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Machine Learning and IoT Enabled Fusion of Face Recognition Based Door Lock System and Hand Gesture Controlled Smart Home

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ABSTRACT: To improve home automation and security, this paper presents a comprehensive combination of machine learning (ML) and Internet of Things (IoT) technology. It combines gesture-based appliance control for user-friendly automation, face recognition-based door lock technology for safe access, and Internet of Things-based remote control of household appliances. ML algorithms are utilized by the face recognition-based door lock system to precisely identify authorized users, guaranteeing safe and easy entrance to the premises. Furthermore, users can operate various home appliances using a hand gesture-controlled interface, which improves efficiency and convenience. Moreover, IoT connectivity makes it possible for homeowners to remotely operate their home appliances, giving them access to do so from any location with the help of smartphones or other linked devices. For contemporary homeowners, this integration provides a complete solution that offers improved security, convenience, and control over

KEYWORDS: Machine Learning; Manets; Internet of Things; appliances; automation

I. INTRODUCTION

The rapid evolution of smart home technology has significantly transformed our daily routines, simplifying tasks and prioritizing security. Outdated door locks, susceptible to manipulation, are being replaced by robust biometric authentication methods like facial recognition, ensuring the safety of our homes. Additionally, for individuals with limited mobility, the ability to control household appliances from the comfort of their beds is made possible through gesture recognition technology, enhancing accessibility and convenience. The incorporation of machine learning algorithms further enhances these technologies, continually refining accuracy and performance. With the integration of IoT connectivity, remote management of home appliances becomes effortless, reducing energy consumption and optimizing efficiency. Ultimately, this paper aims to investigate the viability and effectiveness of merging facial recognition door locks with gesture-controlled smart home functionalities. Through the utilization of machine learning and IoT capabilities, this system seeks to offer users a secure, user-friendly, and forward-thinking solution for accessing and managing their smart homes.

II. RELATED WORK

Python is favoured over MATLAB in image processing due to its cost-free accessibility and robust computer vision libraries. In a study [1] comparing blob analysis for fruit detection across MATLAB, Python, and SCILAB, it was discovered that Python exhibited quicker response times for object detection in both video clips and images compared to SCILAB and MATLAB. This advantage is attributed to Python's efficient utilization of well-established CV libraries, particularly OpenCV, which are implemented in C/C++.

[2] explores various facial recognition techniques like Linear Discriminant Analysis (LDA) and Principal Component Analysis (PCA) in the context of a door-locking system based on facial recognition. The model utilized Haar Cascade Classifier for face detection and the Eigenface method for face recognition, achieving successful face detection and recognition. However, it did not incorporate any Internet of Things (IoT) applications. It's worth noting that while Eigenface is effective, it tends to have lower accuracy compared to algorithms like LBPH.

In [3], the system operates with two main phases: first, the creation of a database by storing images, and second, the comparison of new images with those in the database for facial recognition using the LBPH algorithm. Raspberry Pi is

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preferred over a PC for its physical convenience. Additionally, an alert system via GSM is integrated to notify when an authorized person opens the door.[4] discusses facial recognition utilizing the Eigenfaces algorithm, which has a limitation in accurately recognizing faces from frontal views only.[5] details hand gesture detection and recognition, where the grayscale image of the hand is separated from the background using Otsu's thresholding method. OpenCV's Haar Cascade Classifier is then employed to track the hand gesture. Although the system effectively recognizes hand movements under typical lighting conditions, its performance is affected by variations in lighting environments.

[6] utilizes Raspberry Pi, Python, and the OpenCV library for gesture recognition. The implementation involves converting captured frames to grayscale to rectify Regions of Interest (ROI), followed by background removal through segmentation. Hand counters are drawn twice for optimal clarity. To generate enough template vectors for various experimental cases, each of the five directional gestures is practiced fifteen times across four different experimental cases, resulting in seven stored templates.[7] introduces a palm detection model and a hand landmark model. Initially, the palm detection model is trained due to the challenge of detecting hands with hinged fingers. The hand landmark model then prepares a key point layout of twenty-one three-dimensional coordinates of the hand's knuckles through regression after palm detection. Preprocessing is carried out using the CV2 library, while hand landmark detection is facilitated by the MediaPipe library, which offers a vast collection of models trained on diverse Google datasets. Following hand landmark detection, data cleaning and normalization are performed, followed by prediction using machine learning algorithms such as Support Vector Machines (SVM). This model achieves accurate hand gesture recognition.

