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Secure IoT-Based Smart Home Automation System with Multi-Sensor Integration and Real-Time Monitoring

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Abstract: Smart home automation systems have become the need of the hour to develop safer, energy-efficient, and user-sensitive dwelling environments. This paper discusses a robust IoT-based smart home automation system comprising multiple sensors, including a gas sensor, a DHT11 temperature and humidity sensor, an ultrasonic water level sensor, an LDR-based light controller, and a facial recognition module for door access automation. It is powered by an ESP32 microcontroller, enabling sensors and actuators to communicate directly over Wi-Fi. The temperature sensor maintains comfort by automatically controlling ventilation, while the gas sensor enhances domestic security through flammable gas detection and alarming. Lighting is optimised by modulating light intensity based on illumination levels, reducing wasted power. Water levels in the tanks are continuously measured by ultrasonic sensors, with automatic pumping to prevent shortages and overflows. This is complemented by a face recognition module that provides access control by allowing only authorised persons based on real-time image processing. The entire set of sensor readings is gathered and transmitted via an IoT interface to facilitate remote monitoring and manual override via mobile applications. The converged system features a single, smart platform that emphasises maximum convenience, security, and sustainability.

Keywords: ESP32 Controller; DHT11 Temperature and Humidity Sensor; MQ-2 Gas Sensor; DHT22 Temperature Sensor; Ultrasonic Sensor (HC-SR04); IoT Home Automation; Sensor Integration.

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1. Introduction

In today's home automation, systems have been put in place to provide intelligent control of home appliances, energy management, and security. Most current systems, however, are limited in capability and rely on simple sensors or remote manual control via a mobile app. Although these systems offer some convenience, they do not provide high-end automation functionality. They are generally built around stand-alone functions such as light control, security alarms, or temperature control. Most conventional home automation systems use motion detectors, infrared (IR) sensors, or basic presence detectors to control lighting and other appliances. These are typically binary sensors that respond to movement and switch devices on or off, without the ability to differentiate between people. Although these systems can minimise energy use to some extent, they are not efficient at maximising energy use based on user-specific activity or preferences. In addition, today's systems are mostly entered manually on smartphones or tablets, limiting automation and requiring constant user interaction. Security-wise, most home automation systems utilise camera-based monitoring and alarm triggering.

Although these systems offer general monitoring, they typically do not involve familiarity or unfamiliarity detection, which can lead to false alarms or privacy intrusions. Most systems also do not use speech-based alerts and real-time feedback, thus resulting in low usability and interactivity [1]. Further, though some home automation systems have adopted IoT to monitor and control homes remotely, they generally focus on a single appliance rather than an end-to-end solution for controlling a house's overall operations. These systems do not have a holistic approach towards automating different functions of a house, like lighting, security, and water management, from one platform. Finally, water detection in modern systems is generally handled via separate leak detectors or moisture sensors. Such mechanisms are typically separate appliances and are not part of the rest of the home automation system, resulting in siloed control and monitoring features. In most scenarios, users are forced to install and operate several applications to monitor different parts of their home, which is time-consuming and inefficient. In short, existing home automation systems have only limited control and monitoring capabilities, but no advanced features such as face recognition, personal automation, built-in water detection, or live voice alerting. These shortcomings justify the need for a smarter, integrated system that can readily and effectively automate a majority of home management [2].

2. Literature review

Internet-Based Monitoring of Supply Control Systems by Sagar and Kusuma [1] presents a low-cost, yet flexible and uncompromising home-automation system that promotes safety, powered by an Arduino microcontroller. The system benefits from IP connectivity, using resident Wi-Fi to provide authorised remote access and to manage the device through a mobile application. It is not server-dependent and uses the Internet of Things (IoT) to monitor diverse applications, ranging from technical equipment to consumer items. Users can access the devices via online or smartphone applications or an infrared module [3]. To demonstrate the system's effectiveness and feasibility, a home-automation setup using an Arduino UNO microcontroller and an ESP8266-01 Wi-Fi module is employed. This allows users to manage devices such as home lights, fans, and TVs while drawing conclusions based on sensor feedback from a distance. A Bluetooth-based home automation system connects equipment to the Arduino BT board via I/O ports. The Arduino panel was programmed in a high-level interactive C language tailored for microcontrollers, with connections established via Bluetooth. Due to security concerns, password protection is used to grant access only to authorised users. The Bluetooth connection allows a wireless link between the smartphone and the Arduino Bluetooth circuit. An analogous System for Smart Home Controller of Appliances Based on Remote Speech Interaction by Iliev and Ilieva [2] argues for the need for automated systems in place of manual ones. The pervasive impact of the Internet on everyday life has brought many new technologies. Among them, the Internet of Things (IoT) is likely to dominate the technological landscape in the near future. This home automation system uses IoT methodology to sense and control electrical and electronic appliances from any remote location using a smartphone. The study proposes a low-cost, universal home automation system that enhances wireless communication, enabling users to control various appliances remotely [4].

