Smart Home Security Using IoT: An Integrated Approach with ESP32 Microcontroller

Kunal Rane, Dharmik Rathod, Diya Wade, Siddhi Shivgan, Ulhaskumar Gokhale
Electronic and Telecommunication Atharva College of Engineering Mumbai, India

Abstract: ***The project "Smart Home Security with IoT" aims at transforming residential security systems to use an ESP32 microcontroller platform. Different sensors such as PIR MQ2 smoke, and flame sensors; with a module of PZEM004T, for acquiring electrical parameters, with the help of ESP32 Cam board, carrying out real-time image processing automatically, along with the control lock for the entrance door. The system can be managed by a custom-built Android application in Kodular and allows users to monitor and control devices remotely. Alerts, such as captured images in the case of security breaches, are sent via Telegram for prompt response from the user. This project shows the capabilities of IoT to improve security with real-time monitoring, multi-sensor integration, and remote management.***

Keywords: ***IoT, Smart Home Security, ESP32 Microcontroller, Home Automation, Security System, PIR Sensor, Smoke Detection, Flame Sensor, Energy Monitoring, Real-Time Monitoring, Image Processing, Telegram Notifications, Android Application, Kodular***

I. INTRODUCTION

Smart home technology is transforming the residential environment through the inclusion of automation and superior security systems. The rise in the rate of urbanization has heightened the demand for effective home security solutions. The proposed system surmounts the issues of the conventional security system, which fails to provide multiple functionalities and lacks remote access through the facilities of the ESP32 microcontroller. The proposed solution will incorporate motion detection, smoke sensing, fire detection, and energy monitoring with real-time image processing and remote access to the device.

This project focuses on developing a smart home security system using the ESP32 microcontroller, an affordable yet powerful platform known for its wireless communication capabilities and extensive support for IoT applications.

The ESP32 microcontroller is at the core of this project, chosen for its versatility, low power consumption, and built-in Wi-Fi and Bluetooth connectivity. The system uses PIR sensors for motion detection, MQ2 sensors for smoke detection, flame sensors for fire detection, and a PZEM004T module to monitor electrical parameters. Additionally, an ESP32 Cam board is employed to capture images and control an automatic door lock using image processing techniques. The entire system is controlled via an Android application developed on Kodular, which allows users to manage connected devices and receive alerts remotely.

One of the key features of this system is its ability to send real-time images to the user via Telegram, providing instant visual feedback during security breaches. This adds a layer of security by enabling users to verify and respond to threats promptly. The integration of multiple sensors and IoT technology ensures comprehensive monitoring and control, making this system a significant advancement over traditional home security solutions.

II. LITERATURE SURVEY

In [1], the authors propose an IoT-enabled design framework for the security sector. The conceptual model developed for the IoT-based Home Security System has been built using the fundamentals of IoT Layered Architecture feature. In [2] the authors present a design and prototype implementation of a new home automation system that uses Wi-Fi technology as a network infrastructure connecting its parts. In [3] the authors proposes the use GSM based security system to enhance the security. In [4], the author proposed the home appliance control system based on GSM network technology is used for transmission purposes of SMS from the sender to the receiver. SMS sending and receiving is used for universal access of appliances which is allowing breach control at home. In [5], the author designed a standalone embedded board with Android ADK (Accessory Development Kit) at home. The appliances of home are connected to the ADK and communication is established between the Android mobile device and ADK.

In [6], Home automation is becoming popular due to its numerous benefits. Home automation refers to the control of home appliances and domestic features by local networking or by remote control. In [7], In recent years, there has been a growing interest among consumers in the smart home concept. The home automation system represents and reports the status of the connected devices in an intuitive, user-friendly interface allowing the user to interact and control various devices with the touch of a few buttons. Some of the major communication technologies used by today's home automation system include Bluetooth, Wi-MAX and Wireless LAN (Wi-Fi), ZigBee, and Global System for Mobile Communication (GSM). In [8], Internet of Things is a concept where each device is assigned to an IP address and through that IP address anyone makes that device identifiable on Internet. In [9], IoT has received much attention from scientists, industry, and governments all over the world for its potential to change modern-day living. In [10], the Home Automation System uses the technology of Internet of Things for monitoring and controlling of the electrical and electronic appliances at home from any remote location by simply using a Smartphone.

