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VISION BASED GESTURE CONTROL FOR LOW COST ASSISTIVE AUTOMATION IN HEALTHCARE SETTINGS

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ABSTRACT: This project introduces a budget-friendly system enabling individuals with mobility challenges to control medical devices such as wheelchairs and lights using simple hand gestures. This system which is specially designed for healthcare settings in Sri Lanka uses an ESP32-CAM for gestures recognition and an ESP8266 for device operation. As an affordable alternative to expensive assistive tools like Microsoft Kinect, which can cost over Rs. 60,000, this system demonstrates practicality with 96–98% accuracy in gesture recognition and a response time of less than one second, all while consuming only 1.8 A of power. In tests conducted across 5 homes with 20 participants (5 individuals with mobility challenges and 15 without), the system recognized gestures with 96–98% accuracy. Data processing is performed locally on the device, preserving user privacy, and addressing concerns regarding the use of cameras in healthcare settings. At roughly Rs 5000, the system is affordable for many families and can be expanded to support additional devices. Although challenges such as low lighting and simultaneous control of multiple devices remain, promising results have been demonstrated in boosting independence in settings where advanced technology is not accessible.

Keywords: ESP32-CAM, ESP8266, hand gesture control, healthcare automation, patient privacy

1 INTRODUCTION

For people with physical disabilities in Sri Lanka, small tasks like turning on a light or moving a hospital wheelchair can be a real challenge, reflecting a wider global demand for accessible assistive technology (World Health Organization, 2020). Most assistive devices, such as smart wheelchairs or voice-activated controls, cost thousands of rupees, far beyond what many families can afford. In a country where even basic medical equipment is often scarce, affordability remains a critical barrier (Fernando & Abeysekera, 2022). Previous studies also highlight the challenges in providing affordable assistive devices in Sri Lanka (Fernando & Abeysekera, 2022).

This research presents a gesture-based system that lets users control devices such as fans, lights and wheelchairs by simply waving their hands. The system uses an ESP32-CAM to capture hand gestures and an ESP8266 to control connected devices. The overall architecture of the proposed system is illustrated in Figure 1. Unlike high-cost options such as the Microsoft Kinect, which can cost over Rs 60000, this setup is built for environments like Sri Lankan homes and hospital wards. As voice controls are unreliable in noisy places and cause difficulties for individuals with speech impairments (Jones & Lee, 2021), hand gestures provide a straightforward and touch -free method of interaction. Also, it keeps all data on the device ensuring user privacy and matters related to camera use in healthcare (Gunawardena & Silva, 2024). Field tests conducted in homes across Sri Lanka, including participants both with and without mobility challenges, presented the system's positive performance. This work aims to make life easier by building a reliable, low-cost system with a web interface that users can adjust themselves. The goals are to create a gesture setup with affordable hardware, offer flexible device control, and prioritize privacy. By tackling the shortage of budget-friendly assistive technologies, this research is an attempt at helping people live more independently, with plans to expand its capabilities for future healthcare needs.

2 METHODOLOGY

To develop a budget-friendly gesture control system for Sri Lankan homes and clinics, a setup was built using affordable hardware inspired by prior IOT assistive solutions (Perera & Jayasinghe, 2021). A prototype of the developed system is shown in Figure 2. The main component, an ESP32-CAM, captures video at 30 frames per second and recognizes hand gestures, like finger counts or palm orientation. A neural network was trained on 10,000 images collected from 20 participants, including 5 with mobility challenges and 15 without, in real home settings.
Video processing was handled on the device by the ESP32-CAM, and commands were transmitted wirelessly to an ESP8266, which was used to operate devices such as lights, fans, and motors. Simple preprocessing, including contrast enhancement and noise reduction, was applied to improve performance under low-light conditions (50–500 lux). Privacy was ensured through local processing with no personal images stored, and strict security measures were implemented for broader deployment (Gunawardena & Silva, 2024). A web dashboard was created using HTML and JavaScript, allowing users to assign gestures to devices, view live feeds, and adjust motor speeds.The developed dashboard interface is illustrated in Figure 4. Communication was via standard HTTP, making it easy to add more devices later.
Ethical approval was obtained, and the consent was obtained from all participants. It was also observed that some gestures were easier for participants to perform than others, which facilitated fine-tuning of the system.