Sharma et al. [3] outline the evolution of home automation through IoT, enabled by innovations from top players such as Apple, Amazon, Google, and Samsung, which have created platforms and solutions for smart homes. The paper thoroughly reviews the academic literature, business white papers, expert discussions, and web-based databases that address IoT concepts. The objective is to provide an overview of IoT, Layouts, the required tools, and their applications in everyday life. The proposed system by Esposito et al. [4] enables automatic control of home devices based on duration and communication, ensuring safety and preventing accidents when the homeowner is away. This system primarily focuses on automatic control of lights and other home devices via the Internet, aiming to conserve both electrical power and human effort. Using the Internet of Things and Arduino Nano, several appliances are connected via a wireless network [5]. The key objective of a Home Automation System is to create a setup that enables the device to be operated remotely via RF (Radio Frequency) technology. As methodologies advance, homes are becoming smarter, transitioning from traditional on/off switches to centralised control systems that incorporate RF-controlled switches. Conventional wall switches located throughout the home can be inconvenient, particularly for ageing or physically disabled individuals. Home automation via remote control offers a simpler solution using RF technology. To implement this, an RF remote can link to a microcontroller on the sender end, which transmits an ON or OFF signal to the receiver connected to the gadgets. Using the remote, users can turn appliances ON/OFF from a distance via wireless communication [6]. Microcontroller-based remote surveillance using mobile phones with spoken commands by Jawarkar et al. [5] presents a smart building concept that aims to reduce human effort, enhance energy efficiency, and save time.

This system uses ASP.NET, with appliances connected to sensors that relay their status to a web interface. Users can operate electrical appliances through this website. The main purpose of this home automation system is to assist elderly and disabled individuals by enabling them to operate home appliances and receive emergency alerts. Remotely Controlled Home Automation providing Android app via Wi-Fi connection - Johri et al. [6]. The purpose of the paper is to construct a home automation system that provides comprehensive safeguards while enabling control of home appliances via wireless communication, specifically Wi-Fi. This intelligent home system integrates relevant hardware and software elements. For extra security, the system employs Passive Infrared Sensors (PIR) and a vibration sensor to detect movement and vibrations, helping deter theft. If a security attack occurs, the system triggers an alarm through a buzzer and initiates an HD spy camera to capture evidence of the breach. All rooms, with exhaust fans if necessary, are to provide favourable conditions.

Furthermore, a water-level sensor ensures the overhead tank is full without water wastage [7]. In their discussion of utilising IoT for environmental condition surveillance in homes, Kelly et al. [7] note that the Internet of Things has become a trending methodology. It involves a network of physical items equipped with detectors, software, electronics, and communication, enabling them to perform more efficiently and share details with other connected devices, operators, or manufacturers. Home automation based on IoT allows users to access and control various home applications remotely using smartphones. This methodology is particularly beneficial for individuals with physical disabilities and enhances home security. Ultimately, it improves users' quality of life by making homes safer and more efficient. The Home Automation utilising Cloud-Based Systems emphasises the design and implementation of a home gateway that collects data from household devices and transmits it to a cloud information host for storage in the Hadoop Distributed File System (HDFS). This data is processed using MapReduce to facilitate Surveillance tasks for remote users now working from home. The automation continually enhances its resilience by integrating new features to meet users' increasing demands [8].

Microcontroller-Based Remote Surveillance via Mobile and Speaking Commands by Amoran et al. [8] focuses on designing a Bluetooth home-automation system that enables clients to operate electrical devices via an Android application, setting control actions on their mobile devices. This system uses Bluetooth technology to enable home automation at a cost-effective price [9]. The Internet of Things is recognised as an emerging methodology and the third wave of internet development. It is also expected to affect consumer goods, business, and overall cultural trends on a massive level. As fantastic as the promise of IoT applications sounds, cutting across multiple industries, production, and supply chains, it is still in its infancy. The Remotely Controlled Home Automation System by Singh et al. [9] discusses how, today, there is a trend toward automated systems rather than manual ones, fueled by the power of the Internet. The most promising and desired technology of the present era is the IoT, which can take the future by storm [10]. This Home Automated System uses IoT to remotely monitor and control electrical and electronic devices through a smartphone. The article explains an economical, adaptive home-automation system that improves wireless communication, enabling users to control appliances more conveniently. Economically Low-Cost Management System for Internet of Things-Integrated Smart Homes by Ruslan et al. [10] suggests the development of an IoT-based home automation system using Arduino Nano and ESP-32. This paper aims to develop a home-automated system that can be operated from any mobile phone. Integration of IoT into Home Automation makes it an extremely intriguing area of study. ESP 32, being a credit card-sized microcomputer, can support a wide range of peripherals and communication interfaces. This flexibility enables simultaneous control of household appliances. For this arrangement, a local server is set up on the ESP32 microcontroller.