[8] presents a home automation model utilizing Blynk as an IoT platform. NodeMCU, controlled through 4-channel relay modules, manages household appliances, enabling remote control for users. The proposed system offers user-friendly convenience, employing the Blynk mobile application as its interface.From [9], it's evident that the proposed model aims to introduce automation into homes. Household appliances connect to NodeMCU via relay modules, with control facilitated remotely through the Blynk application. This system, incorporating Blynk and NodeMCU, serves various purposes such as lighting and fan control, temperature monitoring, and early warning functionalities.

III. PROPOSED SYSTEM

Here, a prototype is created. The model is designed to demonstrate the project concept with various interconnected components. A webcam captures images of faces and hand gestures, which are processed by computer software to recognize them. A servo motor represents the door, while the NodeMCU controls the fan and light via a relay module. When a face is recognized, the computer instructs the NodeMCU to activate the motor. Likewise, appropriate gestures trigger the relay module to operate the fan and light. Users can also remotely control these components using the Blynk application through the internet when in Manual mode. In Auto mode, face recognition and gestures recognition are used for local control.

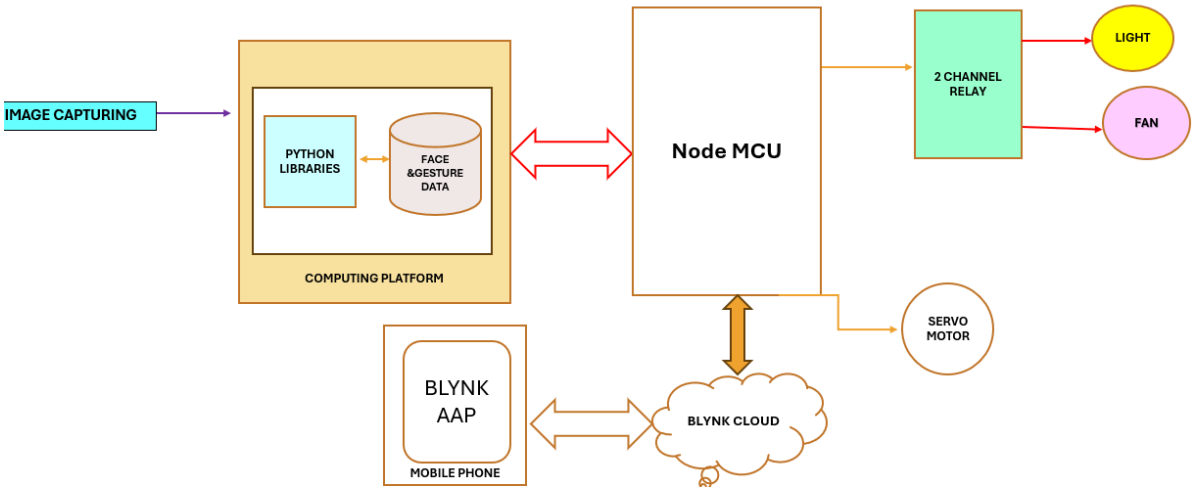

Fig.1: Block Diagram of the Model

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IV. HARDWARE AND SOFTWARE COMPONENTS

A. NodeMCU ESP 8266

Fig.2: Node MCU ESP8266

The model utilizes the NodeMCU ESP8266, a cost-effective Wi-Fi chip primarily employed in IoT applications. NodeMCU serves as the development board for ESP8266, incorporating the chip itself. With 17 general-purpose input-output pins, 11 are utilized while the remaining 6 facilitate communication with onboard flash memory chips and pulse width modulation. This microcontroller boasts UART, SDIO, IR remote control peripherals, SPI, and I2C functionalities. Firmware upgrades are conducted via OTA or UART download. Operating voltage spans from 2.5V to 5V, with an average current rating of 80mA, rendering it a robust component for the system.

B. Dual Channel Relay Module

It is used here to control fan and light. The low power electric signals like signal from computer can be used to control the dual channel relay so that it can be said that it works as an electric switch. By using this, high power devices such as motor, fan. Etc can be controlled from computer on phone.