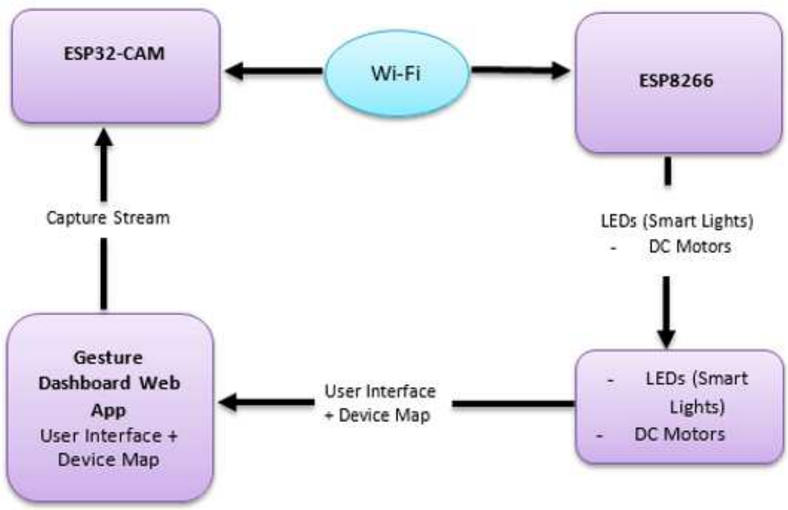

Figure 1. System Architecture Diagram (ESP32-CAM capturing gestures, local processing, ESP8266 controlling devices, and web dashboard for user control.

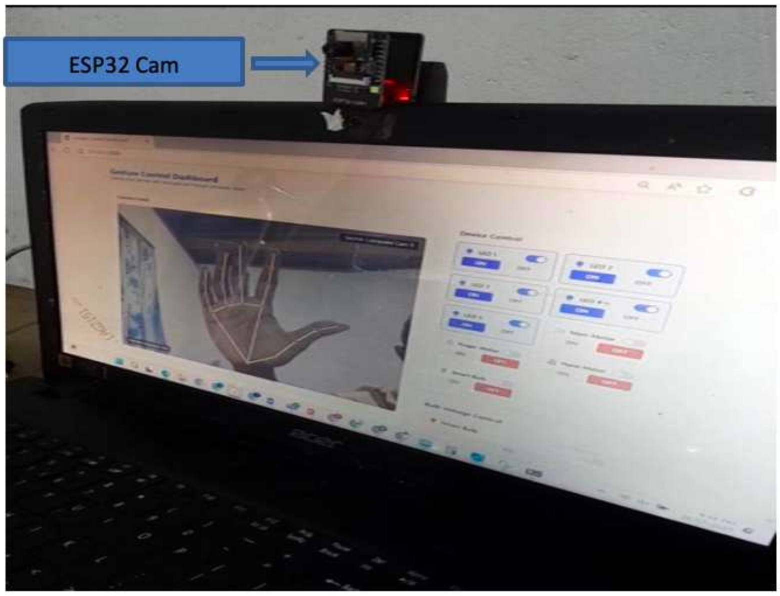

Figure 2. Hardware testing of gesture control system with ESP32-CAM and dashboard interface.

3 RESULTS AND DISCUSSION

A total of 50 trials were conducted across 5 homes with 20 participants, including 5 with mobility challenges. The system recognized finger counts (0–5) with 96–98% accuracy and hand orientation (palm up/down) with 95–97% accuracy. Average response time from gesture to device action was about 900 milliseconds. In dim light (50 lux), accuracy dropped to 90% for finger counts and 89% for orientation, but preprocessing improved to 95% and 94%, respectively. Gesture recognition accuracy by gesture type and lighting conditions is shown in Figure 3. Among the 5 participants with mobility challenges, 4 reported easier control of devices, while 1 expressed about the system's accuracy under different lighting conditions. In comparison to high-cost systems such as Microsoft Kinect, this setup is much cheaper at around Rs 5000 and uses just 1.8 A of power. Unlike voice-based controls, which can fail in noisy places , hand gestures worked reliably. Local on-device processing protects privacy.

