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Low Cost IOT Based Smart Monitoring System

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***Abstract*—Abstract—Modern surveillance systems with motion detection are widely available. This paper presents a costeffective prototype for a smart monitoring system designed using Espressif's ESP32 microcontroller. The system incorporates motion-triggered image capture technology alongside a Passive Infrared (PIR) sensor.The monitoring system utilizes a PIR sensor and vibration sensor to detect motion and activate an ESP32 CAM module, which captures images of detected subjects. These images are then securely transmitted to a designated Telegram account over a continuous Wi-Fi connection. Additionally, a DHT11 sensor is integrated to measure environmental parameters like temperature and humidity, with the collected data uploaded to the ThingSpeak platform for remote monitoring and analysis. A connected bulb can also be controlled on demand, reducing power consumption and increasing energy efficiency. This intelligent system not only provides enhanced security but also contributes to sustainable energy management.**

Keywords—Internet of Things, PIR Sensors, Surveillance, Telegram Bot, ESP32 microcontroller, Low-cost, ThingSpeak.

I. INTRODUCTION

The integration of an ESP32 micro-controller with a PIR (Passive Infrared) sensor and a temperature sensor offers a versatile platform for creating IoT (Internet of Things) solutions that involve motion detection, environmental monitoring, and remote device control. The ESP32, known for its robust connectivity options and processing power, serves as the central control unit, facilitating communication between the various components.

The PIR sensor detects motion by sensing changes in infrared radiation within its field of view, while the temperature sensor provides real-time environmental data. By combining these components, developers can design smart systems capable of responding intelligently to environmental cues, making them ideal for applications ranging from home automation to industrial monitoring. This integration represents a fundamental building block for creating sophisticated IoT solutions that enhance efficiency, convenience, and safety in diverse settings.

The ESP32 serves as the computational hub, harnessing its processing capabilities and connectivity features to orchestrate the interaction between the disparate components. The PIR sensor, a staple in motion detection systems, detects changes in infrared radiation caused by movement, providing a reliable means of identifying activity within its detection range. Complementing this, the temperature sensor offers insights into environmental conditions, enabling monitoring and control in scenarios where temperature regulation is crucial.

This integration not only showcases the versatility of the ESP32 platform but also underscores its role as a catalyst for innovation in the realm of IoT, driving the development of smart, interconnected systems that redefine the way we interact with and manage our environments. With its seamless integration of diverse sensors and robust computational capabilities, the ESP32 ecosystem presents a fertile ground for the realization of sophisticated IoT solutions that promise to revolutionize industries and enhance the quality of life for individuals worldwide.

II. RELATED WORK

In recent years, the integration of IoT and smart monitoring systems has gained significant attention in enhancing security through motion detection and remote communication technologies. This literature survey examines several key implementations, highlighting their innovations, applications, and limitations in the context of modern security needs.

Indoor sensors are crucial for optimizing energy saving, thermal comfort, visual comfort, and indoor air quality in buildings. They play a significant role in connecting environmental variables with building control systems, thus impacting occupant productivity and health. Challenges for enhancing indoor environmental quality and energy efficiency are explored in this context [1].

Similar concepts are reflected in various smart home systems that utilize low-cost, flexible technologies. For instance, the integration of sensors with Arduino Yun microcontrollers´ allows remote control and monitoring via Android apps, enhancing usability and scalability [2].

Additionally, IoT-based smart home controllers, such as those using NodeMCU Lua V3 microcontrollers and Telegram chat applications, offer effective home automation by integrating fire, motion, temperature, and humidity sensors, providing a cost-effective and power-saving solution [3].

The focus on integrating facial recognition and home automation highlights the potential for enhanced security and convenience. IoT-based face detection approaches for smart home automation are discussed, emphasizing gaps, challenges, and future research directions [4].

Similarly, smart home control systems using ESP32 microcontrollers and Telegram chat for automation show lowcost, efficient solutions for lighting and environmental monitoring, with accurate sensor readings and minimal alarm delay [5]. These systems also extend to home security monitoring using Raspberry Pi, integrating PIR sensors, cameras, and various environmental sensors to provide real-time alerts via Telegram, thereby enhancing home safety [6][7].