III. METHODOLOGY

The Smart Home Security System project incorporates various features to create a comprehensive health monitoring device with a focus on accessibility, portability, and cost-effectiveness. Here's a detailed explanation of each key feature:

1. Hardware Implementation:

-The ESP32 Cam board is used to implement an image processing system that captures images when motion is detected. These images are then processed to determine whether to trigger the automatic door lock, adding an extra layer of security. The ESP32 Cam board also sends captured images to the user's Telegram account, ensuring real-time visual alerts.

-The 4-channel relay module is employed to control three household devices and one door lock. These devices can be managed remotely via an Android application developed using Kodular. The application provides an intuitive user interface, enabling users to monitor sensor data, control connected devices, and receive alerts.

2. Software Development:

-The communication between the ESP32 microcontroller and the Android application is facilitated through Wi-Fi, allowing real-time updates and control. The project also includes the integration of a cloud platform for data storage and retrieval, ensuring that sensor data and images are securely stored and accessible to the user.

-The detected heart rate, along with any diagnostic alerts, is then displayed on the I2C LCD screen. Additionally, the ESP32 is programmed to transmit the ECG data to a cloud server using its Wi-Fi capability.1

3. Communication and Control:

-The system integrates sensors and actuators using Wi-Fi for real-time updates. The Android application acts as a control interface, enabling remote monitoring and management. Notifications, including images, are sent to the user's Telegram account for immediate action.

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4. Testing and Validation:

-The final phase involves rigorous testing of the entire system, including hardware, software, communication control-ESP32 Microcontroller, and Android Application is tested in various conditions to ensure reliability, accuracy, and user-friendliness.

IV. BLOCK DIAGRAM

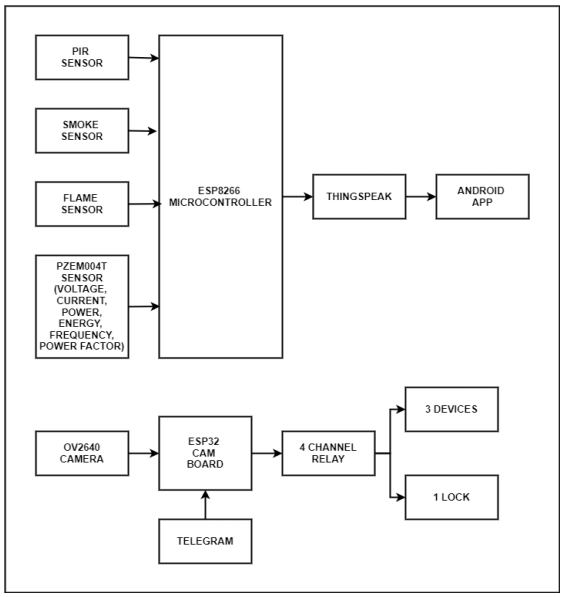

Fig. 1. Block Diagram

The "Smart Home Security with IoT" project focuses on enhancing residential security by leveraging the ESP32 microcontroller platform. This system integrates multiple sensors and modules to create a comprehensive, real-time home monitoring solution. It includes a PIR sensor for motion detection, an MQ2 sensor for smoke detection, a flame sensor for fire alerts, and a PZEM004T module for monitoring electrical parameters like voltage, current, power, energy consumption, frequency, and power factor. These components work together to ensure that the home environment is constantly monitored for any anomalies or potential security threats.

CIRCUIT DIAGRAM:

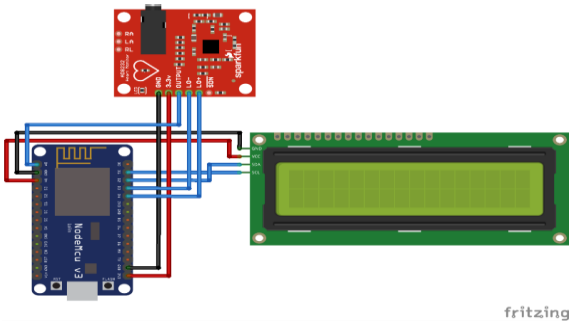

Fig. 1. Circuit Diagram

V. WORKING

In addition, the ESP32 Cam board is utilized for real-time image processing, which plays a crucial role in the automatic door lock system. The camera captures images when movement or other triggers are detected, enhancing the overall security by allowing visual confirmation of any potential intrusions. A 4-channel relay module is also integrated into the system, enabling control over three household devices and the door lock

