Journal of Semiconductor Devices and Circuits(JOSDC)

ISSN: 2455-3379
Volume-11
Issue-1
Year-2024

Review Article

Date of Receive- 21th-May-2024
Date of Acceptance- 30th-May-2024
Date of Publication- 08th-June-2024

Hand Gesture Control Robotic Arm using OpenCV and NodeMCU

Vaibhav Vaijnath Sakhare1*, Rohit Ingale[2], Atharv Mehetre[3], Jai Desai[4]

[1,2,3,]Students, Department of Electronics and Telecommunication Engineering,Sinhgad College of Engineering, Savitribai Phule Pune University, Pune.

[4]Professor, Department of Electronics and Telecommunication Engineering,Sinhgad College of Engineering, Savitribai Phule Pune University, Pune.

Author for Correspondence Email- vaibhavsakhare2020@gmail.com

Abstract

In this research paper, an innovative method is proposed for controlling a robotic arm through the use of hand gestures, utilizing the advanced features of Node MCU and OpenCV. By bringing together these cutting-edge technologies, the system enables seamless real-time communication and image processing between the user and the robotic arm. The process involves capturing hand gestures through a camera and using the powerful OpenCV library to identify and interpret them. This translation of gestures into corresponding commands allows for intuitive and precise manipulation of the robotic arm. To enable wireless control and communication, the system utilizes the Node MCU microcontroller. Through experimental analysis, the effectiveness and accuracy of this hand gesture control approach are demonstrated.

Keywords: Hand Gesture Recognition, Robotic Arm, Node MCU, OpenCV, Image Processing, Human-Machine Interaction.

INTRODUCTION

Everything is mechanized in the modern world, and artificial intelligence is becoming more and more common. Robotics is one of the main components of innovation. Robotics and artificial intelligence are two different but related fields. AI is the process of making robots mimic human decision-making and learning processes, whereas robotics is the process of creating machines that can carry out tasks without the need for human aid[1]. While AI and robots can coexist, they can also function separately, and in

many cases they already do. Because most robots' jobs are straightforward, predictable, and preprogrammed, they can be performed by them without the need for sophisticated artificial intelligence[2]. A robot is a machine that can carry out a variety of intricate activities automatically, including ones that require computer programming. Either an external control device or an internal control system can operate the robot. While some robots are designed to resemble people, the majority of robots are machines that prioritize functionality over expressive aesthetics when performing jobs. Gesture-controlled robots are those that can be operated by gestures as opposed to standard buttons[3]. All you have to do is hold an accelerometer-equipped little transmitter in your hand. This will communicate the necessary commands to the robot, enabling it to carry out any work that we assign to it.When we hold the transmitter in our hands, the gesture-controlled robot will move in response to the growth of our hand. When we turn to face ahead, the robot moves forward and keeps going until we provide another instruction. Until another order is issued, the robot switches states and begins to move in the opposite direction as its arm tilts to the opposite side. The robot will travel left and in the opposite direction when we spin it to the left. When we insert our hand, the robot rotates to the right. In addition, we need to maintain calm hands in order to halt the robot.This research is fueled by our natural tendency towards non-verbal communication and the need to convert those subtle expressions into practical instructions for robotic technology. With hand gestures serving as an innate and expressive means of communication, they have the power to greatly improve the human-machine interface. Our goal is to develop a system that allows users to effortlessly control a robotic arm through simple hand movements, ultimately enhancing the user experience and making human-robot interaction more intuitive and effortless[4-9].

In this research, the integration of the versatile and compact Node MCU microcontroller plays a pivotal role. Boasting powerful features such as wireless communication and real-time data processing, the Node MCU is the perfect choice for promoting smooth interaction between the user and the robotic arm. Additionally, with the integration of the OpenCV library, the system is further enhanced, utilizing advanced image processing techniques to accurately interpret and respond to dynamic hand gestures

Through this exploration of hand gesture-controlled robotics, we aim to pave the way for more natural and user-friendly interfaces, fostering a closer integration between humans and machines. The subsequent sections of this paper delve into the related work, system architecture, gesture recognition algorithm, Node MCU integration, experimental setup, results, and conclusions, providing a holistic understanding of the research and its implications[10-12].

RELATED WORK

The field of hand gesture control robotic arm using Open CV and Node MCU is rapidly evolving, with numerous research projects exploring various functionalities and applications. Here's a detailed analysis of some noteworthy, related works: “Gesture-Controlled Robotic Arm Utilizing OpenCV" [13]:

- Similarities: Both utilize Open CV for control and image processing for remote monitoring.
- Differences: This robot arm focuses on image processing using a camera
- Insights: Explore how your robot arm could integrate a camera for visual monitoring And image processing.