The design and implementation of object motion detection systems, including those utilizing Telegram for notifications, aim to improve home security by providing immediate alerts about detected motion [9].

IoT-based intelligent smart home control systems and agricultural surveillance systems further demonstrate the integration of sensors for real-time data and remote management, enhancing efficiency in both home and agricultural environments [10][11].

Low-cost smart home systems and prototypes, including those with Arduino and IoT Cloud integration, emphasize affordability and practical applications [12][13].

Real-time monitoring systems combining IoT technology with Telegram bots provide effective surveillance and userfriendly remote management for home security [14].Similarly, systems for plant monitoring and smart home security using Telegram chatbots and ESP32-CAMs address environmental monitoring and intrusion detection, providing real-time updates and control [15][16][18].

The development of low-cost prototypes and surveillance systems utilizing ESP32-CAMs and Raspberry Pi for video monitoring and data storage addresses issues of cost, efficiency, and data management [19][21][22].

III. METHODOLOGY

Fig 1, proposed system comprises several components, including the ESP32-CAM, PIR sensor, DHT11 sensor, and a relay module. The ESP32-CAM serves as the primary processingunit, capturing images upon motion detection and sending them to a pre-configured Telegram account. The DHT11 sensor monitors environmental conditions, while the relay module controls external devices such as a connected bulb to optimize power usage. The methodology is detailed and well-structured, providingclear descriptions of the components used and their integration.Including more technical specifications and diagrams (e.g.,circuit diagrams) would enhance the understanding of the system setup. A flowchart (as mentioned) is included but could be more detailed to show step-by-step processes.

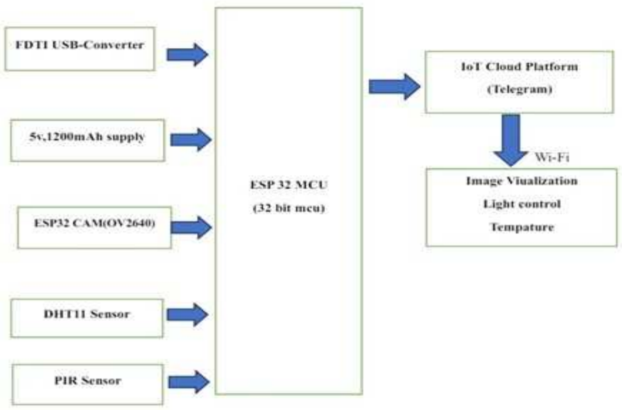

Fig. 1. Proposed Block Diagram

A. ESP32 CAM

The ESP32 microcontroller comes equipped with a built-in camera and multiple input/output pins, as shown in Fig. 2. This versatile design allows seamless integration of multiple sensors or devices in a single setup. One of the most significant advantages of the ESP32 is its affordability compared to similar microcontrollers, combined with a rich set of features, including its onboard camera, making it an ideal choice for projects requiring multi-sensor configurations.

B. TTL Programmer

Serial communication plays a vital role in debugging and transferring data during project development. The ESP32 supports serial input and output through UARTs (Universal Asynchronous Receivers/Transmitters), enabling efficient data transfer between the microcontroller and a computer. This communication method, known as TTL (Transistor-Transistor Logic), is handled via a TTL programmer. Fig. 2 illustrates the connection setup between the ESP32 CAM module and the TTL programmer, showcasing the simplicity of this communication interface.

C. PIR Sensor

The Passive Infrared (PIR) sensor detects motion by measuring infrared radiation emitted by objects with temperatures above absolute zero. This system utilizes the PIR sensor to identify human movement by sensing body heat. When motion is detected, the sensor activates and triggers the ESP32 to capture an image. The PIR sensor employs pyroelectric sensors that focus heat energy onto the detection surface through a series of lenses, maximizing the sensor's range and coverage. The frame size of the camera module can be configured before programming the ESP32 for optimal performance.