3. Methodology

The methodology of the proposed system is based on integrating facial recognition, IoT control-based methods, and ultrasonic sensor methods to ensure transparent home automation. The system has been developed using Python for facial recognition, IoT protocols for remote control, and ultrasonic sensors for water detection. The process starts with facial recognition to identify people heading to the house. A pre-trained machine learning model is used to recognise known and unknown faces, enabling the system to correct lighting and alert security based on the identified person. Figure 1 illustrates the block diagram for an IoT-based smart home automation system with real-time monitoring. The system also includes strategically placed ultrasonic sensors to measure water level and trigger an alarm in the event of leakage or overfilling. The IoT smartphone application serves as the user interface for remote access to real-time notifications, home security alerts, and lighting control. The app interacts with the system via Wi-Fi or other IoT communication protocols, delivering seamless, consistent performance. Each component, facial recognition, IoT control, and water detection, is designed to work in tandem to enhance energy efficiency, security, and convenience. Python-based algorithms handle image processing and IoT protocols, making it easier for users to communicate with household products.

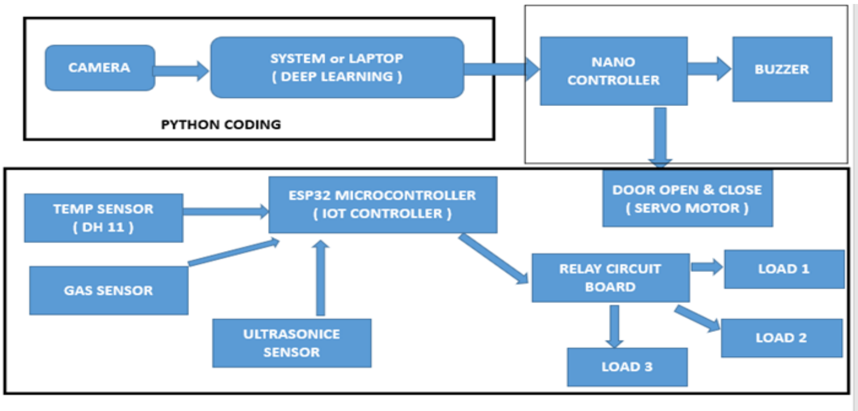

Figure 1: Block diagram for IoT-based smart home automation system with multi-sensor integration and real-time monitoring

Figure 2 provides the circuit diagram of IoT home automation. There are two main divisions for system design. The device can establish an association with the router. Additionally, it would be able to turn specific things on and off, like fans and a lamp.

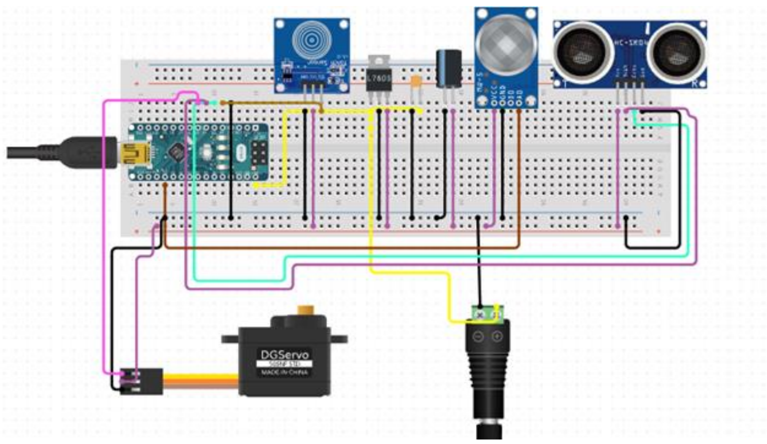

Figure 2: Circuit diagram of an IoT-based smart home automation system

3.1. Control Unit

Arduino UNO is the company's flagship board for novice and more experienced users. To process data and connect several units for operation, the system requires a microcontroller. The goal was accomplished by the Arduino Uno, which is equipped with an ATMEGA328P CPU. It has 14 digital input/output pins and six analogue input pins. It can run on 12V from an external power source or 5V from a USB connector. Pins 0 and 1 serve as the Arduino Uno's default transmit and receive pins. A channel relay module is attached to Uno, and the Uno's output is linked to a series of household appliances, including a TV, a fan, a light, a room heater, and so on. A low-current, low-voltage relay triggers a switch coupled to a high-voltage source. Relay's four input ports are attached to an Arduino, which receives a 5V supply and can trigger up to 10A and 250V. ESP8266-01: This incredibly small board can be used as a stand-alone board or as a serial (RX/TX) peripheral for any other board. Any FTDI device that runs at 3.3 V can be used to program the board, which needs 3.3 V Power, TX/RX, CH_PD to turn on the chip and two general-purpose input/output (GPIO) pins. WIFI: The ESP8266-01 module can connect to a Wi-Fi hotspot using the Wi-Fi (wireless fidelity) protocol. To connect the smartphone and ESP8266-01, the router assigns each module a distinct IP address. Temperature Sensor: It measures both the room's temperature and humidity. It has a range of under 20 meters. It will measure temperatures from 0 to 50°C because of its Negative Temperature Coefficient (NTC) and humidity-sensitive elements. The software design comprises the Blynk IoT Platform, and the Android device would incorporate these applications. The Node MCU microcontroller with a 4- or 8-channel relay board forms the Control Unit. The relay board controls the relays using a ULN2803 IC. Over the internet, the Blynk app on a mobile device transmits the desired signal to the microcontroller. The hardware, sometimes called the Control Unit, consists of a NodeMCU microcontroller and a relay board. NodeMCU outputs are connected to the relay board's relay pins. Each relay connects to an appliance. The system's implementation involves several key components working together to achieve the desired functionality.

