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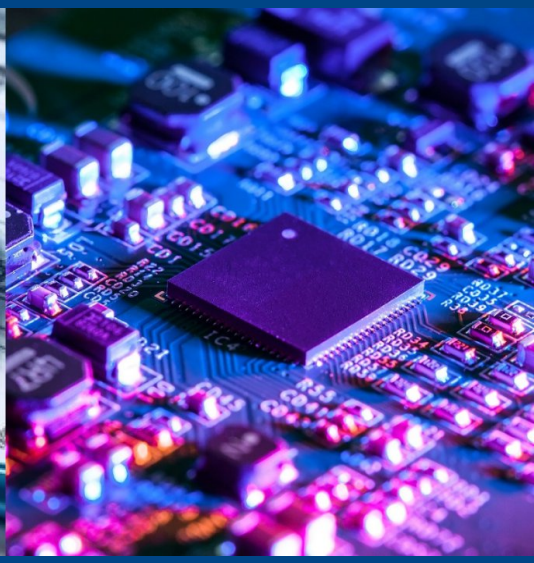

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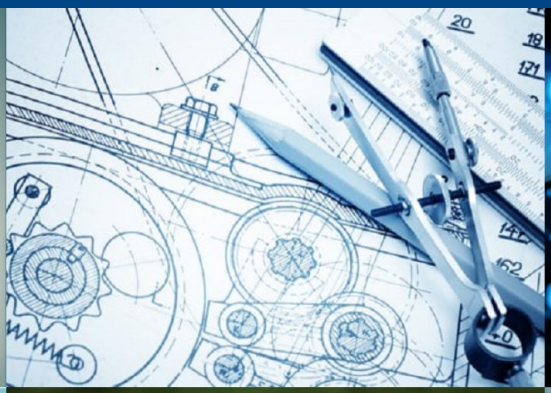

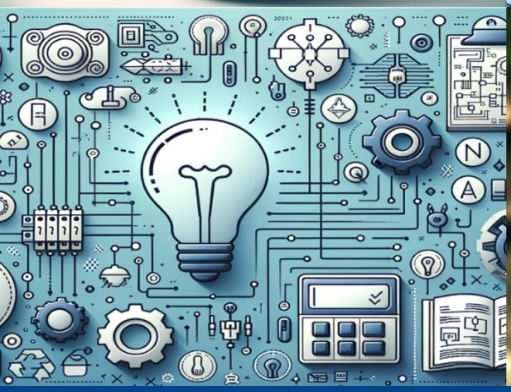

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Gesture Controlled Robotic Arm Using Python Programming

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ABSTRACT: The history of human-computer interaction has led to the development of intuitive and touchless interfaces, where gesture control has become highly popular because of its user-friendly nature. This project focuses on designing a robotic arm controlled through hand gestures by converting human hand movements into robotic actions in real time. Touchless control systems are increasingly important in fields such as healthcare, hazardous work environments, and assistive technologies. In this system, images captured through a standard camera are processed using the OpenCV library to detect finger positions and hand center points. The major component of the project is the use of MediaPipe for accurate hand tracking and gesture recognition.Hand gestures are identified based on the number of raised fingers and the position of the palm in front of the webcam. These gestures are then used to control the movements of the robotic arm.

KEYWORDS: Python, OpenCV, MediaPipe, PyFirmata, Arduino Uno, Servo Motors, 3D Printed Robotic Arm

