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Gesture-Driven Home Automation System

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Abstract—
This project addresses the critical challenge of making home automation accessible and inclusive for individuals with physical disabilities and visual impairments. Existing home automation methods, such as voice control, mobile apps, and timers, exhibit shortcomings that hinder their effectiveness for this demographic. To overcome these limitations, the project shows the development of a gesture-based home automation system. This system integrates gesture recognition and security functionality. It operates in two stages: user authentication through face recognition and gesture-based appliance control. A Convolutional Neural Network (CNN) processes webcam-captured gestures, with signals relayed to an Arduino via Pyfirmata for appliance activation. A model was trained where it could detect the human hand(s) and more soshow the 20 landmarks that media pipe offers. The system worked well in controlling various home appliances using gestures. Through this innovative approach, the project contributes to the advancement of accessible smart home technology, fostering independence and inclusivity for users with diverse abilities.

Keywords— *Pycharm, Convolutional Neural Network, Media pipe*

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I. Introduction

Home automation systems are widely used to control various aspects of the home environment, including lighting, heating, ventilation, air conditioning, and security, as well as to manage electrical and electronic appliances through various control systems and sensors(Venkatraman, Overmars, & Thong, 2021). Traditionally, these systems have relied on physical switches or, more recently, voice-activated commands through platforms like Alexa, Siri, and Bixby (Devi, Shahriar, & Ko, 2023). While voice automation is popular, it presents accessibility challenges for individuals with speech difficulties, such as those with autism, stammering, or mutism. Additionally, physical switches and voice controls can be inconvenient for people with limited mobility, highlighting the need for a more accessible, user-friendly solution. Gesture-based home automation emerges as a promising alternative, offering an intuitive, hands-free approach that can provide greater independence and accessibility for users of all abilities (Isa & Sklavos, 2017).

Home automation systems have evolved from traditional physical switches to advanced controls, including sensor-based, mobile app, and voice-operated technologies. Physical switches, such as toggle and pushbuttons, offer simplicity and reliability but lack remote and automated functionality, which limits their convenience in modern smart homes(Singla & Sharma, 2022). Sensor-based automation, using tools like proximity sensors and temperature switches, enables hands-free control and scheduled actions, which are helpful for tasks like energy-efficient lighting and climate management (Chioran & Valean, 2020). Meanwhile, mobile apps allow users to manage devices remotely via Bluetooth, Wi-Fi, or Zigbee, integrating with platforms like Amazon Echo, Google Home, and Apple Siri for seamless device interaction(Majeed, Abdullah, Ashraf, Zikria, Mushtaq, & Umer, 2020). Voice-controlled systems, such as Alexa, Google Assistant, and Siri, provide hands-free operation but are less accessible to individuals with speech impairments, raising concerns about inclusivity and accessibility (Schomakers, Biermann, & Ziefle, 2021).

This project addresses the critical accessibility challenges faced by individuals with physical disabilities and speech impairments within home automation. Current solutions, which primarily rely on visual interfaces or voice commands, often fall short for these users, limiting their ability to independently control and interact with their home environments. Gesture recognition technology, with its recent advancements, offers a promising solution to these limitations by providing a more accessible and user-friendly interface. This project develops a comprehensive, customizable, and intuitive gesture-based home automation system to empower individuals with disabilities, enhancing their independence, quality of life, and inclusivity in their own homes. By bridging the accessibility gap, this project contributes to a more equitable and adaptable smart home environment that caters to a diverse range of needs and preferences.

II. Proposed System

Hardware Setup

The hardware part as shown in Figure 1 and Figure 2, comprises of LED, bulb, personal computer, fan, 2 channel relay, breadboard, Servo motor and the arduino. When a certain gesture is made, the webcam processes the gesture and classifies it accordingly. This is sent to the Arduino and the Arduino switches on or off the appropriate appliance to which the gestures have been made. The LEDs in the breadboard serves as an indicator just in case the LED bulb fails.