3.2. Facial Recognition Module

The face recognition system is built on Python with libraries such as OpenCV for image acquisition and processing. The camera module is mounted on the door for acquiring real-time images. The system is trained on a list of known faces to achieve accurate identification. Once the decision on the person's recognition status (known or unknown) is made, the facial recognition model's output triggers appropriate responses, such as sending security notifications or activating lights.

Ultrasonic Sensor for Water Detection: These sensors are placed where water leaks are most likely to occur. By measuring the time of return from reflected ultrasonic waves, these sensors can determine the amount of water. Upon detection of high water levels, the system will alert.

IoT Mobile Application: The Internet of Things app provides a straightforward user interface for controlling and monitoring household appliances. It instructs the system via a NodeMCU or other IoT controller, which in turn controls the appliances connected to the system. Users can remotely switch the lights on and off, track water levels, and receive alerts from strangers. Users can also set their own configurations, e.g., adjust their lighting settings upon identification.

System Control and Integration: An Arduino or NodeMCU microcontroller manages communication between the sensors, the facial recognition system, and the IoT app. The system operates wirelessly, sending real-time updates and allowing users to control devices via the mobile app.

3.3. BLYNK IOT Platform

The Blynk Server facilitates connectivity between smartphones and hardware. It is a free source, supports hundreds of devices, and can be operated on a device. Blynk Libraries entitle interfaces to the intranet and the processing of inbound and outbound requests on all preeminent hardware systems. Each time you press an icon in the Blynk application, an apprise is sent to the Blynk Cloud and mysteriously routed to the hardware. Works the same way in other supervision, so everything happens in the blink of an eye.

4. Hardware Implementation and Results

The Internet of Things-based smart home automation systems have demonstrated significant capabilities for automating, monitoring, and controlling various home functions using data from devices and user inputs. The combination of gas detection, facial recognition, temperature and humidity monitoring, lighting management, and safe entry methods improved convenience, safety, and energy savings. Below are the results and key insights from the system’s implementation and testing. Figure 3 represents the IoT hardware model of a smart home automation system.

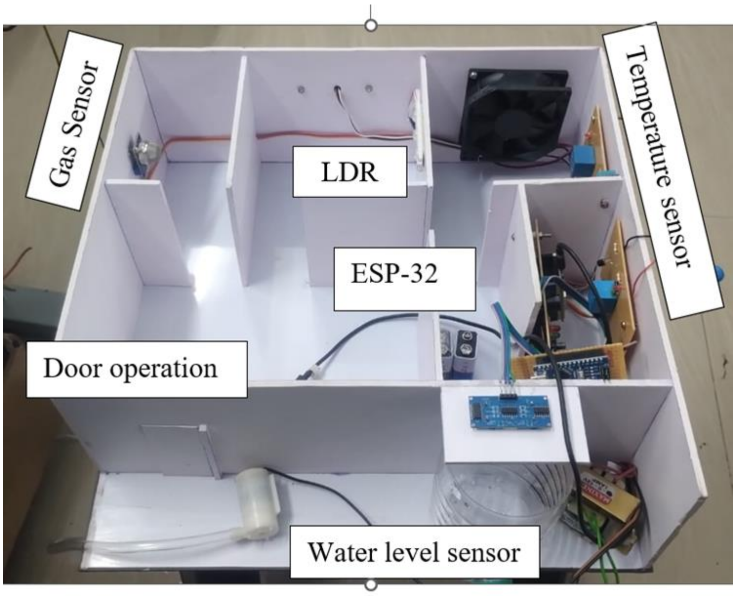

Figure 3: Hardware module of IoT-driven smart home system incorporating facial recognition, environmental sensing, and automated control

The system begins by scanning the entrance for faces using a camera module connected to the facial recognition system. As soon as someone enters the house, the system uses a pre-trained facial recognition algorithm (such as OpenCV and Haar Cascades) to detect and identify the individual. If the individual is a frequent user, the system automatically turns on the lights at their command, which is stored in the system's database. Whenever the system detects a stranger, it sends a security alert with an audio alarm, notifying the user via the mobile application of the stranger's presence. This enhances home security by providing real-time information about potential intruders. Figure 4 describes the face identification using a door camera.

