

IoT Based Gesture Controlled Smart Switching System Using Computer Vision

Dr. Kumar S *, Dr. Kannan M **

*Asst. Professor of Electronics, Sri Vasavi College (SF Wing), Erode, TN - 638316.

Email: yeskumar.com@gmail.com

** Asst. Professor of Electronics & Communication Systems, KSG College of Arts and Science, Coimbatore, TN - 641015.

Email: kannanziskin@gmail.com

Abstract:

The rapid advancement of touchless technologies has significantly transformed modern human-machine interaction systems. This paper presents the design and implementation of an Internet of Things (IoT)-based gesture-controlled smart switch system that enables users to operate electrical appliances without physical contact. The system employs a webcam to capture hand gestures, which are processed using computer vision techniques implemented in Python with OpenCV and MediaPipe libraries. The recognized gestures are translated into control commands and transmitted wirelessly via Wi-Fi to an ESP8266 microcontroller, which subsequently controls relay modules connected to electrical appliances. The proposed system provides a hygienic, intuitive, and efficient alternative to conventional switching mechanisms. Experimental observations demonstrate reliable gesture recognition and real-time responsiveness, making the system suitable for applications in smart homes, healthcare environments, and assistive technologies.

Keywords — Gesture Recognition, Internet of Things (IoT), Smart Home Automation, Computer Vision, ESP8266, OpenCV, MediaPipe.

I. INTRODUCTION

In recent years, the demand for intelligent and touchless control systems has increased significantly due to rapid technological advancements and the growing need for safer and more convenient human-machine interaction. Traditional control mechanisms, such as switches, buttons, and remote controls, require physical contact, which may not always be efficient or hygienic, particularly in shared or sensitive environments. This limitation has encouraged the development of alternative interaction methods that eliminate the need for direct contact.

Hand gesture recognition has emerged as a promising solution in the fields of computer vision and artificial intelligence. It enables systems to interpret human hand movements through visual input and convert them into meaningful commands. By analyzing finger positions, orientations, and motion patterns, gesture-based systems provide a natural and intuitive interface for controlling devices. Such technologies are widely applied in domains including robotics, gaming, virtual reality, and smart home automation.

This paper proposes a gesture-controlled smart switch system that integrates real-time hand gesture recognition with IoT-based device control. The primary objective is to enhance user convenience, improve hygiene, and promote energy-efficient operation of electrical appliances through an intuitive and contactless interface.

II. RELATED WORK

Existing research in gesture-based control systems has explored various approaches, including sensor-based and vision-based techniques. Early systems relied on wearable devices equipped with sensors, which limited user convenience and flexibility. Infrared-based detection systems were also employed but suffered from environmental constraints and limited accuracy.

Recent advancements in computer vision have enabled more robust and accurate gesture recognition systems using cameras and machine learning algorithms. Libraries such as OpenCV and MediaPipe have simplified the implementation of real-time hand tracking and gesture analysis. Simultaneously, IoT-based smart home systems have gained popularity, typically relying on mobile applications or voice assistants for control. However, gesture-based control offers a silent, intuitive, and non-intrusive alternative.

The proposed system builds upon these advancements by combining vision-based gesture recognition with an ESP8266-based wireless control mechanism, resulting in a cost-effective and scalable solution.

III. SYSTEM ARCHITECTURE

The architecture of the gesture-controlled smart switch system is designed as a layered model consisting of input, processing, and output components that work together to achieve seamless operation. The input layer is responsible for

capturing real-time video using a webcam, which continuously monitors the user's hand movements. This visual data is then passed to the processing layer, where gesture recognition is performed.

The processing layer utilizes Python along with OpenCV and MediaPipe libraries to detect hand landmarks and interpret gestures. MediaPipe identifies key points on the hand, enabling precise tracking of finger positions and movements. Based on this information, the system classifies gestures into predefined commands corresponding to specific control actions.

Once a gesture is recognized, the command is transmitted wirelessly through Wi-Fi to the output layer, which consists of an ESP8266 microcontroller. The ESP8266 acts as a web server that receives HTTP requests from the Python application and processes them to control relay modules. These relay modules are connected to electrical appliances, enabling them to be switched on or off based on the received commands.

This modular architecture ensures efficient communication between software and hardware components while maintaining scalability and flexibility for future enhancements.

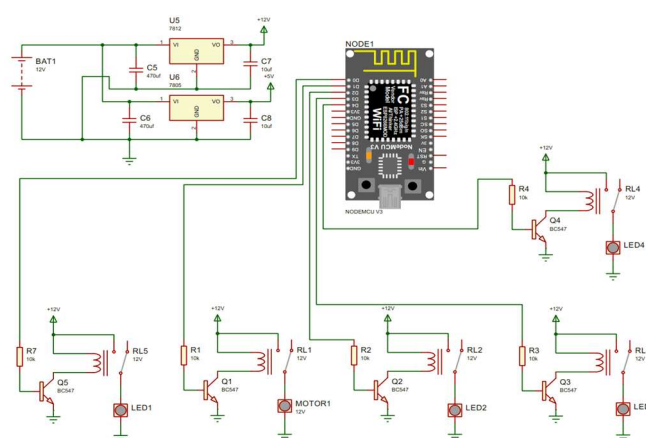


Fig. 1 Circuit Diagram of the Proposed System

IV. METHODOLOGY

The methodology of the proposed system involves three major stages: gesture recognition, communication, and hardware control. Initially, the webcam captures live video frames, which are processed to detect hand landmarks using MediaPipe. The system analyzes the relative positions of fingers to determine whether they are open or closed, thereby identifying specific gestures.