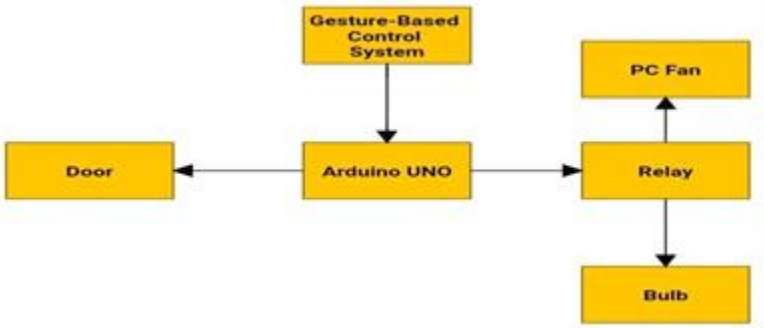

Figure 1: Block

Figure 1: Hardware Setup

System Operation

Figure 3 shows a smart home control system designed to integrate gesture recognition with robust security functionality. The system operates in two distinct stages. The first stage focuses on security, ensuring that only authorized users can interact with the system. Using face recognition technology, the system scans and verifies the user's identity. Once authenticated, the user gains access to the second stage, which involves gesture-based control of home appliances.

The second stage detects and classifies relevant hand gestures to be used as commands. The WEBCAM provides a video thread of images which are used as the primary data acquisition for the Media Pipe python library. he captured gesture images undergo a series of preprocessing steps to ensure consistency and improve recognition accuracy. These steps include resizing the images to a standard size, applying data augmentation techniques to enhance model performance, and converting the images from BGR (Blue-Green-Red) format to grayscale for simpler processing.

A Convolutional Neural Network (CNN) algorithm analyzes the preprocessed images, extracting features and classifying them into predefined gesture categories. If a recognized gesture is detected, the system generates a corresponding signal, which is sent to the serial terminal. The Pyfirmata library facilitates communication between the Python environment and an Arduino Uno microcontroller. The Arduino reads the signal from the serial terminal, decodes it, and activates or deactivates the relevant home appliance or component.

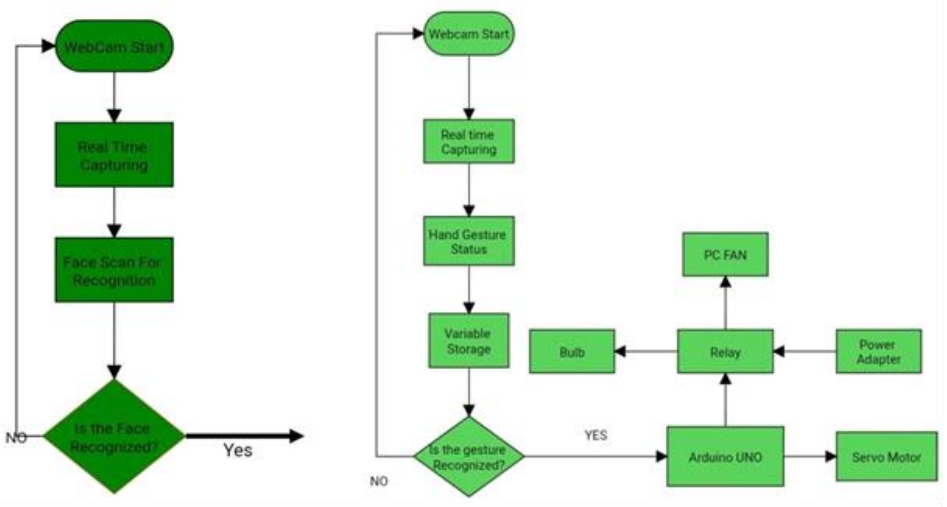

Figure 3: Flow chart diagram

III. Results And Discussion

Face Detection and Recognition

In this part the users' faces were detected by the webcam and processed accordingly by the face detection and recognition system model. If the face matched the ones trained in the system, then the user was allowed to access the other parts of the smart home.

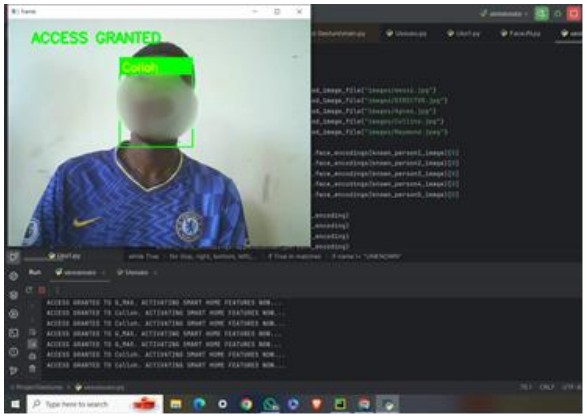

Figure 4: User Access Granted

This was a security concern since in this gesture recognition technology there were no security identifiable markers in the gestures.