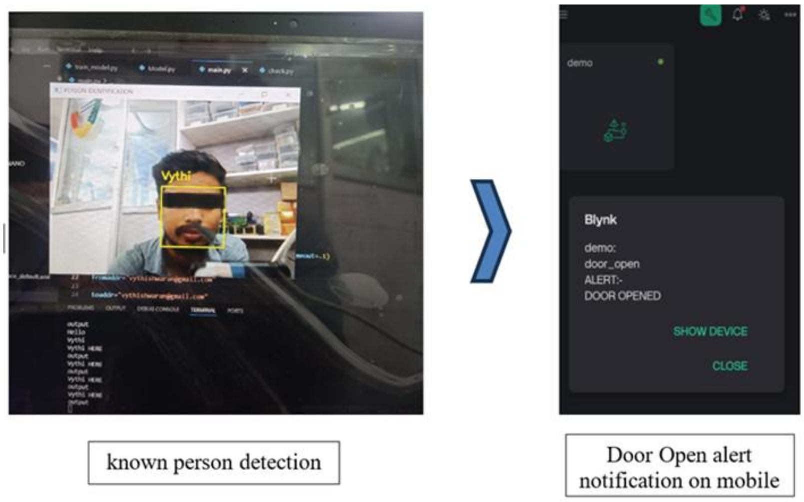

Figure 4: Face identification using a door camera with mobile notification alert

Facial recognition door control combines machine vision technology and IoT-based automation. The system uses either a camera module integrated with an ESP32 or a computer with Python and OpenCV libraries. Feature extraction using measurements such as eye distance, jawline, and nose shape is applied to the processed face image and cross-checked against stored datasets using Haar Cascade classifier algorithms. If the face is recognised to belong to an authorised individual, a servo motor connected to the door lock is driven by a PWM signal, opening the door lock to a specific angle (e.g., 0° closed, 90° open). In the event of an uncertain face, the system warns with a buzzer or sends a security alert to the owner's cell phone. This touchless access control system enhances home security and convenience, particularly for older people or those with disabilities. The process provides convenient entry authorisation with maximum security for real-time verification.

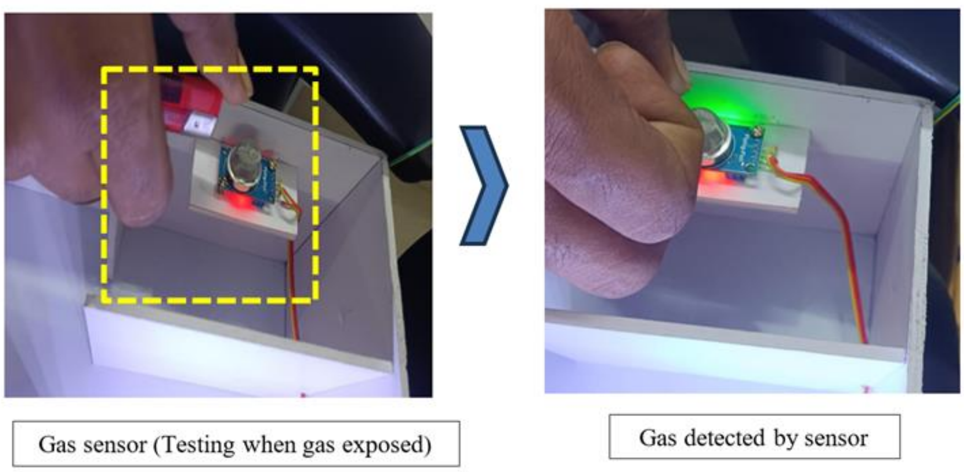

Figure 5: Gas leakage detection

Figure 5 illustrates gas leakage detection using IoT. If the gas sensor detects a gas level of 3800, both the fan and buzzer will come on, warning of a potential gas leak and prompting ventilation. The system also includes a door sensor that detects when the door opens or closes. Whenever such a movement is undertaken, the buzzer will signal, acting as a door status indicator for safety or awareness. The gas sensor (typically of the MQ type) is a crucial component in the security of smart home systems. The sensors detect specific gases by measuring changes in electrical resistance.