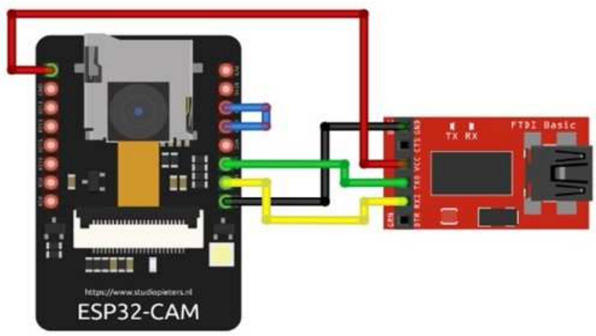

Fig. 2. Connection Of ESP32 With TTL Programmer

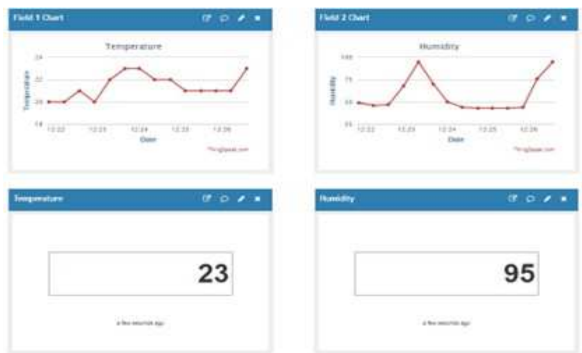

Fig. 3. Thingspeak Dashboard Example

D. DHT11 Sensor

The DHT11 is a cost-effective sensor widely used for measuring temperature and humidity. It features a capacitive humidity sensor and a thermistor to sense environmental conditions, outputting data digitally. Known for its ease of use, the DHT11 delivers temperature accuracy of ±2°C and humidity accuracy of ±5

E. Breadboard

The breadboard is a solderless prototyping tool that allows users to create and experiment with temporary circuit designs. It features numerous small holes that serve as connection points for components and wires. The top and bottom rows of the breadboard are linked horizontally, typically functioning as power rails for positive and negative connections, enabling a streamlined design process.

F. Telegram Bot

Telegram bots are automated tools designed to interact with users via the Telegram messaging platform. These bots are particularly valuable in IoT systems, where they facilitate realtime communication. In this setup, the Telegram bot receives data from sensors, such as motion or environmental sensors, and sends notifications to users. Additionally, it allows remote control of connected devices, offering a convenient interface for managing IoT applications with simple commands.

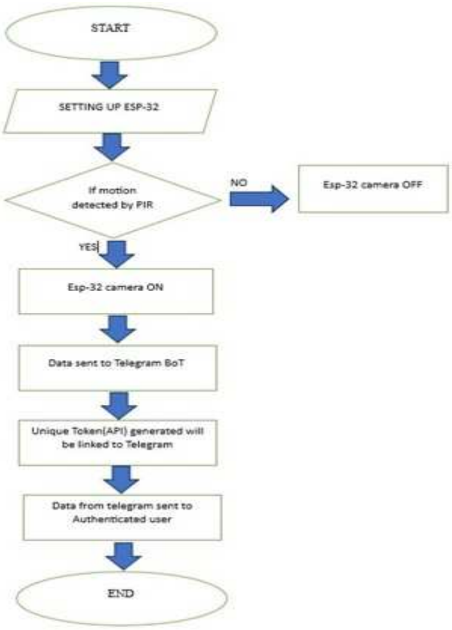

Fig. 4. Flow Chart Of Proposed Model

G. ThingSpeak

ThingSpeak is a powerful IoT analytics platform that enables users to collect, visualize, and analyze live data streams in the cloud. Using HTTP and MQTT protocols, the platform aggregates data from connected devices for real-time monitoring and analysis. Users can generate charts, perform advanced calculations, and integrate third-party tools like MATLAB to expand the system's capabilities. Fig. 3 showcases a ThingSpeak dashboard, demonstrating how it can efficiently track and display sensor data.