I. INTRODUCTION

- Human-computer interaction has evolved significantly, moving from keyboard-based systems to advanced touchless technologies.
- Gesture recognition is one of the most natural ways of communication, allowing users to interact with machines using simple hand movements.
- Robotic arms are widely used in industries, healthcare, automation, and hazardous environments where precise and remote operations are required.
- Controlling robotic arms through traditional methods such as joysticks or buttons can be less in- tuitive and slower for real-time tasks.
- Hand gesture-based control systems provide a user-friendly, cost-effective, and efficient alterna- tive for operating robotic devices.
- This project uses computer vision techniques to detect and interpret hand gestures through a webcam in real time.
- OpenCV is used for image processing, while MediaPipe is used for accurate hand landmark de- tection and gesture tracking.
- Recognized gestures are converted into commands and sent to an Arduino Uno board using PyFirmata.
- The Arduino controls multiple servo motors that move the robotic arm according to the user's hand gestures.
- The system demonstrates the integration of software and hardware to create an intelligent and touchless robotic control mechanism

II. LITERATURE SURVEY

- The review of existing literature on gesture control systems and robotic arms control is crucial for understanding the present situation in this field and the use of technology. This literature review summa- rizes information from articles related to gesture detection and control of robotic mechanisms.
- Technologies in Gesture Recognition Technologies suggest a paper entitled "Vision-Based Hand Gesture Recognition: A Review" (Rautaray & Agrawal, 2015) that identifies two main types of gesture recognition techniques:

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device-based (such as data gloves) and vision-based (including webcam and im- age Processing).

- Though the former methods allow achieving high accuracy, they require wearable devices. In turn, vision-based technologies appear more intuitive and less expensive, especially when RGB cameras are employed.
- Thanks to Media Pipe developed by Google, there have been several new articles (for instance, Zhang et al., 2021)
- revealing its capability to detect real-time hand tracking without using depth sensing. Thanks to light-weight machine
- With learning models employed, MediaPipe becomes accessible even for low-end devices and is
- Human-Robot Interaction and Robotic Arm Control
- Research entitled "Real-Time Control of Robotic Arm Using Hand Gestures" (K. Sharma et al., 2020) demonstrates
- gesture-based robotic control with computer vision and Arduino

III. BLOCK DIAGRAM

1. User Hand Gestures

The process starts when the user performs different hand gestures in front of the webcam. These gestures act as input commands to control the robotic arm.