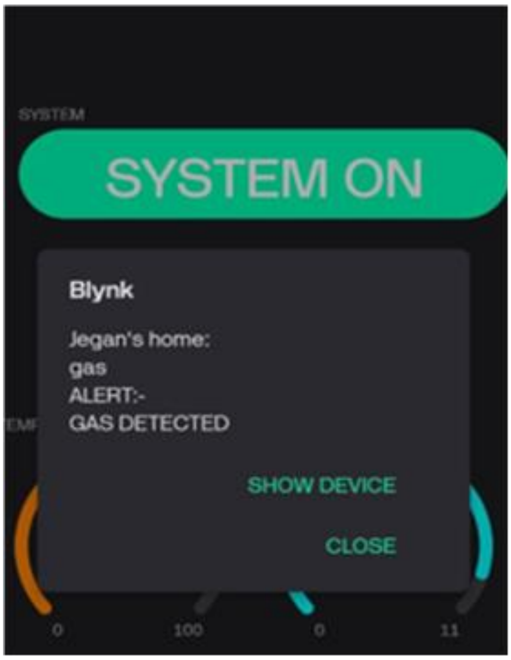

Figure 6: Gas leakage detection and mobile alert notification system

The sensing material, typically tin dioxide (SnO_2), is said to exhibit resistive variability that decreases in the presence of combustible gases such as LPG, methane, or carbon monoxide. The ESP32 microcontroller perceives such variation as an equivalent voltage signal. The system activates the alarm buzzer and ventilation fan when the gas concentration exceeds a predefined level to reduce the risk of fire or explosion. In the IoT system, such information is conveyed in real time to the cloud via Wi-Fi for remote processing. Through this, the system acquires response security at the local level and remote real-time notification, thereby enhancing the reliability of the residential gas monitoring system. This integration not only reduces potential risk but also enables the automation framework's active response feature. Figure 6 provides a gas-leakage detection system via a mobile application.

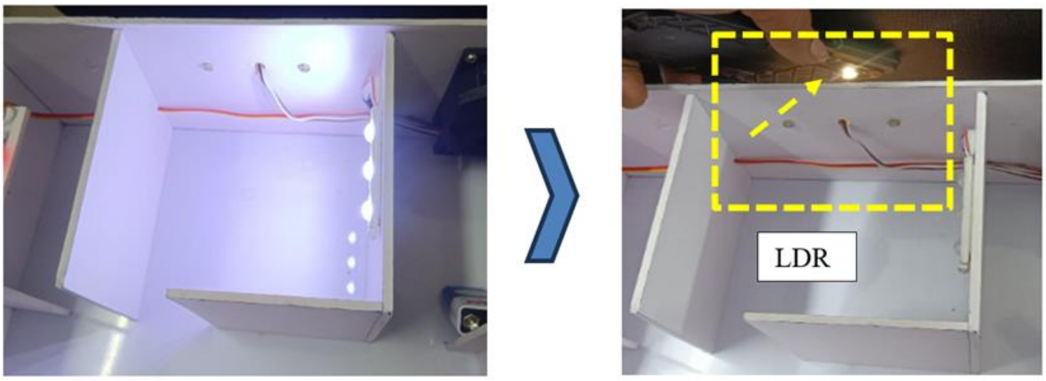

Figure 7: Automatic room lighting control using the IDR sensor

The ultrasonic technique is highly precise and reliable, making it well-suited for maintenance-free, real-time liquid level measurement in household applications. LDR is an uncomplicated and effective sensor for automatic lighting. LDR is based on photoconductivity, i.e., a decrease in resistance with increasing illumination. Because the LDR has low resistance during the daytime, the ESP32 can detect sufficient light and turn off the wired room light. If the environment is dark, the LDR's resistance is high, which automatically turns on the lights. Figure 7 shows the LDR-based automatic light-control home-automation IoT model. This is a system that automatically controls indoor light adjustments based on environmental conditions without any human intervention. When integrated into IoT monitoring systems, such a system can monitor light consumption and enhance energy efficiency. Sensor-driven automation like this is especially relevant in energy conservation, especially for homes wanting to reduce carbon footprints via smart control systems.

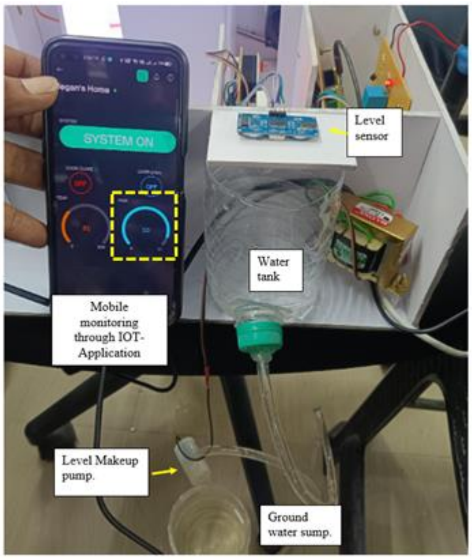

Figure 8: Automatic water level monitoring and pumping control using ultrasonic sensing

