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Red Universitaria e Institución Benemérita de Jalisco
Centro Universitario de los Valles

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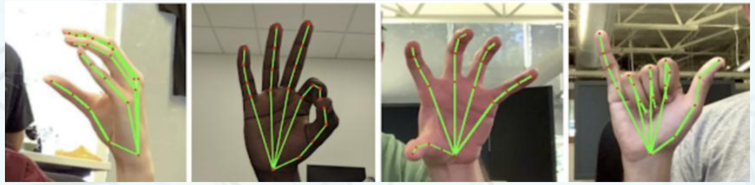
Vision-Controlled Hand Gesture Recognition System for Home Automation



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Luis Gilberto Rangel Pérez, Rodolfo Omar Domínguez García, Miriam González Dueñas, Miguel Angel de la Torre Gómora

Dr. Rodolfo Omar Domínguez García
University Center of the Valleys of the University of Guadalajara, Jal, Mx.
odomi@academicos.udg.mx

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Dr. Rodolfo Omar Domínguez García holds a degree in communications and electronics engineering and a Ph.D. in educational research and innovation from the University of Málaga.

He is a senior research professor in the Department of Computer Science and Engineering at the Centro Universitario de los Valles (CUValles) of the University of Guadalajara in Jalisco, Mexico.

Dr. Domínguez is the coordinator of the Master's Program in Software Engineering at CUValles (www.mis.cuvalles.udg.mx).

He is in charge of the Internet of Everything group..

Dr. Domínguez is a member of Mexico's National Research System, Level 1, and is the chair of the Innovation and Technological Development Laboratory at CUValles.

The working group's topics of interest: Internet of Things, smart cities, environmental monitoring, facial and object recognition.

An environmental and soil monitoring system is currently being developed. It will measure the following 20 variables: wind speed and direction, rainfall, air quality (PM 1.0, 2.5, and 10), temperature, relative humidity, CO_2, light intensity, UV radiation, altitude, and barometric pressure. The system will also measure soil humidity, conductivity, temperature, pH, nitrogen, phosphorus, and potassium.

The system also includes a dedicated website for real-time data verification.

The physical prototype of the hand gesture recognition system for home automation is being developed.

A prototype for facial recognition based on Raspberry Pi 5 is being implemented, using an AI camera.

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Abstract

The increasing need to support elderly individuals and people with disabilities has driven the development of innovative assistive technologies that enhance independence and improve quality of life. This manuscript presents a gesture-controlled home automation system that allows users to intuitively operate household devices, such as lights and blinds, without physical contact. The architecture of the proposed system is supported by a Raspberry_Pi 4, with OpenCV and MediaPipe for real-time hand gesture recognition. The system interprets commands and executes corresponding actions on connected devices, taking advantage of finger positions. Unlike traditional automation solutions that rely on voice commands or touch interfaces, this approach offers an accessible and hygienic alternative, particularly beneficial for individuals with mobility or speech impairments. The system exhibits high accuracy, rapid response times, and user-friendly operation, making it a cost-effective and scalable solution for smart home applications. This is achieved through the integration of low-cost devices and open-source libraries. Through this work, we contribute to the advancement of inclusive and contactless technology, fostering greater autonomy and accessibility in everyday living environments.

Keywords- Assistive technology, hand gesture recognition, home automation, Raspberry_Pi, accessibility