IV. Implementation

The integration of an ESP32 microcontroller with a PIR (Passive Infrared) sensor and temperature sensor provides a versatile IoT platform for motion detection, environmental monitoring, and remote device control. When the PIR sensor detects motion by sensing changes in infrared radiation, it sends a signal to the ESP32. Additionally, the ESP32 can capture an image using its camera module shown in Fig.5 and Fig.6 and send an alert to a designated Telegram account shown in Fig.7, allowing users to receive real-time notifications of motion events.

The temperature sensor continuously monitors the ambient temperature and humidity and provides real-time data to the ESP32. This data can then be uploaded to a cloud service like ThingSpeak for remote monitoring and analysis shown in Fig.6. By accessing ThingSpeak, users can monitor environmental conditions from anywhere in the world. If the temperature exceeds a predefined threshold, it can send

Fig. 5. 640x480 Dimension

alert message to users through telegram Bot. The ESP32's WiFi capabilities ensure seamless communication with remote servers and devices, enabling real-time updates and remote control, making this system ideal for home automation, security systems, and industrial monitoring.

The integration of an ESP32 microcontroller with a PIR sensor, temperature sensor, camera module, and relay module presents a cost-effective and reliable IoT solution.The ESP32, being multifunctional and inexpensive, reduces overall system costs, while the PIR and temperature sensors offer affordability without compromising functionality. Although the camera module is slightly pricier, it remains within a reasonable budget for its capabilities. Reliability is ensured by the ESP32's robust performance and extensive library support, while the sensors and camera generally perform dependably, though environmental factors may occasionally affect sensitivity. Together, these components create a durable system suitable for both home automation and industrial applications.

Integrating an ESP32 microcontroller with a PIR sensor, a temperature sensor, and a camera module creates a powerful and flexible IoT platform for comprehensive monitoring and control. The PIR sensor detects motion by measuring changes in infrared radiation, which triggers the ESP32 to initiate a series of actions. Simultaneously, the ESP32 can capture images using the camera module, providing visual confirmation of detected motion. This captured image, along with the motion alert, can be sent to a designated Telegram account, enabling real-time notifications to users. The temperature sensor continuously measures ambient temperature and humidity, transmitting this data to the ESP32. The ESP32 then uploads this data to a cloud service such as ThingSpeak, where it can be accessed remotely for ongoing monitoring and analysis. The ESP32's integrated WiFi capability ensures seamless communication with the cloud service and remote devices, making it ideal for applications in home automation, security systems, and industrial monitoring. This setup allows users to monitor environmental conditions and receive alerts from anywhere in the world, offering both real-time and historical insights.

Fig. 6. Setup Overview: ESP32 With TTL Programmer

V. Results and Discussions

To set up the ESP32 module with the TTL programmer on the breadboard, carefully connect the components as follows. Use jumper wires to attach the VCC (3.3V) pin of the ESP32 to the VCC of the TTL programmer. Then, link the UOR pin of the ESP32 to the TX pin of the TTL and the UOT pin of the ESP32 to the RX pin of the TTL. Next, connect the GND pin of the ESP32 to the GND of the TTL. To enable programming mode, also connect the GND of the ESP32 to its IO0 pin. Finally, attach the USB port of the TTL programmer to your computer. This setup is illustrated in Fig. 8.

A. Steps to Retrieve API Pin and Chat ID from Telegram

- Install the Telegram application on your smartphone or other device.
- In Telegram, search for "BotFather" and press the "Start" button.
- Type the command "/newbot" to begin creating a new bot.
- Provide a name for your bot (e.g., "Motion Trigger").
- Assign a unique username for your bot. Upon successful creation, an API token will be displayed—make sure to save it.
- Open Telegram, locate your bot by its username, and click "Start" to activate it.
- Search for "Get ID Bot" in Telegram, start it, and follow the instructions to obtain your unique chat ID.