Ultrasonic sensors installed in water-sensitive areas, such as the kitchen or bathroom, continuously monitor for leaks. If water is detected, the user's smartphone app is notified so they can respond quickly to avoid damage. The water tank is also continuously monitored, and as soon as the water level reaches 5, the pump will turn on to fill the tank and maintain the predetermined level. This system ensures continuous observation and automatic feedback, ensuring safety, comfort, and efficiency in the surroundings. Figure 8 represents an IoT-based water-level monitoring system using an ultrasonic sensor. A smart home utilises efficient water management through an ultrasonic sensor (HC-SR04). It measures the distance to the water level by emitting high-frequency sound waves and calculating the time to the echo. ESP32 calculates water level from the speed of sound and time-of-flight. When the water level reaches a preset level, the microcontroller turns on a 12V DC pump via a relay circuit to fill the tank. The pump turns off automatically as soon as the pre-set level is achieved. Water level data is also sent to an IoT dashboard for logging and monitoring. This type of automation prevents both water scarcity and overflow and saves resources in an eco-friendly manner.

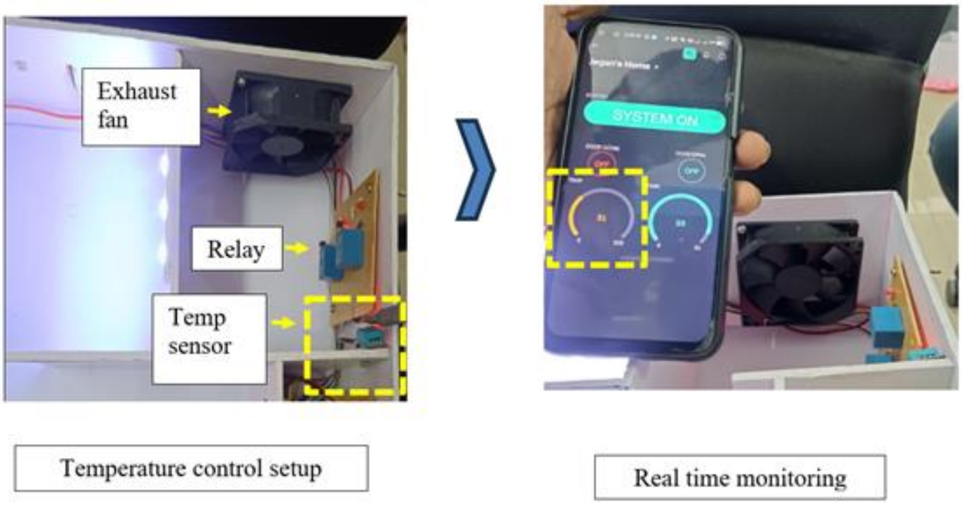

Figure 9: Automatic temperature control via relay-controlled fan and real-time mobile monitoring

The system is configured to detect and respond to various conditions via modules and sensors. The LDR 3900 sensor is always in the ON mode but turns OFF when the light intensity exceeds a certain threshold, indicating that the environment is sufficiently lit. Temperature is being monitored, and when it exceeds 32°C, the fan will automatically turn on to cool the environment. All home IoT smartphone apps allow for remote control of appliances, including fans, lighting, and other connected devices. The app displays all connected devices and allows users to turn them on or off, monitor water levels, and receive security notifications. Figure 9 shows IoT-based room temperature control and a real-time monitoring system.

Temperature control is achieved using the DHT11 sensor, which measures ambient temperature and humidity. The sensor uses a thermistor to sense temperature and a capacitive sensor to sense moisture. These are measured in analogue form and provided to the ESP32 controller, which computes them to make decisions, such as turning on fans or heaters automatically. For instance, if the room temperature is above 32°C, the microcontroller energises a relay that powers a cooling fan. Otherwise, at colder temperatures, the fan is turned off, thus saving energy. With this feedback loop integrated into a mobile IoT platform like Blynk, people can track temperature trends and remotely switch on/off devices. This closed-loop environment offers thermal comfort and energy efficiency through smart automation driven by sensors. Internet of Things-based Home Automation systems have tremendous potential to automate, monitor, and control household operations by leveraging data from devices and user input. The addition of gas detection, face recognition, temperature and humidity sensing, light control, and secure entry systems maximised convenience, security, and energy efficiency. Results and observations during system implementation and testing are listed below.

5. Results and Discussion

IoT Smart Home Automation Systems are a reliable solution for home function automation and management. Important findings and implications from the paper's outcomes are addressed below.

5.1. System Responsiveness and Reliability

The ESP32's performance as a master controller was flawless; it gathered data from various sensors and sent updates with minimal latency. Such a rapid response is essential for security applications, such as gas detection, where early warning can save damage. The convenience of the system, however, largely depends on the reliability of the internet connection used for remote monitoring. Under offline conditions, local automation (such as temperature-variable fan control or light automation) continues to function, but remote access is temporarily interrupted.

5.2. Energy Efficiency

Lighting control and appliance automation directly encouraged energy saving. The LDR efficiently reduced energy use by switching on the lights only when needed, while fan automation did not waste power by adapting to actual temperature readings. Proper energy management, particularly with a relay water pump, can reduce water and electricity bills, making the system both environmentally friendly and economically advantageous.