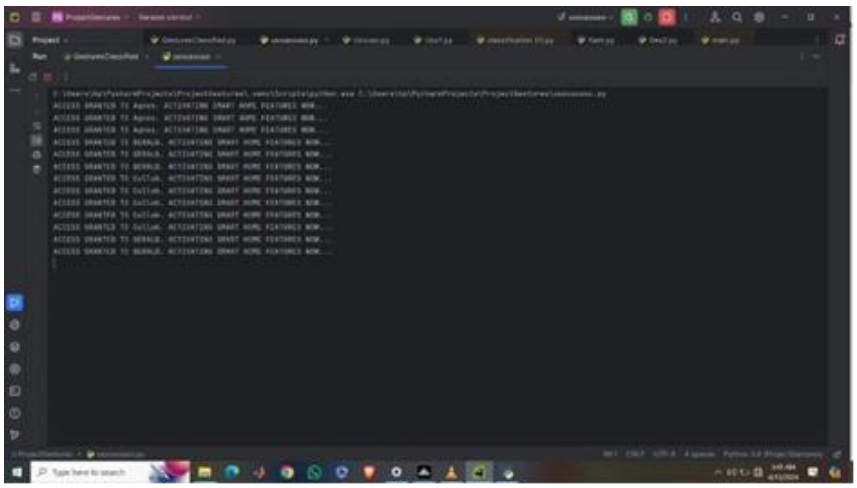

Figure 5: Terminal User Access Grant

If the user was denied access, then the system would not grant him/her any further access to the system.

Smart Home part

This was the next part after face detection and recognition. The scanned faces were the only ones able to access the part of now controlling the smart home appliances using the gestures trained in the model. From the start of this project a model was trained where it could detect the human hand(s) and more so show the 20 landmarks that media pipe offers. The 20 landmarks are as shown below;

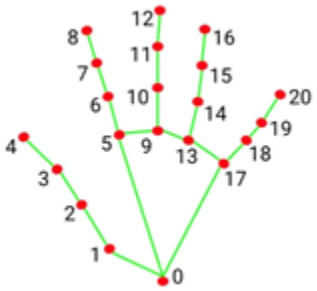

Figure 6: Media pipe hand landmarks

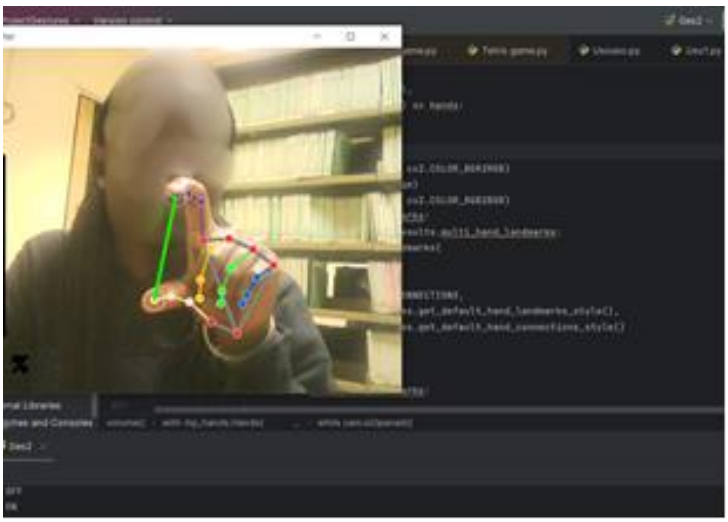

Figure 7: Hand Detection

This model assisted in the next step where gestures had to be trained for each of the appliances to be controlled. The Gestures used were as follows;

'Hello' sign or 'High-five sign' – this included all the five fingers. This 'Hello' sign was to test if all the five fingers responded to the gesture training model.

