IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 14, Issue 12, December 2025

DOI: 10.17148/IJARCCE.2025.141234

Smart Home Automation -Based Hand Gesture Recognition Using Feature Fusion and Neural Network

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Abstract: Smart home automation systems have gained significant popularity in recent years, enhancing comfort, safety, and energy efficiency in modern households. Traditional smart home systems often rely on mobile applications, voice assistants, or remote controls. However, these approaches can sometimes be inconvenient or inaccessible for certain users. In this project, we propose a gesture based smart home automation system using the Mediapipe library integrated with Raspberry Pi 3B+. A camera captures hand gestures, which are processed in real-time using Python and Mediapipe. Based on the recognized gestures, three electrical appliances are controlled via a 3- channel relay board connected to the Raspberry Pi.

Keywords: Feature fusion, Home automation, Deep learning, IOT, Gesture control.

I. INTRODUCTION

Smart homes integrate various technologies to provide automated and efficient control over household appliances. Common smart home solutions include smartphone apps, IoT devices, and voice-activated assistants. However, these solutions either require internet connectivity, specialized hardware, or interaction through touch/voice. Hand gesture recognition provides a more natural, intuitive, and contactless interface. With the advances in computer vision libraries such as Mediapipe, gesture recognition has become computationally feasible on small devices like the Raspberry Pi 3B+. This project aims to create a smart home automation system where hand gestures replace traditional switches or voicecommands for operating electrical devices.

In recent years, home automation has emerged research topic. Many researchers have started investigating the demand criteria for home automation in different envi ronments. Human–computer interaction (HCI) is considered a more interactive and resourceful method of engaging with different appliances to make the system work. In the conventional approach, different devices like a mouse, keyboard, touch screen, and remote devices are used to fulfill requirements so that users can interact by only using their hands with different home appliances, home healthcare, and home monitoring systems. Usually, changing channels and controlling light on/off switches are more demanding research areas for HCI .

II. OBJECTIVES

- To implement gesture recognition using the Mediapipe library in Python.
- To design a smart home automation system controlled via hand gestures.
- To use a Raspberry Pi 3B+ as the processing and control unit.
- To integrate a 3-channel relay module for controlling three light bulbs.

III. METHODOLOGY

The proposed methodology for smart home automation using hand gesture recognition integrates feature fusion techniques with a Recurrent Neural Network (RNN) to achieve accurate and real-time gesture-based control of home appliances. The system begins with the acquisition of gesture data through either a vision-based camera (such as an RGB or depth camera) or wearable inertial sensors (like accelerometers and gyroscopes). The captured data is then preprocessed to remove noise and standardize the input. In vision-based systems, preprocessing includes operations like background subtraction, skin detection, and frame normalization, while for sensor-based systems, filtering and normalization of motion signals are applied.

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The fused feature vector is then passed into a Recurrent Neural Network, particularly suited for handling sequential data due to its ability to model temporal dependencies. In some cases, Long Short-Term Memory (LSTM) units are used within the RNN to manage long-range dependencies and reduce vanishing gradient issues.

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These separated feature streams allow the system to emphasize and process different aspects of the gesture more effectively.By integrating these three modules, the proposed solution creates a holistic framework that addresses the challenges of monitoring vessel activities, detecting encroachments, and managing information related to violators within port limits.

The smart home automation system based on hand gesture recognition using feature fission and a recurrent neural network (RNN) operates through a sequence of well-defined stages. Initially, the system captures real-time hand gestures using an image or depth-sensing device such as a camera or Kinect sensor.

The captured data is then sent to a preprocessing module, where background noise is removed, the hand is segmented from the rest of the image, and the input is normalized to ensure consistency in size, orientation, and lighting conditions. The Once the data is preprocessed, it is passed to the feature extraction module, which uses a technique called feature fission to divide the input into distinct components — typically spatial features (such as hand shape and contours) and temporal features.