B. "Gesture-Controlled Robotic Arm" (Feb 2023):

- Similarities: Both employ Image processing for control functionality robotic arm
- Differences: This robot focuses on Arduino based control, while yours prioritizes autonomous control navigation and sensor-based detection.
- Insights: Consider incorporating microcontroller control capabilities for targeted robotic arm alongside image processing[14].

C. "Gesture Controlled Robotics Hand: (Feb 2023):

- Similarities: Both utilize image processing technique and wireless communication.
- Differences: This relies primarily on visual inspection for glove to control robot.
- Insights: Explore integrating your image detection capabilities with the image processing feature for enhanced identification[14].

D, “Bluetooth Controlled Arduino Based Robotic Arm" (2017):

- Similarities: Both utilize image processing technique and wireless communication.
- Differences: This robot utilizes Raspberry Pi for additional processing power and image recognition, while yours focuses on cost-effective Node MCU -based solutions[15].
- Insights: Consider researching the potential of adding basic image recognition for enhanced image

confirmation within framework.

E." Internet Of Things (Iot) Based Robotic Arm" (2017):

- Similarities: Both involve working of robotic arm and autonomous navigation.
- Differences: This research focuses on integrating IoT for object recognition and pathfinding optimization, while yours prioritizes a cost-effective Node MCU and Open CV solution.
- Insights: Investigate the feasibility of incorporating basic AI modules for more nuanced object identification and improvements within your budget constraints[16].

PROPOSED SYSTEM

The proposed Hand Gesture control robotic arm using Open CV and Node MCU comprises the following key components:

Hardware:

1. Microcontroller:
   - Node MCU : Serves as the central processing unit, controlling robotic arm,sensors, motors, and communication modules. Model of Node MCU is shown in Figure 1.

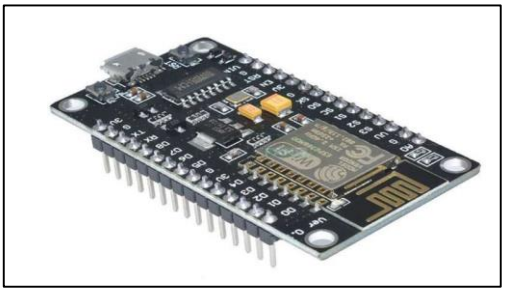

Fig1.Node MCU

2. Communication Modules:
   - Bluetooth/Wi-Fi (optional): Facilitate local communication with a remote control device or mobile app for manual navigation and monitoring.
3. Motor System:
   - Servo motors: Drive the robot's movement and navigation. Controlled through motor driver circuits for precise maneuverability.
4. Additional Considerations:

- Chassis: A sturdy base frame to mount all components and protect them from environmental damage.
- Power Supply: Rechargeable battery or reliable power source to sustain the robotic arm operation.

Software:

1. Arduino IDE: Used to program the robot's functionality, including:
   - Sensor data processing and interpretation for working of arm movement
   - Motor control algorithms for precise movement and navigation.
   - Communication protocols for Bluetooth/Wi- Fi or GSM data transmission.
2. OpenCV
   - OpenCV is an Open-Source Computer Vision library that provides real time image processing.
   - OpenCV is open source and cross-platform. OpenCV can be configured to run the application on a computer's graphics processing unit (GPU) or a central processing unit (CPU). Within this project, all image processing is done on the CPU.
   - Even though GPUs are specialized for image processing, we ran the image processing on the CPU rather than the GPU to understand the minimum processing power needed for real time gesture recognition for control systems. Model OpenCV is shown in Figure 2.

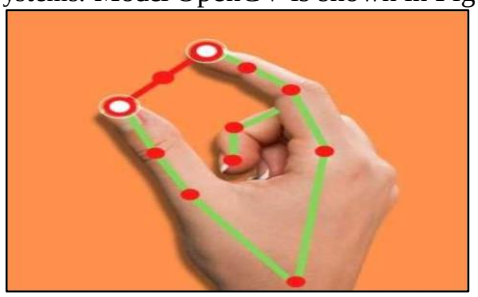

Fig 2. openCV

Proposed Workflow:

1. Sensor Monitoring: The robot continuously scans its surroundings using camera sensor by implementing open CV
2. Image Processing: When a camera sensor detects a movement near the camera sensor ,it gives a predefine node element for processing the image signal.
3. Working of Robotic Arm : These process data is then provided to Node MCU, .NodeMCU provide data to the robotic arm which acts as per the predefine instructions set in the program. Robotic arm uses image processing to detect the surrounding arm movement.
4. Communication: Depending on the environment and available connections, the robot:
   - Can receive sensor data via Node MCU to designated users in remote areas.
   - Transmits data and camera feed via Bluetooth/Wi-Fi to a nearby control device or app.
   - User Response: Users can remotely track the robot's arm location, view camera feed and control its movement to assess the situation and initiate appropriate actions.

