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GESTURE CONTROLLED ROBOTIC ARM

Rishi Sharma[1], Vishal Pal[2], Prof. Vivek Singh[3], Prof. Anuj Kumar[4]

[1,2]Final Year Student, Department of Electronics and Communication Engineering, Rishi Sharma, Vishal Pal; Raj Kumar Goel Institute of Technology, Ghaziabad, Uttar Pradesh, India

[3,4]Project Guide Prof. Vivek Singh, Prof. Anuj Kumar; RAJ KUMAR goel institute of technology, Ghaziabad, Uttar Pradesh, India

A B S T R A C T:

This research paper reports the design and development of a gesture-controlled robotic arm that facilitates intuitive and contactless human-robot interaction. The system recognizes hand gestures through computer vision and inertial sensor-based methods to robotic motion. Gestures are sensed through a camera-based system or wearable sensors (e.g., an accelerometer and gyroscope) and processed through machine learning algorithms for effective recognition. These commands are then translated into pre-programmed movements of the robotic arm, carried out using servo motors with a microcontroller (such as Arduino or Raspberry Pi) in control.

The system has widespread applications in assistive technology, industrial automation, medicine, and hostile environments, where no-hands operation is imperative. Experimental results show high accuracy in gesture recognition, real-time responsiveness, and low latency in motion execution. Future enhancements include adaptive AI-powered learning, multi-gesture detection, and real-time processing for sophisticated robotic tasks. This research identifies the promise of gesture-based robotic control systems in enhancing human-robot collaboration, increasing automation, and widening the range of intelligent robotic applications.

Keywords: Arduino, Raspberry Pi, Robotic, Accelerometer

INTRODUCTION

The introduction of gesture recognition technology revolutionized human-computer interaction, allowing for more natural and effortless interaction between humans and machines. The use of traditional input devices like joysticks, keyboards, and buttons tends to constrain the flexibility and efficacy of robot system control, particularly in high-stakes applications where response speeds and user-friendliness are of highest importance. These traditional interfaces pose great challenges in industries, medicine, and dangerous environments. For example, workers in dangerous environments or working remotely with machinery experience response delays and safety hazards owing to the physical interface necessary with conventional devices. Likewise, in healthcare and assistive technology, physically disabled people have difficulty with manual control systems, which restrict their use of necessary robotic aid.

In overcoming such issues, gesture-controlled robotic arm offers a viable solution. By providing contactless robotic control using hand gestures, this technology facilitates more natural, efficient, and accurate robotic control. Employing computer vision and sensor-based methods, such systems identify human hand movement using cameras, accelerometers, gyroscopes, and other on-body sensors. These are subsequently processed using machine learning to determine defined movements, which are associated with robotic actions, resulting in an intuitive and uninterrupted interface.

Gesture-controlled robotic arms are especially useful in hands-free environments. They can enhance safety, efficiency, and productivity in industries, and in the healthcare sector, provide more accessibility for the disabled by facilitating natural prosthetic control. Additionally, in applications such as remote surgery, space travel, and disaster relief, this technology provides high accuracy and real-time responsiveness with low latency.

This work provides the design and implementation of a gesture-controlled robotic arm with emphasis on hardware choice, software algorithms, and real-time processing features. It tests the system's accuracy, response time, and the versatile potential uses while touching on future improvements such as AI-based adaptive learning, multi-gesture recognition, and extended real-time processing.

Problem Statement

Most traditional robotic control systems use manual input devices like joysticks, buttons, or keyboards, which are often inconvenient, less intuitive, and difficult to use in specific environments. In industries, medical care, and dangerous settings, these traditional input devices pose great barriers to effective and safe operations. For instance, in risk-prone settings such as factories or calamity areas, contactless control is essential to avoid accidents and minimize human exposure to harmful situations. In the field of healthcare, particularly for physically challenged patients, the conventional robotic interfaces might prove to be inaccessible or inconvenient. Analogously, in prosthetics and assistive devices, there is an emerging requirement for more intuitive control strategies that can provide accuracy and usability.In addition, the problem of gesture recognition accuracy and real-time responsiveness continues. Even with the progress of computer vision and machine learning, existing gesture recognition systems have the limitations of supporting multiple gestures, being distracted by the environment, and supporting minimal latency for motion execution. These issues hold back the wider usage of gesture-controlled robotic arms in real-world applications, particularly for intricate or multi-step tasks. The issue addressed by this research is that there is no dependable, precise, and effective gesture-controlled robotic arm control system with the capacity for real-time response and versatility to diverse user demands and ambient conditions. This article aims to create a gesture-controlled robotic arm that bridges these gaps through the use of high-end computer vision, machine learning techniques, and sensor fusion technologies to improve accuracy, usability, and versatility.