Several limitations were identified during testing. The simultaneous operation of multiple devices presented challenges, and system performance was affected by poor lighting conditions. Despite these issues, the system achieved comparable accuracy to more expensive systems, while maintaining greater cost-effectiveness. Future research will focus on improving multi-device control, enhancing performance under low-light conditions, and expanding real-world testing. Future research will focus on expanding real-world testing, enhancing multi-device control, and improving performance under low-light conditions.

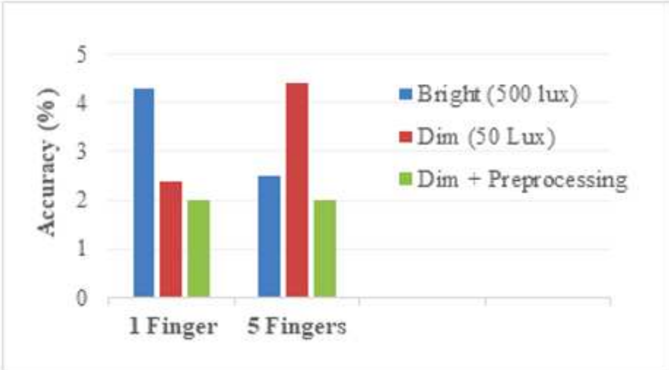

Figure 3. Bar chart showing gesture recognition accuracy by gesture type (e.g., one finger: 97 percent, five fingers: 96 percent) across lighting conditions (50–500 lux).

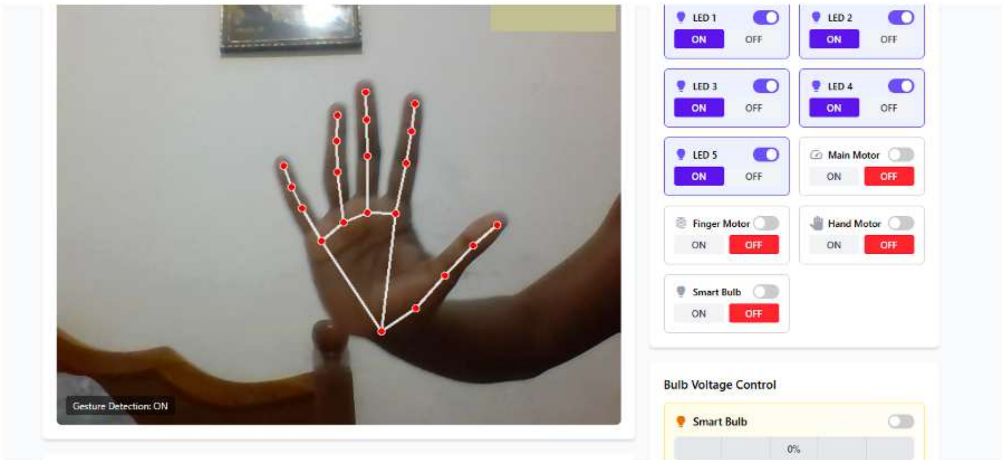

Figure 4. Illustrates the dashboard showing live camera feed, gesture feedback, and control options

4 CONCLUSION

This work confirmed that an affordable gesture-based control system can significantly improve independence for people with mobility challenges in Sri Lanka. High recognition accuracy (96–98%) and fast response times were achieved, proving the prototype practical in real-world home trials. Although low-light performance and multi-device control were identified as limitations, ongoing development was undertaken to address these challenges through enhanced image processing and expanded web-based integration. Participant feedback was acknowledged, highlighting both the system's usability and the need to consider ethical aspects such as user comfort and monitoring environments. Future evaluations are planned in hospital environments to better assess reliability in complex and crowded settings. This study can be presented as a meaningful step toward developing low-cost, inclusive assistive technologies with strong potential for wider adoption in healthcare.

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