Each recognized gesture is mapped to a predefined command, such as turning a light on or off. These commands are then transmitted from the Python application to the ESP8266 microcontroller using HTTP requests over a Wi-Fi network. The ESP8266, configured as a web server, receives the commands and interprets them accordingly.

Upon receiving a command, the microcontroller activates the corresponding relay module, which controls the connected electrical appliance. This process occurs in real time, ensuring minimal delay between gesture recognition and device response.

V. DEVELOPMENT ENVIRONMENT

The development of the system is carried out using both software and hardware tools. The gesture recognition module is implemented in Python, utilizing OpenCV for image processing and MediaPipe for hand tracking. The hardware component, consisting of the ESP8266 microcontroller, is programmed using the Arduino IDE. Communication between the software and hardware components is established via Wi-Fi using HTTP protocols.

Testing and debugging are performed using the Python console for software verification and the Serial Monitor in the Arduino IDE for monitoring microcontroller behavior. This integrated development environment ensures efficient implementation and troubleshooting of the system.

VI. RESULTS AND DISCUSSION

The system was evaluated under various environmental conditions to assess its performance and reliability. The results indicate that the gesture recognition module performs accurately in real time, with minimal latency in communication between the processing unit and the microcontroller. The system successfully controls electrical appliances based on detected gestures, demonstrating its practical applicability.

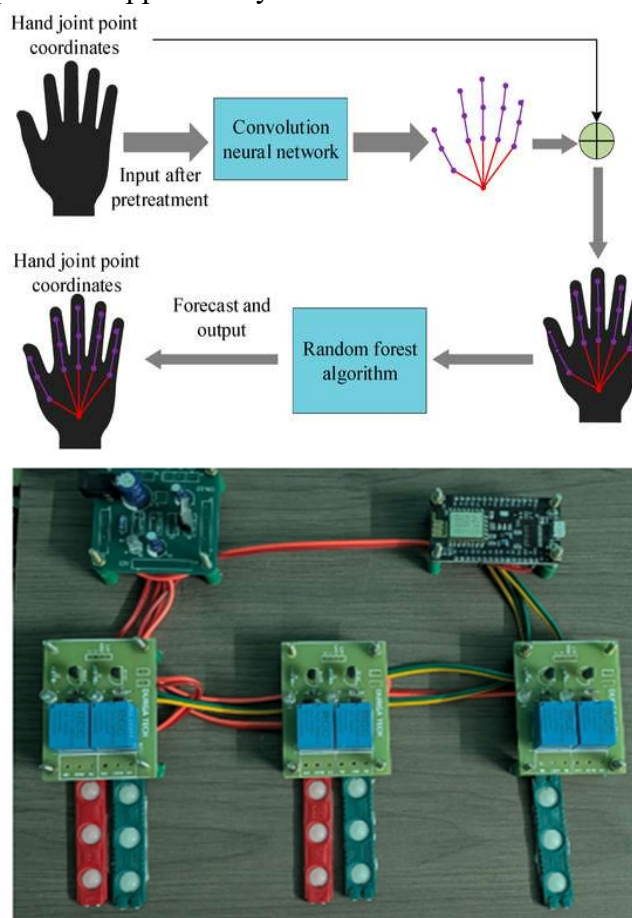


Fig. 2 Hardware and Simulation Result of Gesture-Controlled Switching System

However, certain limitations were observed, particularly in low-light conditions and complex backgrounds, which can affect gesture detection accuracy. These challenges highlight the need for further optimization, such as incorporating advanced machine learning techniques or improving image preprocessing methods.

VII. APPLICATIONS

The proposed system has a wide range of applications in smart home automation, where it can replace traditional switches with touchless control mechanisms. It is particularly beneficial in healthcare environments, where maintaining hygiene is critical. Additionally, the system can assist individuals with physical disabilities by providing an accessible means of controlling appliances. Industrial environments may also benefit from gesture-based control systems to improve safety and efficiency.

VIII. CONCLUSION

The gesture-controlled smart switch system presented in this paper demonstrates an effective integration of computer vision and IoT technologies to achieve touchless device control. By eliminating the need for physical interaction, the system enhances user convenience, promotes hygiene, and supports energy-efficient practices. The modular design ensures scalability and adaptability, allowing future enhancements such as the integration of advanced gesture recognition algorithms and additional communication protocols.

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