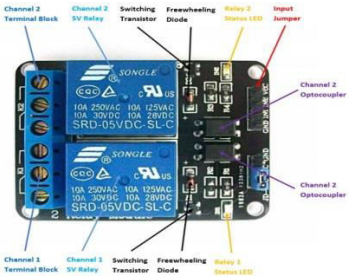

Fig.3: Dual Channel Relay Module

C. Servo Motor (SG90)

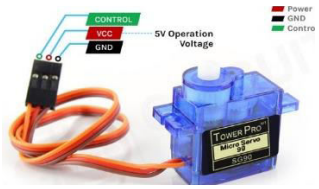

Fig.3: Servo Motor

This model uses servomotor to represent closing and opening the door. It is very small in size and high output power. Precise control of angular motion can be done by this servo motor

D. Python- Version 3.8.10

Python is the primary programming language for this project. It is an object-oriented programming language. Here Python is used for implementing the functionalities such as face detection, face recognition, gesture recognition and device control. It is an interpreted language. It has simple syntax.

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E. OpenCV (Open-Source Computer Vision Library)

This library is employed for conducting computer vision tasks, specifically handling face detection and recognition. OpenCV integrates algorithms and predefined functions for these purposes. Within OpenCV, the Haar Cascade Classifier is utilized to detect faces, while LBPH (Local Binary Pattern Histogram) is employed for face recognition.

F. Media Pipe

In this project, the system utilizes MediaPipe Hands for gesture detection and recognition. Developed by Google, MediaPipe Hands is a pre-trained solution designed to track hand and finger movements, forming a part of the broader MediaPipe framework. This solution offers a range of pre-trained models for computer vision tasks. Leveraging extensive datasets, MediaPipe Hands accurately identifies key points on hands and fingers. Optimized for real-time applications, it provides ease of use in implementation.

G. Arduino 1.8.19

This software tool, akin to Arduino's IDE, facilitates the writing, compiling, and uploading of code onto Arduino boards. It operates as an open-source platform, with version 1.8.19 introducing numerous improvements and bug fixes compared to its predecessors. Compatible with a broad spectrum of Arduino boards, it also extends support to third-party boards

H. Blynk

Blynk serves as an IoT platform comprising a mobile application, cloud service, and libraries designed for devices like Arduino and ESP8266. Its mobile app, available on both Android and iOS, acts as a conduit between users and their connected devices, allowing remote control. Users can craft personalized dashboards featuring buttons, sliders, and other widgets for device interaction. The Blynk cloud functions as the intermediary linking the mobile app to the target devices. Hardware integration with the Blynk platform is facilitated by dedicated libraries tailored for various hardware platforms

V. WORKING OF THE MODEL

A. Auto Mode

The system utilizes OpenCV's LBPH (Local Binary Patterns Histogram) algorithm for face recognition due to its balanced performance in accuracy and computational efficiency. It begins by loading a pre-trained model (train.yml) containing facial data of authorized users. Real-time face detection is achieved using the Haar Cascade classifier (haarcascade_frontalface_default.xml), operating on video frames captured by the laptop camera. Upon detecting a face, the system extracts its features and compares them with the trained model. If the confidence score of the match falls below a predefined threshold (set at 70 in this instance), the face is identified as belonging to an authorized user. Subsequently, gesture recognition is activated for further interaction. Users are assigned predefined IDs, and continuous successful recognition over 60 frames is required to confirm the user's identity before proceeding with further actions.

After successfully recognizing a face, the system initiates the gesture recognition module. This module utilizes Mediapipe's Hands solution to detect and interpret hand gestures. Mediapipe offers a convenient API for detecting hand landmarks and deducing gestures based on these landmarks. The system analyzes video frames to pinpoint hand landmarks and assesses which fingers are raised by comparing their positions. In this prototype, the recognized gestures involve raising between one and four fingers, each associated with specific actions such as controlling lights, fans, or doors. For example, raising one finger activates Light 1, while raising two fingers deactivates it. Similarly, raising three fingers turns on the fan, and four fingers turn it off. The system encodes these gesture commands and transmits them to the Arduino for execution.

The Arduino microcontroller, equipped with an ESP8266 module, handles the physical control of home appliances. It connects to the laptop via serial communication, receiving encoded commands based on recognized gestures. The Arduino setup includes a servo motor for door control and relays for managing the fan and light. When a command is received, the Arduino decodes it and performs the corresponding action. For example, a command to turn on the fan sets the relay to a low state, completing the circuit and powering the fan. Similarly, the servo motor adjusts to open or close the door based on the command.