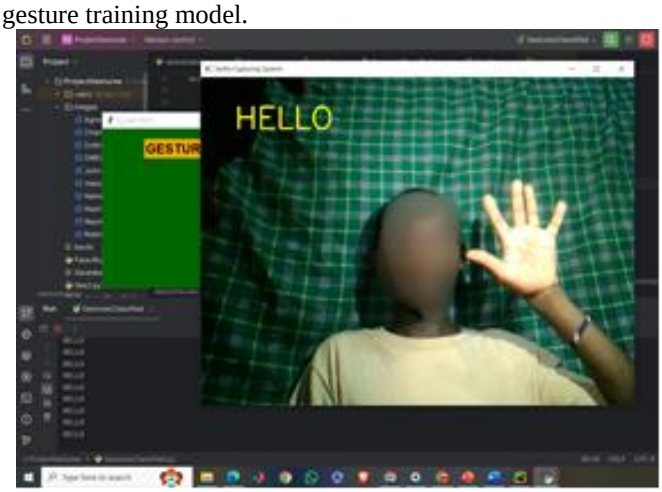

Figure 8: HELLO sign

Thumb + Index + Middle Finger = Close Door

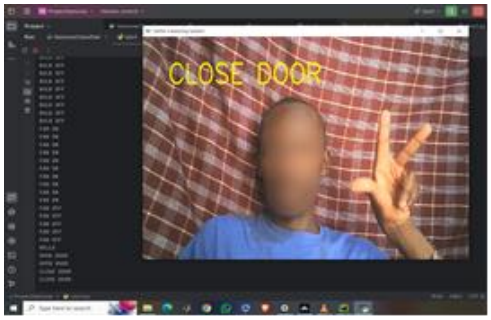

Figure 9: Close Door Command

When this gesture was made, the servo motor moved to symbolize closing of the door.

Index + Middle Finger + Ring Finger = Open Door

Figure 10: OPEN DOOR Command

When this gesture was made, the servo motor moved to symbolize opening of the door.

Thumb + Middle Finger + Pinky = Bulb ON

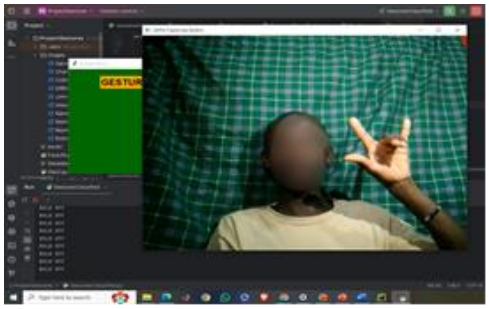

Figure 11: Bulb ON Command

This gesture turned on the lights. The prints 'Bulb ON' had to be redacted for effective working ofthis gesture, due to issues in the coding part in the while loop.

Thumb + Index + Pinky = Bulb Off

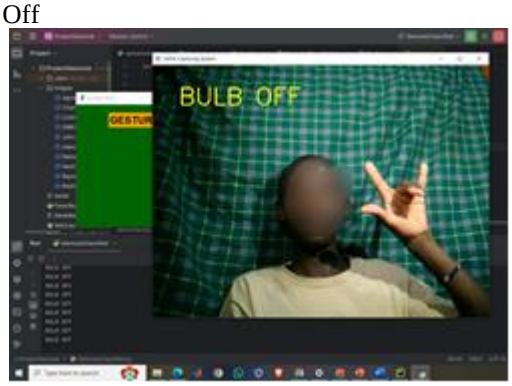

Figure 12: Bulb off sign

This Gesture sent a command signal to the Arduino which processed it to turn the lights off.

Thumb + Index + Middle Finger + Pinky = Fan ON

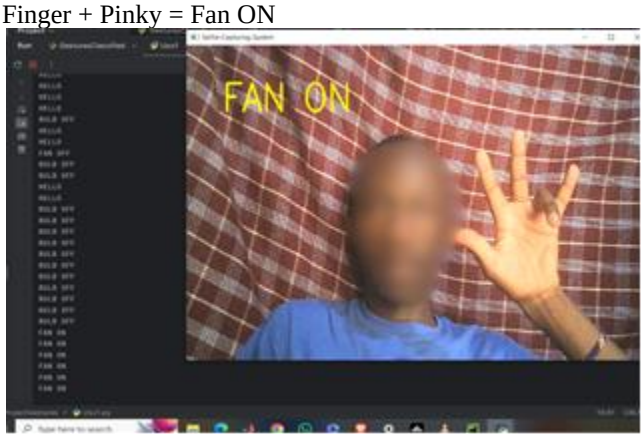

Figure 13: Fan ON command

Thumb + Index + Ring Finger + Pinky = Fan Off

Figure 14: Fan OFF

IV. Conclusion

In conclusion, this project successfully demonstrates a gesture-based home automation system that combines security and accessibility. Utilizing the Pyfirmata library, seamless communication was established between the Python environment and an Arduino Uno microcontroller, enabling the control of various home appliances such as lights, fans, and automated door systems. By leveraging face recognition for user authentication and CNN-driven gesture recognition for appliance control, it was noted that the system can offer an inclusive solution for individuals with physical disabilities and visual impairments.

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