5.3. Security Enhancement

Face recognition provided a trusted, painless degree of security, perhaps more acceptable than PINs or keys. Face recognition capability, though, could be weakened by lighting conditions and camera input accuracy, so that the innovation could enhance it, for example, with infrared cameras. The ultrasonic sensor's ability to detect proximity was beneficial not just for security but also for monitoring water levels, demonstrating the versatility of some sensors across various applications.

5.4. Scalability and Expandability

It is highly expandable. Additional sensors, such as moisture, air quality, or vibration sensors, could be mounted to add more functionality. The modularity of the ESP32 and the system's use of conventional communication protocols make future additions simple. But additional sensors can impose power and processing requirements, which may require additional resources, such as power management solutions or latency-optimised code.

5.5. User Experience and Engagement

The buzzer feature of the AR-based monitoring and control offered a friendly, easy-to-use interface that was easy to see, enabling easy control of the system. This method is best applied to training new users to work with IoT systems. The mobile phone app interface provided clients with continuous, unbroken access to all system controls and feedback, and it met convenience expectations at the centre of a smart home installation. The system has a range of sensors and devices that respond to certain conditions. The LDR 3900 sensor is continuously under surveillance and remains in the ON condition. It turns OFF as soon as light intensity exceeds a certain threshold, so ambient lighting is enough. The temperature is carefully monitored, with a fan that automatically turns on when the temperature exceeds 32°C to cool and prevent overheating. In the case of high gas, when the gas sensor reads 3800, the buzzer and fan are ON, indicating a possible gas leak or dangerous situation and providing ventilation. There is also a door sensor that senses when the door opens and closes. Each time the door is opened or closed, the buzzer will ring to notify individuals of the movement and to serve as an audible security alarm. Finally, the system monitors the water tank level, and when the level reaches 5, a water pump starts, providing the tank with water as needed to maintain proper levels. Such an integrated system guarantees an instant response to environmental changes, promoting safety, comfort, and automation (Table 1).

Table 1: Components used in an IoT-based smart home automation system

Component	Features	Task
Gas Sensor (MQ-2)	Detects gases like LPG, methane, and smoke; provides analogue and digital output	Monitors air quality and detects harmful gases
LDR (Light Dependent Resistor)	Detects light intensity; low cost; analogue output	Used to sense ambient light levels
DHT11 Sensor	Measures temperature (0–50°C, ±2°C) and humidity (20–90%, ±5%)	Tracks environmental temperature and humidity
Ultrasonic Sensor (HC-SR04)	Measures distance (2–400 cm, ±3 mm); operates at 40 kHz	Detects object proximity or water level
DC Light	Low-power LED or incandescent bulb for DC operation	Provides illumination
Servo Motor (SG90)	Lightweight; rotational range 0–180°; torque ≈ 1.8 kg·cm	Controls precise angular motion, e.g., door or gate operation
ESP32 Controller	Central microcontroller for IoT and Wi-Fi capabilities	IoT and Wi-Fi capabilities
Buzzer	Produces sound; operates on 5–12V; small and lightweight	Provides alerts or alarms within the system
DC Pump	Operates on low voltage (6–12V); compact size; water flow 80–120 L/hr	Pumps water for small-scale irrigation or tank refilling
DC Fan	Operates on 5–12V; small size; low power consumption	Provides cooling or ventilation

6. Conclusion

The IoT-based home automation system implemented synergises various sensing and control mechanisms seamlessly into a single smart platform. All the modules synergise to deliver efficiency across the entire system—security, comfort, and energy savings. The use of a buzzer and gas sensor is an essential safety feature to prevent gas leakage, and the DHT11 sensor helps maintain accurate environmental conditions by enabling temperature-controlled devices. The energy waste in the LDR-controlled lighting system is reduced by the real-time response to natural light fluctuations, and the ultrasonic sensor enables efficient water management by automating the pump based on the current tank level. Door automation using facial recognition technology is also a progress in the right direction towards securing the home. Upon image-based verification, the system enables non-physical key- or intervention-based access control. The ESP32 microcontroller is the hub for data processing, acquisition, and communication, and is easy to integrate with hardware and the IoT platform. Worldwide, the system demonstrates how IoT technology can transform traditional homes into responsive smart environments. It is economical, scalable, and ideal for home and small business environments. Its future also focuses on innovations in cloud-based data analysis, voice-control system integration, and machine learning algorithms to anticipate user actions and enable further automation. In this paper, a solid foundation has been established for designing a secure, sustainable, and user-centric smart home environment.

6.1. Future work

An Internet of Things Smart House Automation System provides a solid foundation for automating and securing a home environment. Nevertheless, as practice advances and users' requirements continue to grow, there are many alternatives for extending the system further to enhance its functionality, performance, and usability. Some possible future extensions to the system's capability are described below.

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