Introduction

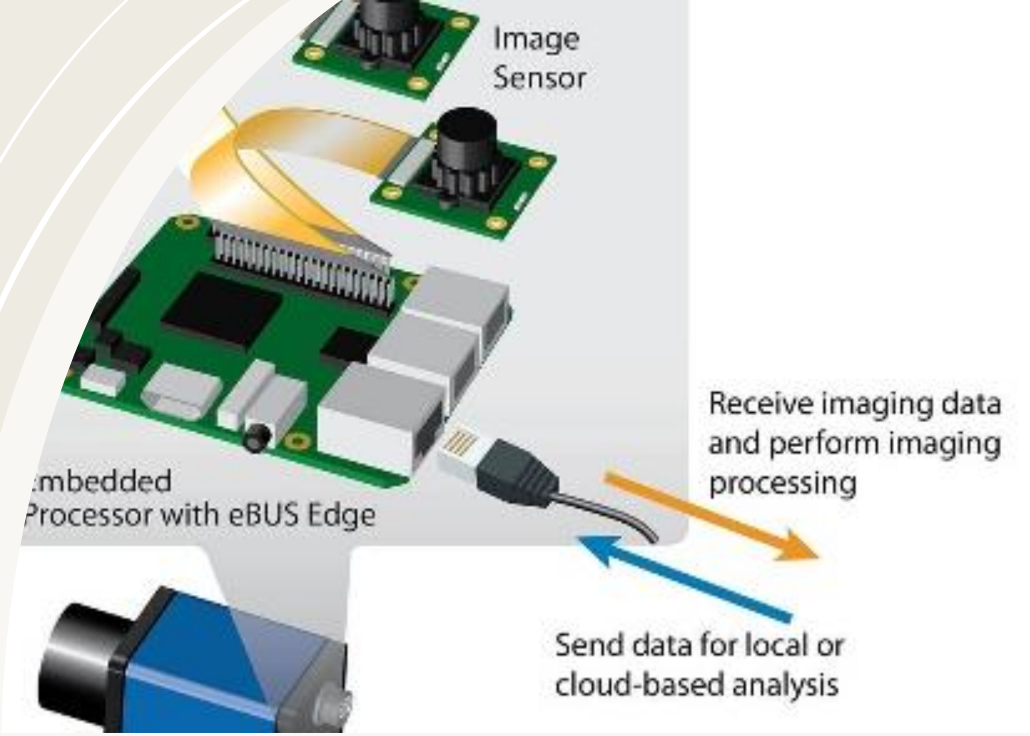
According to the World Health Organization (WHO), there are 1 billion people in the world who need an assistive device, yet only 1 in 10 has access to one. In low- and middle-income countries, only 5% to 15% have access to AT. In Mexico, the 2020 National Census of Population and Housing shows that 20.8 million people - 16.5% of the total population - have some form of disability [2].

To enhance quality of life, the WHO, together with the Global Cooperation in Assistive Technology (GATE) initiative, recognizes access to assistive technologies as a universal right. These technologies play a crucial role in enabling individuals to lead healthy, productive, independent, and dignified lives, facilitating their participation in education, the workforce, and social activities.

Introduction

Unlike traditional home automation systems that require touch interfaces or voice commands, gesture-based control offers an innovative alternative that is ideal for people who have difficulty speaking or using physical devices. The COVID-19 pandemic highlighted the importance of non-contact technologies to reduce the spread of disease, and these types of solutions can help improve hygiene and safety in different contexts.

Finally, this project has significant educational and technological value as it combines the use of open-source hardware and software, promoting learning in areas, such as computer vision, image processing and embedded control. Its modular and scalable design allows for future improvements and adaptations, making it a basis for the development of more complex automation and accessibility systems.



Related Work

For instance, in [11], the current populace of the elderly is apparently abandoned by the younger generations due to their individual circumstances. To enhance vitality and improve the well-being of elderly individuals, an assisted home care system can serve as a valuable solution by offering comprehensive nursing care and continuous monitoring.

Gourob et al. [12] reveal that Human-Robot Interaction (HRI) has become an important topic in today's robotic world, especially in assistive robotics. Vision based hand recognition systems provide solutions for these types of human demands.

In [13], the authors reviewed the sign language research in the vision-based hand gesture recognition system from 2014 to 2020. They identified progress and relevant needs that require more attention. The review shows that vision-based hand gesture recognition research is an active field of research, with many studies conducted, resulting in dozens of articles. published annually in journals and conference proceedings.

The authors in [14], propose a Home Automation System with hand gesture recognition based on Mediapipe, using Arduino UNO. As one gets older, his/her mobility tends to decrease. Therefore, simple tasks such as getting up to switch the lights on or turning the fan off can become difficult. Thus, it became imperative to create a system which allows them to perform these tasks - a "Hand Recognition based Home Automation System".

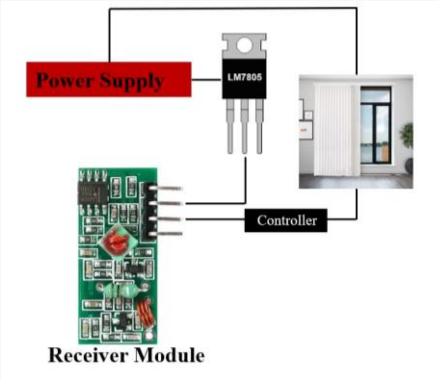
. In [15], the authors propose a remote control method based on one-handed gestures for mobile manipulator, so that the operator can control the entire robotic system with only one hand. In this study, they combined real-time hand key points detection technology provided by MediaPipe, with the RealSense D435i depth camera to address the inaccuracy in depth recognition problem of the original method.