B. Uploading Code In Arduino IDE

Launch the Arduino IDE and configure it as follows: - Select "ESP32 Wrover Module" under the "Board" option in the Tools menu. - Set the upload speed to 921600, flash frequency to 80 MHz, flash mode to QIO, and partition scheme to "Huge App." - Choose the correct COM port (e.g., COM11) and ensure the core debug level is set to "None."

Connect the TTL programmer to your computer and begin uploading the code. During the upload process, press the reset button on the ESP32 module to enter programming mode. After the code has been uploaded successfully, remove the

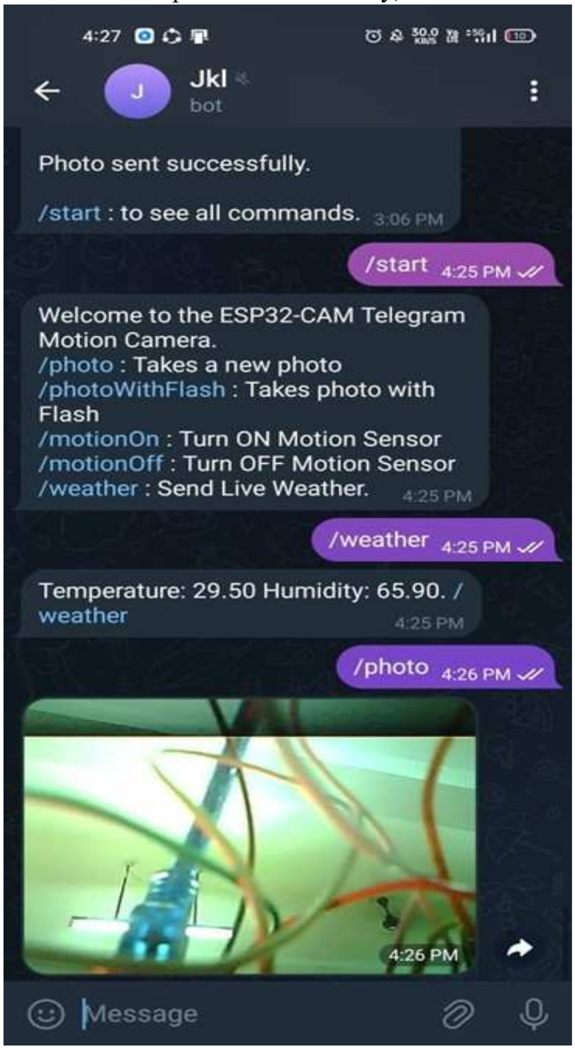

Fig. 7. Telegram Bot Interaction For Alerts

jumper wire between the IO0 and GND pins. Open the serial monitor in the Arduino IDE, set the baud rate to 115200, and reset the ESP32 CAM module. Within a few moments, the serial monitor will confirm a successful connection to telegram.org and display the unique IP address for the web server hosted by the ESP32 CAM, as shown in Fig. 9.

C. Finalizing Connections With The PIR Sensor

Once the code is uploaded, connect the VCC of the PIR sensor to the VCC pin of the ESP32. Attach the output pin of the PIR sensor to the IO13 pin of the ESP32 and connect the GND of the PIR sensor to the ESP32's GND using jumper wires. Ensure that all connections are secure and place the module in a fixed position with continuous internet access for both the ESP32 and the connected mobile device. Fig. 8 shows the complete setup after all connections are made.

D. Quantitative Data and System Performance

The integration of the ESP32 microcontroller with a PIR sensor, temperature sensor, and camera module demonstrates

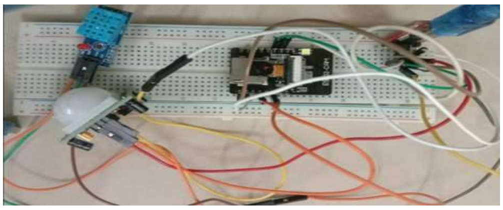

Fig. 8. Proposed Prototype

effective performance in motion detection and environmental monitoring. The PIR sensor offers a quick response time of 12 seconds for motion detection, ensuring timely alerts through the Telegram bot. The accuracy of motion detection depends on sensor placement and field of view, which can be adjusted to suit specific needs. The temperature and humidity sensors, with accuracies of ±1°C and ±2

Despite its strengths, the system has limitations. The PIR sensor's range can be impacted by environmental factors and obstacles, while the temperature and humidity sensors may experience drift or accuracy loss over time. Connectivity issues, due to reliance on WiFi, can disrupt real-time data transmission and notifications, affecting system reliability. Regular calibration and optimal sensor placement are essential to maintaining accuracy.