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B. Manual Mode

In the manual mode of the face and gesture-based smart home automation system, users can control appliances directly through the Blynk mobile app. This mode provides a fallback mechanism when gesture recognition might not be practical or when multiple users need to interact with the system. Using the Blynk app, users can operate devices by interacting with virtual buttons, which correspond to specific virtual pins mapped to the Arduino microcontroller (ESP8266). For example, virtual pin V0 controls the servo motor for the door, V1 manages the fan, and V2 toggles the light. The app sends these control commands via Wi-Fi to the Arduino, which in turn actuates the connected devices. The Arduino processes these commands to either turn on/off the fan and light through relays or adjust the servo motor's position to open or close the door. This mode allows users to bypass automated control and maintain direct, real-time control over their home environment using a simple and intuitive interface on their mobile device. The manual mode enhances user convenience and system reliability by providing immediate and flexible control over the appliances, ensuring that the smart home system remains functional and accessible under various conditions.

VI. RESULT

The faces are effectively detected by Haar cascade classifier within the video feed. At varying lighting conditions, successful face detection is archived. After the recognition of face, the servomotor, controlled by NodeMCU , responded by rotating 90 degree .After some second ,the servomotor returned back to initial position, indicating closing the door

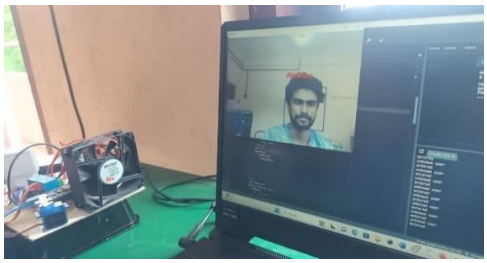

Fig:3. Result of Face Recognition-Known Person

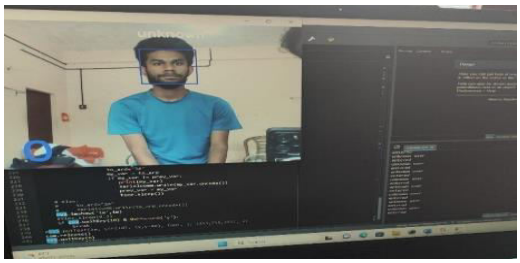

Fig:3. Result of Face Recognition: Unknown Person

Hand gestures are accurately detected by MediaPipe Hand. Then these gestures are translated into control signals for the devices. Each gesture (1 to 4 fingers) is recognized.
If finger count is one, light is turned on
If finger count is 2, light is turned off
If finger count is 3, fan is turned on
If finger count is 4, fan is turned off

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Fig:4. Result of hand gesture recognition

In manual mode, Blynk application provides direct control over servo motor (Door), light and fan. We can switch between auto and manual mode in Blynk application. The communication between the virtual pins and NodeMCU is effective. Proper internet coverage is required to avoid the delay.

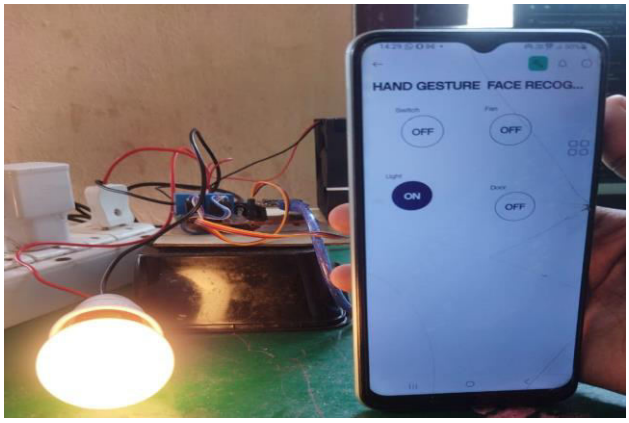

Fig: 5.Result of manual mode control by Blynk

VII. CONCLUSION

This system effectively integrates face recognition, hand gesture control and IoT technologies to automate home. The system can quickly identify faces and open the door. Also, devices can be controlled by hand gestures. The performance of the Blynk depends on Wi-Fi stability. While it performs well, system is sensitive to lighting condition. The important future improvement includess expanded gesture recognition, and additional security measures.
Overall, this project efficiently combines computer vision and IoT to create a responsive and adaptive smart home solution

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