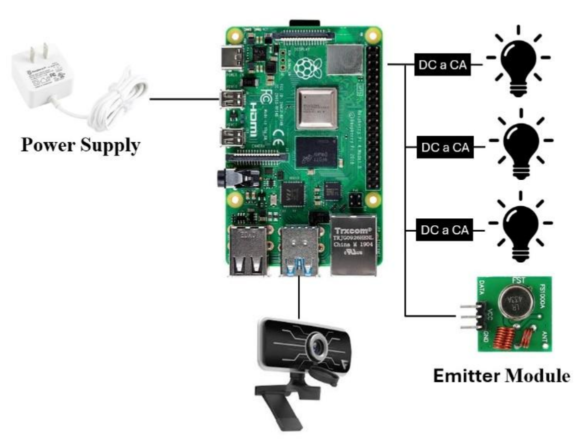
In [16], the authors focus on the design of a gesture-controlled robotic arm that is navigated with the help of a webcam and OpenCV-enabled real-time hand tracking. Embedded with OpenCV's hand tracking module, the system successfully identifies the hand landmarks from the live camera captured hand movement of the user

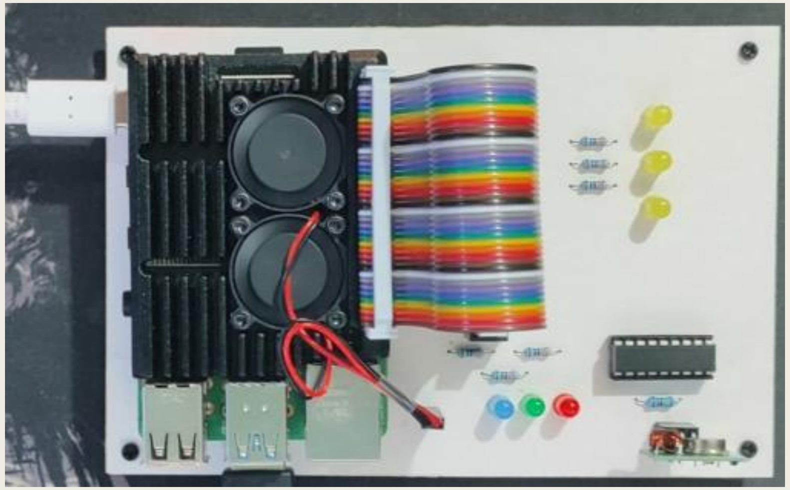
Materials and Metods

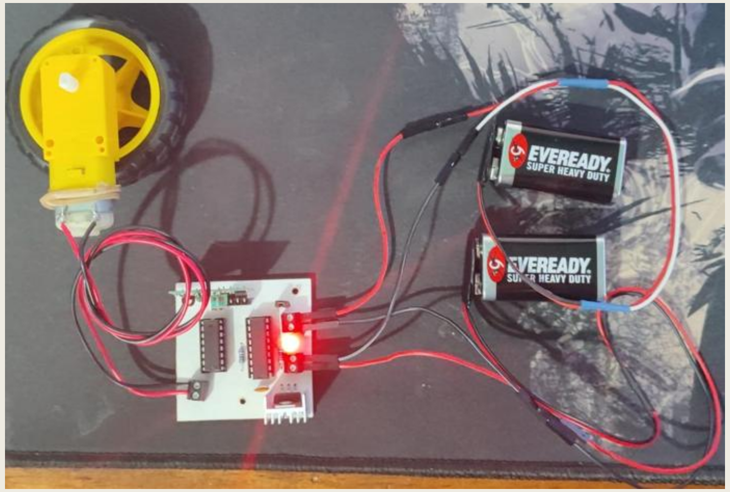
Gesture recognition is a technique that interprets hand or body movements to interact with electronic devices without the need for physical contact. It has a wide range of applications, from video games and augmented reality to home automation and accessibility for people with disabilities.

The Raspberry_Pi 4 [17] is a low-cost, high-performance microcomputer ideal for image processing and embedded control applications









Materials and Metods

These figures show the prototype implemented to carry out the tests and observe how the programmed gestures interact with the system. With the corresponding gesture, the lights are turned on or off accordingly. With other gestures, the blinds are closed or opened (the motor turns on or off).

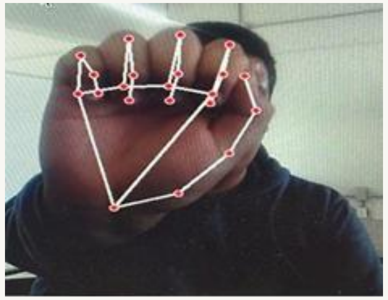
Materials and Metods

Gesture	Thumb	Index	Middle	Ring	Pinky	Action
A	0	0	0	0	0	System enable state
B	1	1	1	1	1	It enters you into the power on menu
C	1	0	0	0	1	It takes you to the shutdown menu
D	1	0	0	0	0	Spotlight on/off 1
E	1	1	0	0	0	Spotlight on/off 2
F	1	1	0	0	1	Spotlight on/off 3
G	0	1	0	0	1	Motor (blinds)

According to Table 1, gesture A is the first action to set the *system enable* state to recognize the on and off orders of the devices. This leads to gestures B or C, which indicate that a device wants to be turned on or off. The system then waits for any gesture from D to H to turn on or off the chosen device. Once the system receives gesture from D to H, and the required action is given, the system returns to the *system enable* state, waiting for gesture A in order to repeat the process.