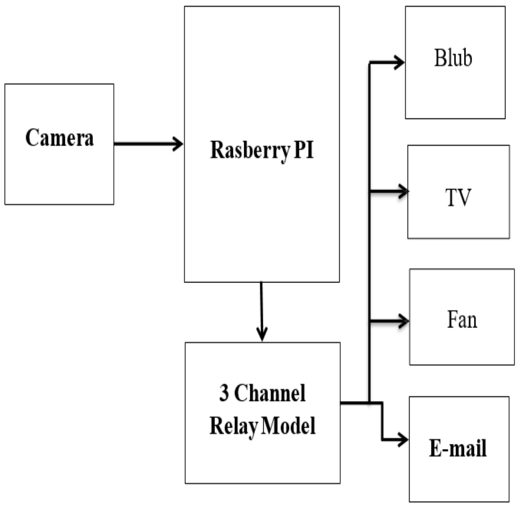

Fig 1: Smart Home Authomation -Based Hand Geasture

IV. IMPLEMENTATION

The smart home automation system based on hand gesture recognition using feature fission and a Recurrent Neural Network (RNN) follows a modular and layered design approach. The system begins with the data acquisition phase, where hand gesture inputs are captured either through a vision-based device such as an RGB camera or a depth sensor, or through wearable devices equipped with Inertial Measurement Units (IMUs) like accelerometers and gyroscopes. These raw inputs are then passed through a preprocessing stage where noise is removed using filters (e.g., Gaussian for images or Butterworth for signals), and the data is normalized to ensure consistency across varying input conditions. For camera-based input, hand segmentation is performed using color thresholding or contour detection, while for IMU data, the time-series signal is segmented into fixed-length windows.

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1.Controlling Home Appliances: Recognize hand gestures to control lighting, temperature, security systems, and entertainment systems.
2. Voice-Free Control: Provide an alternative to voice assistants for people with speech impairments or in noisy environments.
3. Elderly and Disabled Assistance: Enable easy control of home devices for seniors and individuals with disabilities.
4. Energy Efficiency: Automate devices based on hand gestures, reducing energy consumption and promoting sustainability.
5. Enhanced Security: Use gesture recognition for authentication and access control, adding an extra layer of security.
6. Smart Lighting: Control lighting levels, color, and patterns with specific hand gestures.
7. Entertainment System Control: Manage media playback, volume, and channel switching with gestures.

V. RESULT

This project presents a novel gesture-controlled smart home automation system enhanced by real-time emotion detection for safety monitoring. By integrating Mediapipe and a pre-trained emotion classification model with Raspberry Pi, we provide an efficient, low-cost, and practical solution for controlling home appliances while ensuring user safety. The automatic emergency notification feature makes the system especially helpful for elderly or differently-abled users, contributing to a smarter and safer home environment.

Fig 2: HAND GESTURE RECOGITION

The hand gesture recognition system can interpret specific commands, such as "turn on lights" allowing users to control devices and systems with simple hand movements.

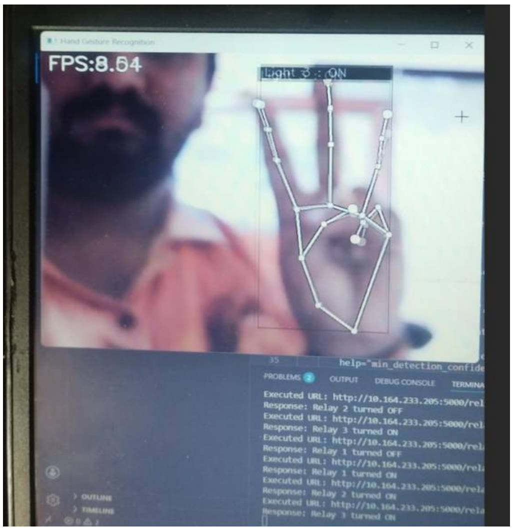

Fig 3: HAND GESTURE RECOGITION

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Fig 4: Hardware connection

VI. CONCLUSION

The Smart Multipurpose Agricultural Robot exemplifies a practical, autonomous, and modular approach to small scale precision agriculture utilizing an Arduino Uno, various sensors (moisture, temp, and humidity), actuators (DC Motors, servo motor, and water pumps), a 16x2 LCD screen and 4-channel relay. The robot is capable performing a comprehensive list of to-dos: seed sowing, grass cutting, precise irrigation, and environmental monitoring- which are laborious, while they are efficient with respect to resource management. The system has been programmed in Embedded C to allow for reliable control of sensors and actuators with the LCD providing relevant feedback, thus providing proof of concept and feasibility in modern agricultural practice.

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