Future enhancements could focus on improving sensor accuracy, incorporating additional sensor types for broader monitoring, and advancing image processing capabilities. Implementing alternative communication methods or backup systems could address connectivity issues and enhance overall performance. While the current system is robust, these upgrades could further refine its effectiveness for smart home and industrial applications.

Overall, the integration of these technologies results in a robust system that not only improves security through realtime alerts and image capturing but also provides valuable environmental data and contributes to energy efficiency through smart lighting control. The successful implementation of this project demonstrates the potential of combining IoT devices for enhanced security, environmental monitoring, and energy management in a smart home setting.

VI. CONCLUSION

This work highlights the effective implementation of an IoT-enabled system for integrated motion detection, humidity, and light control, optimized for smart environments. The motion-triggered image capture, paired with Telegram notifications, demonstrated a response time of around 5 seconds. This system is highly applicable in scenarios requiring uninterrupted monitoring, provided a stable Wi-Fi connection is maintained. Its compact design ensures ease of installation in areas where security is a key concern.

The system also ensures functionality during low-light or power outage scenarios by enabling flash photography. Dashboards are incorporated to provide a visual representation of temperature and humidity data, which is stored and processed

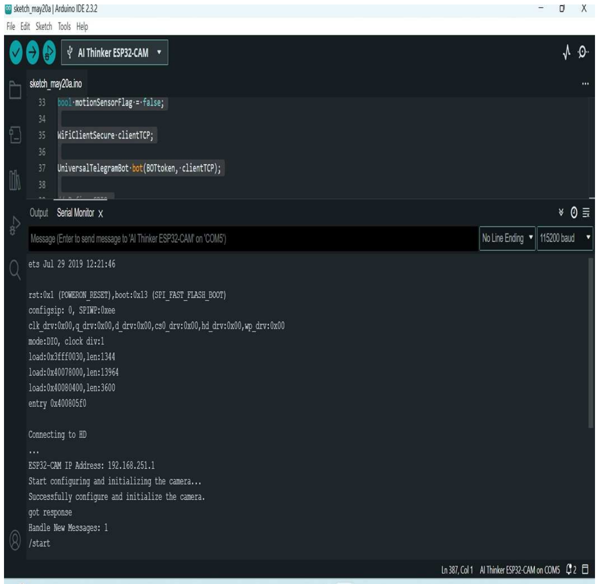

Fig. 9. Picture Of Uploading Code To ESP-32

via cloud services. Additionally, the system supports energy conservation by deactivating power to devices when no activity or human presence is detected in the monitored space.

Additionally, the camera pixel depth is reduced by 30 percent reduction compared to traditional CCTV cameras, further enhancing storage and processing efficiency without compromising essential image quality for security purposes. This includes the implementation of deep learning architectures, such as EfficientNet, to improve the resolution of captured images and facilitate advanced processing tasks like object detection and classification. Real-time weather conditions of the room, including humidity and temperature, are monitored, which are crucial parameters in explosive industries to ensure timely responses and maintain safe environmental conditions.

Looking ahead, future research should focus on enhancing the accuracy of sensors and integrating additional types of sensors to broaden the system's capabilities. Advances in image processing technology could further optimize data handling and improve image quality. Addressing potential WiFi connectivity issues through alternative communication methods or backup systems would also be valuable. Expanding the system's integration with other smart home or industrial IoT devices could enhance its utility and provide further opportunities for innovation.

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