HARDWARE IMPLEMENTATION AND RESULT

1. Robotic Arm Construction:

- Chassis: A custom acrylic or plywood chassis is designed and fabricated to securely house all components.
- Component Mounting: NodeMCU is mounted centrally for easy access and wiring. Sensors are positioned strategically based on their function. Motors and motor drivers are placed near the arm joints for efficient power transmission.
- Power Supply: A rechargeable battery pack or AC- DC adapter can provides reliable power. Voltage regulators ensure stable voltage levels for all components.Model Robotic Arm Construction is shown in Figure 3.
- Wiring and Connections: All components are connected using jumper wires and breadboards for prototyping and easy modifications. Permanent connections can be soldered for improved robustness.

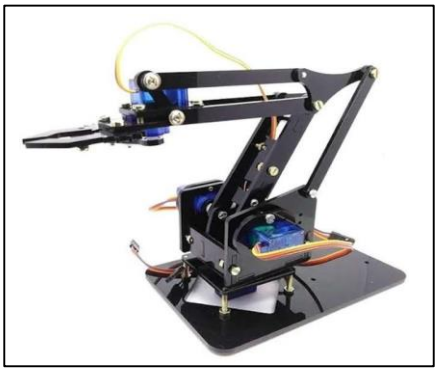

Fig 3.Robotic Arm Construction

2. **Code implementation**:
   - Various servo motor and motor control code are applied
   - these code are implemented through Open CV library and mediapipe library module

3. **Motor Control and Navigation**:
   - Motor driver circuits: Used to control the servo motors and enable precise maneuvers like forward, backward, turning, and up-down movement
   - Navigation algorithms: Implemented in the code to guide the robotic arm along predefined paths or autonomously area while using image processing.

4. **Testing and Results**:
   - Image detection: Conducted in controlled environments with simulated sources. Measured accuracy and response time of camera sensors in triggering time
   - Processing image : Image data is process through the Open CV and Mediapipe library module. The image is process for the various types of nodal information for calculating movement of servo motors attach at the various joints of the Robotic arm
   - Navigation: Assessed the robot's ability to follow predefined paths and reach designated nod of robotic arm accurately. Evaluated the performance of navigation algorithms.
   - Communication: Measured the range and reliability of data transmission through NodeMCU connections. Analyzed latency and signal strength in different environments.

5. **Results Summary**:
   - The image is successfully process for getting the node information
   - This image process information is given to the Node MCU for deciding the node location and axis location of the robotic arm
   - Navigation algorithms guided the robotic arm along predefined paths and reached designated locations accurately.
   - Communication can be done through Bluetooth/ Wi-Fi was reliable within their respective ranges, enabling data transmission and remote control. Robotic Arm with ESP8266 is shown in Figure 4.

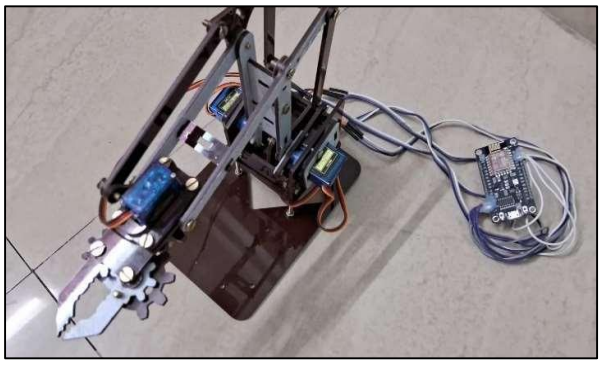

Fig 4. Robotic Arm with ESP8266

6. Discussion and Future Work:

- The hardware implementation demonstrated the feasibility and effectiveness of the proposed design.
- Further optimization of sensor calibration, motor control algorithms, and communication protocols can enhance performance.
- Integrating a camera for image processing alongside image detection could provide additional information for identification.
- Implementing basic AI modules for object recognition and pathfinding could potentially improve accuracy and efficiency. Testing in larger and more diverse environments

PERFORMANCE EVALUATION

The robotic arm performance is evaluated based on the following criteria:

A. Image Detection Accuracy: The accuracy of camera sensors in detecting image sources is measured under different environmental conditions.
B. Error avoidance Efficiency: The success rate of the robot arm in navigating around process without error is evaluated.
C. Navigation Accuracy: The robotic arm ability to follow defined paths and reach designated locations is assessed.
D. Communication Range and Reliability: The effectiveness of Bluetooth or Wi-Fi for local control is measured in terms of range and signal strength.