All of these features are managed via a custom Android application built using Kodular, allowing users to remotely monitor and control devices from their smartphones. The system offers users flexibility in managing their home's security, with remote access ensuring they can react to threats even when away from home. Notifications, including images captured during security breaches, are sent to the user through Telegram, providing immediate alerts for timely response

By combining sensors, real-time image processing, and remote control, the "Smart Home Security with IoT" project demonstrates the potential of IoT in safeguarding homes. It provides a robust and efficient security solution, ensuring that users can monitor their homes in real-time and address any potential threats quickly and effectively. This system not only increases security but also empowers users with the convenience and peace of mind that comes from being able to control and monitor their home environment from anywhere.

VI. SOFTWARE USED

1. Fritzing:

Fritzing is an open-source hardware initiative that makes electronics accessible as creative material for anyone. We offer a software tool, a community website, and services in the spirit of Processing and Arduino, fostering a creative ecosystem that allows users to document their prototypes, share them with others, teach electronics in a classroom, and layout and manufacture professional PCBs

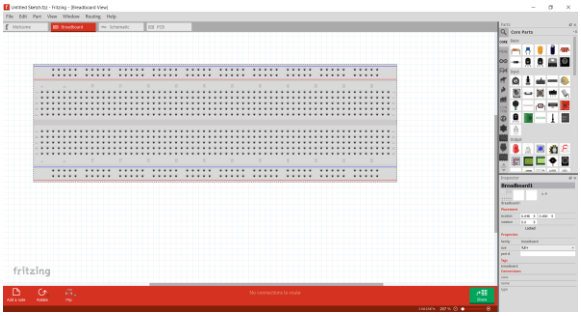

Fig.3. Fritzing Software.

2. Arduino IDE

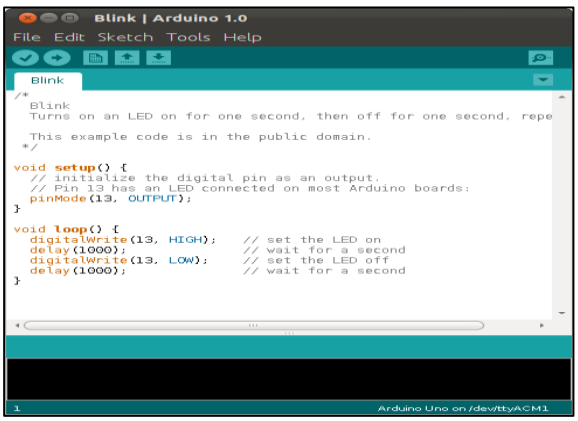

Fig.4. Arudino IDE Software

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino board. The source code for the IDE is

released under the GNU General Public License, version. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

3. ThingSpeak

Fig.5. ThingSpeak Software

According to its developers, "ThingSpeak is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP and MQTT protocol over the Internet or via a Local Area Network. ThingSpeak enables the creation of sensor logging applications, location tracking applications, and a social network of things with status updates".

ThingSpeak was originally launched by ioBridge in 2010 as a service supporting IoT applications.

ThingSpeak has integrated support from the numerical computing software MATLAB from MathWorks, allowing ThingSpeak users to analyze and visualize uploaded data using Matlab without requiring a Matlab license from Mathworks. ThingSpeak has a close relationship with Mathworks Inc.

VII. CONCLUSION

In conclusion, the "Smart Home Security with IoT" project presents a highly effective solution for enhancing residential safety. By integrating various sensors like PIR for motion detection, MQ2 for smoke, and flame sensors, along with real-time image processing through the ESP32 Cam, the system offers comprehensive monitoring and protection against potential threats. The use of an Android app for remote control and Telegram notifications provides convenience and ensures immediate response during security breaches. Additionally, the inclusion of the PZEM004T module allows users to monitor their home's energy consumption, contributing to both safety and energy efficiency.

However, the system's reliance on internet connectivity and potential privacy concerns must be addressed for broader adoption. Despite these limitations, this project demonstrates the transformative potential of IoT in home security, offering a robust, cost-effective, and scalable solution that empowers users with real-time control and peace of mind.

VIII. REFERENCES

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