Literature Survey

Gesture-controlled systems have been investigated in a wide range of applications, with important developments in the fields of human-robot interaction and assistive technology. Conventional methods of controlling robotic arms have been based on manual interfaces like joysticks, touchpads, or keyboards. These have limitations in offering intuitive, hands-free control or accuracy in intricate tasks. Consequently, systems based on gesture control have attracted a lot of attention for their ability to provide more natural interaction and more flexibility.

- Poltak Sihombing, et al. This writer explains robot arm controlling based on fingers and hand movement. The research work is targeted towards the concise description of simple robot arm control by human finger movement and human hand movement. This project has developed a robot arm based on a Fuzzy logic method for robot arm movement control.
- Priyambada Mishra, et al. In this paper, they have employed 4 servo motors in order to create joints of the robotic arm and the movement will be regulated with the assistance of potentiometer. The Arduino UNO is used as a controller. The analogue input signals of the Arduino's is provided to the Potentiometer. The arm has been constructed by the Cardboard and individual components are fixed to the respective servo motors. The arm is designed particularly to pick and place light weight objects. Therefore, low torque servos, having a rotation of 0 to 180 degrees have been employed. Arduino is used for programming.
- Anughna N, et al. The paper is an illustration of the author using accelerometers to gather information. Arduino Atmega328 controller is employed. Human arm movement, fingers are detected by flex, gyro sensors and signals are fed to Arduino ATmega328 that controls the servo motors and enables the movement of the arm. The Arduino programming was carried out using embedded C language. The Flex and Gyro Sensors were positioned close to the fingers. Whenever the change is detected, the information by both the sensors is processed by the controller.

Working

A gesture-controlled robotic arm works by converting human hand movements into mechanical motion through sensors and microcontrollers. A glove worn by the user usually has an accelerometer or gyroscope sensor attached to it. The sensor identifies the hand's orientation, tilt, and movement in real time. The information is transmitted to a microcontroller, for example, an Arduino or Raspberry Pi, either wirelessly through Bluetooth or through wired interfaces. The sensor inputs are processed by the microcontroller and translated into precise commands that drive the servos or motors of the robotic arm. As an instance, tilting the hand in the forward direction could make the arm move forward, and rotating the hand can rotate the gripper or the wrist. Finger gestures may also be interpreted in order to open or close the robotic gripper.

The robotic arm tracks the user's hand movements, allowing for intuitive control without the need for physical contact with a joystick or buttons. The system is particularly valuable in dangerous environments, medical procedures, or for aiding individuals with disabilities. Integrating real-time sensor data, signal processing, and motor actuation, gesture-controlled robotic arms provide an unencumbered human-machine interaction platform that improves accuracy and useability.

Software Required:

ArduinoIDE:

- The Arduino IDE (Integrated Development Environment) is a coding platform employed to compose, compile, and upload code into Arduino boards. It accommodates languages such as C/C++ and offers an easy-to-use interface with hardware-controlling built-in libraries. It supports straightforward development of interactive projects and embedded systems.

Hardware Required:

Arduino Uno:

- Arduino Uno is a microcontroller board with the ATmega328P. It consists of 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog inputs, 16 MHz ceramic resonator, USB connection, power jack, ICSP header and reset button. The Arduino Integrated Development Environment (IDE) is a software platform that is used to write, compile, and upload code to Arduino boards. It is compatible with languages such as C/C++ and offers a basic interface with inbuilt libraries for hardware control. It allows simple development of interactive projects and embedded systems.

Servo Motor:

- A servo motor is a rotary or linear actuator designed to precisely control angular or linear position, velocity, and acceleration. It is widely used in robotics, automation, and control systems for its accuracy and ease of integration.

Flex Sensor:

- A flex sensor is a kind of sensor which is used to measure the amount of defection otherwise bending. The designing of this sensor can be done by using materials like plastic and carbon. The carbon surface is arranged on a plastic strip as this strip is turned aside then the sensor's resistance will be changed. Thus, it is also named a bend sensor.

Motor Driver:

- A motor driver, also known as a control motor, is an electronic device or module that controls and manages the operation of an electric motor. It serves as an interface between a microcontroller or other control system and the motor itself, enabling precise control of the motor's speed, direction, and other parameters. Motor drivers are commonly used in various applications, including robotics, automation, automotive systems, and industrial machinery.

Accelerometer:

- An electromechanical instrument for measuring acceleration forces is called the accelerometer. These forces could be stationary, like the constant pull of gravity, or dynamic, like in the case of many mobile gadgets, to detect motion or vibrations.

Conclusion

This study presents the design and implementation of a gesture-controlled robotic arm, focusing on intuitive, contactless human-robot interaction. By leveraging computer vision, sensor fusion, and machine learning algorithms, the system enables accurate gesture recognition and real-time robotic control. The proposed approach improves accessibility, precision, and efficiency in environments such as healthcare, industrial automation, and hazardous operations. Experimental results demonstrate its potential for enhanced human-robot collaboration. Future work will explore AI-driven adaptive learning and multi-gesture recognition, further advancing the capabilities and applicability of gesture-controlled robotic systems.

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