CONCLUSION

This research has unveiled the design and implementation of Hand Gesture control robotic arm using Open CV and Node MCU, a promising innovation poised to redefine proactive advance solutions. This autonomous guardian, equipped with image processing and remote monitoring capabilities, offers a cost-effective and versatile alternative to traditional image processing systems. The detailed analysis of its components, performance evaluation metrics, and potential applications solidify its value across various sectors.

Key Achievements:

- Real-Time Monitoring and Control: Through remote control apps and data transmission, users gain instant insights into the robot arm surroundings and can issue commands for targeted action.
- Adaptability and Scalability: The platform allows for customization and integration with additional sensors and modules, making it suitable for diverse environments and specific needs.

Future Potential:

- Enhanced AI Integration: Incorporating AI algorithms could enable object recognition, improved path finding, and auto working of robotic hand
- Multi-Robot Communication: Collaborative networks of robots could patrol larger areas and share data for comprehensive working .
- Environmental Monitoring: Adapting the robot's sensors could enable monitoring air quality, noise pollution, and other environmental parameters.

Looking Ahead:

- This Node MCU -based gesture control robot presentsa significant step towards a future where autonomous guardians play a crucial role in our safety and security.
- Its affordability, adaptability, and effectiveness make it a compelling option for residential, industrial, and even environmental monitoring applications.
- Continued research and development in AI integration, multi-robot collaboration, and sensor adaptation hold immense potential for further enhancing the robot's capabilities and solidifying its position as a reliable and proactive protector in our increasingly interconnected world.

REFERENCES

[1] Abhishek, S, K., Qubeley, Fai, L. C., Ho, & Derek. (2016). Glove-based hand gesture recognition sign language translator using capacitive touch sensor. In 2016 IEEE International Conference on Electron Devices and Solid-State Circuits (EDSSC) (pp. 334- 337): IEEE.

[2] Ahuja, M. K., & Singh, A. (2015). Static vision based Hand Gesture recognition using principal component analysis. Paper presented at the 2015 IEEE 3rd International Conference on MOOCs, Innovation and Technology in Education (MITE).

[3] Bretzner, L., Laptev, I., & Lindeberg, T. (2002). Hand gesture recognition using multi-scale colour features, hierarchical models and particle filtering. Paper presented at the Proceedings of fifth IEEE international conference on automatic face gesture recognition.

[4] Chen, F.-S., Fu, C.-M., & Huang, C.-L. (2003). Hand gesture recognition using a real-time tracking method and hidden Markov models. Image and vision computing, 21(8), 745-758.

[5] Dipietro, L., Sabatini, A. M., & Dario, P. (2008). A Survey of Glove-Based Systems and Their Applications. Ieee transactions on systems, man, and cybernetics, part c (applications and reviews), 38(4), 461- 482.

[6] C.-C. Chang, I.-Y Chen, and Y.-S. Huang, "Hand Pose Recognition Using Curvature Scale Space", IEEE International Conference on Pattern Recognition, 2002.

[7] Abhijit Nale, Ankush Barkade, Pravin Ekhande, and Shreyas Dayal, “Hand Gesture Recognition for Robotic Car Control”, IJARCST, Vol. 3, Issue 1 (2015).

[8] Sanwar S, Ahmed MI. Automated Object Sorting System with Real-Time Image Processing and Robotic Gripper Mechanism Control. Journal of Engineering Advancements. 2023 Sep 4;4(03):70-9.

[9] Mahajan V, Kawale S, Koshti S, Kshirsagar V. REVIEW PAPER ON GESTURE CONTROLLED ROBOT WITH ROBOTIC ARM.

[10] Shaikh MA, Dhavalikar M. Design and Development of Prototype for Advanced Industrial Manipulator. International Journal of COMADEM. 2022 Oct 1;25(4).

[11] Malik MJ, Aditya M, Varma DR, Sidhartha G, Sohan P, Rao SG, Adnan MM. Specific Object Picking Robotic Arm Using Haar Cascades. InE3S Web of Conferences 2024 (Vol. 529, p. 04008). EDP Sciences.

[12] Lim YS. Application of intelligent gesture control to simultaneously control multiple remote devices (Doctoral dissertation, UTAR).

[13] Paterson J, Aldabbagh A. Gesture-controlled robotic arm utilizing opencv. In2021 3rd International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA) 2021 Jun 11 (pp. 1-6). IEEE.

[14] Budhiraja A. Gesture Controlled Robotic Arm for Social Distancing. Gesture. 2023 May;2023.

[15] Dasgupta S, Ghosh A. Bluetooth Controlled Arduino Based Robotic Arm. Asian Journal For Convergence In Technology (AJCT) ISSN-2350-1146. 2021 Apr 5;7(1):115-20.

[16] Gawli K, Karande P, Belose P, Bhadirke T, Bhargava A. Internet of things (IoT) based robotic arm. Int. Res. J. Eng. Technol. 2017;4(03).