintain reliability.[16]

VIII. CONCLUSION AND FUTURE SCOPE

The developed IoT-based smart office prototype demonstrates that a combination of embedded sensing, ESP32 processing, wireless communication, biometric authentication and actuator control can automate common office operations. The documented tests show successful operation of the principal sensing, display, authentication, actuation and integration functions.[17]

The next stage can introduce AI-based prediction of user behavior and energy demand, cloud-based data storage and analytics, a dedicated mobile application, voice control, enhanced security through face recognition and real-time alerts, and a centralized energy-monitoring dashboard. The architecture can also be extended from a single office to classrooms, departments and complete smart-campus infrastructure.

Research Significance
The significance of the prototype lies in its unified treatment of office automation, environmental awareness, access security and availability communication. Instead of treating these functions as independent subsystems, the design coordinates them through an embedded controller and wireless interface. This makes the concept suitable for educational institutions, corporate offices and government workplaces, subject to further validation under real operating conditions.

Conclusion
The IoT-based smart office automation system provides a practical embedded architecture for intelligent workplace management. The prototype combines multiple sensors, ESP32 processing, biometric authentication, relay and motor actuation, local display and wireless status communication. The documented test cases show that the implemented modules and their integration performed successfully. The work establishes a functional foundation for subsequent quantitative evaluation and larger-scale smart-campus deployment.

Future Research Directions
- Develop an energy-monitoring subsystem to measure actual electrical consumption and quantify savings over conventional operation.
- Apply machine-learning models to learn occupancy patterns and optimize appliance schedules rather than relying only on fixed rules.
- Add cloud analytics and dashboards for historical trends, alerts and multi-office monitoring.

- Develop a mobile application and optional voice-control interface for authorized remote operation.
- Improve security using stronger authentication, encrypted communication, audit logs and, where appropriate, face recognition.
- Scale the architecture to classrooms, laboratories, departments and campus-wide centralized management.

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