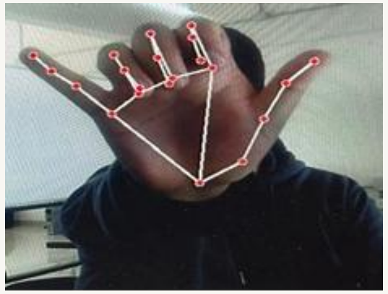
RESULTS

The following images depict the various hand gestures shown in Table 1 on slide 11.

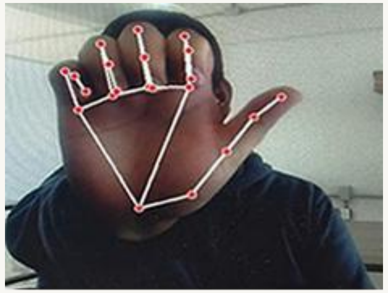


Gesture A, system enable state.

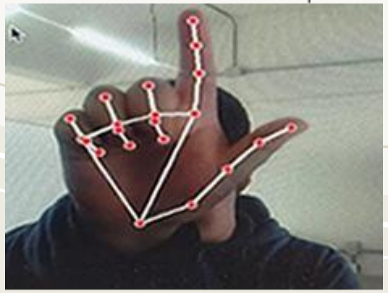
Gesture B grants access to the "power-on menu".



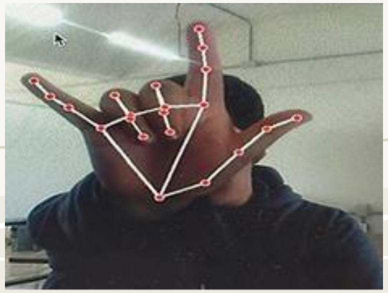
Gesture C, it takes you to the shutdown menu.



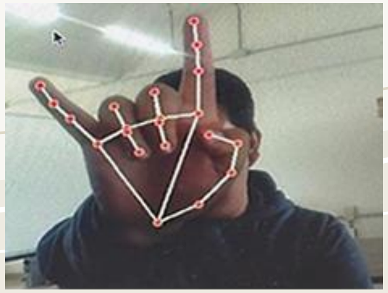
Gesture D, Spotlight 1 on/off.



Gesture E, Spotlight 2 on/off.



Gesture F, Spotlight 3 on/off.



Gesture G, Motor of blind on/off.

RESULTS

The prototype was tested in a controlled environment to observe its operation and estimate its accuracy, response time and ease of use

Gesture A, powering on the system

Gesture B grants access to the

Gesture C, Spotlight on/off. “power-on menu”.

Difference from other projects

Focus on hand gestures: Unlike other home automation systems that rely on touch interfaces or voice commands, this project focuses on hand gesture recognition, providing a more intuitive and accessible alternative for people who have difficulty using physical devices or speaking.

Low-cost technologies: The use of computer vision technologies (OpenCV and MediaPipe) and a Raspberry_Pi 4 allows for a low-cost and highly efficient implementation, which is not common in other similar systems that typically require more expensive or complex hardware.

Optimized for different conditions: The project focuses on optimizing image processing for different lighting conditions and viewing angles, making it more robust and adaptable compared to other systems that may not perform well in variable environments.

Ease of implementation: The modularity of the system allows for easy implementation and the possibility of adding more devices in the future.

CONCLUSIONSAND FUTURE WORK

The proposal shows how embedded systems can be applied to detect hand gestures in real time, and to control devices efficiently and accurately. The Raspberry_Pi 4, based on a single-chip System-on-Chip (SoC), enables features, such as processing power, the ability to run a full operating system, excellent support for Python and its libraries, and various connectivity options, making it an excellent choice for more complex and flexible embedded systems.

The use of OpenCV enables efficient image processing, while MediaPipe facilitates the detection and tracking of hand gestures, optimizing interaction with the system. This approach not only highlights the benefits of the Raspberry_Pi 4 as a computing platform, but also opens the door to future extensions in areas such as automation, accessibility and contactless control in a variety of environments, whether domestic, industrial or commercial.

The affordability of the devices used, coupled with the utilization of open-source software libraries, enables the implementation of this device as a Technology Readiness Level 6 (TR6) prototype. This approach facilitates thorough evaluation and supports the development of a commercial prototype at Technology Readiness Level 9 (TR9).

Additional feedback on system usage from the target population will be collected at a later stage to facilitate a comparative analysis with existing market solutions.

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