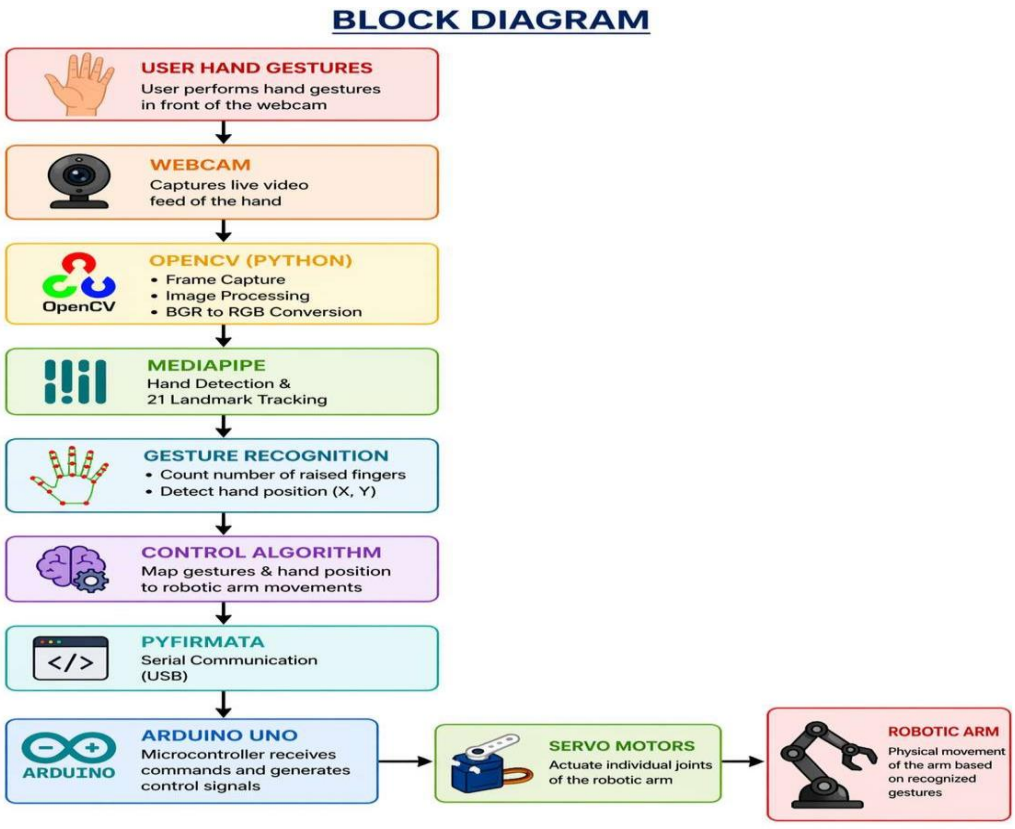
2. Webcam

The webcam captures the live video stream of the user's hand movements and sends the video frames to the computer for processing.

3. OpenCV (Python)

OpenCV is used to process the captured video frames. It performs tasks such as:

- Capturing frames continuously
- Image enhancement
- Converting BGR format to RGB format for MediaPipe compatibility



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4. MediaPipe

MediaPipe detects the user's hand in each frame and tracks **21 hand landmarks** such as fingertips, joints, and palm center.

5. Gesture Recognition

Using the landmark points:

- The number of raised fingers is counted
- Hand center position (X, Y) is calculated
- Specific gestures are identified

6. Control Algorithm

The recognized gestures are converted into robotic arm movement commands. Example:

- One finger → Base rotation
- Two fingers → Up movement
- Closed fist → Stop

7. PyFirmata

PyFirmata is a Python library used for communication between the computer and Arduino Uno through USB serial connection.

8. Arduino Uno

Arduino receives commands from the computer and generates PWM control signals for the servo motors.

9. Servo Motors

Servo motors rotate to specific angles based on Arduino commands. Each motor controls one joint of the robotic arm.

10. Robotic Arm

Finally, the robotic arm moves according to the detected hand gestures, performing real-time actions like rotate, lift, grip, or release

IV. METHODOLOGY

This section describes the systematic steps that were taken to design, construct, incorporate, and test the gesture controlled robotic arm. Computer vision, gesture detection, and servomotor movements form the core concepts used in development. The method is iterative in nature, assuring that each individual part was tested before moving On to the integration stage.

Step 1: Project Planning and Designing

The initial step comprised project planning and components identification, including:

- Determine method of gesture input (vision-based system using webcam).
- Selection of the hand tracking algorithm (Media Pipe).
- Determination of hardware components (Arduino Uno and Servos).
- Identify gestures controlling the various parts of the robotic arm.

Step 2: Hand Detection and Landmark Extraction

In Python, a program was written using OpenCV to capture live video feed and apply Media Pipe's Hands model to analyze the images. Media Pipe extracts 21 hand landmarks per frame and provides their x,y values.

- Frames are captured and horizontally flipped to achieve a mirrored view.
- From BGR format to RGB conversion.
- Hand landmark detection model inference.

Step 3: Gesture Mapping Logic

Based on the extracted data:

- The number of raised fingers is calculated.

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- The hand's position (center_x, center_y) is used to determine arm movement.

Step 4: Hardware Integration

The robotic arm was assembled with five servo motors:

- Connected to pins D4, D5, D6, D7 and D9on Arduino Uno.
- Arduino was flashed with Standard Firmata.ino firmware using the Arduino IDE.

Step 5: Testing and Evaluation

The system was tested in various conditions:

- Different lighting setups.
- Various backgrounds and hand positions.
- Varying gestures and hand speeds. Observed:
- Tracking accuracy.
- Gesture recognition consistency

S.No	Component	Connected To	Pin / Interface	Purpose
1	Webcam	Computer / PC	USB Port	Captures hand gestures
2	Arduino Uno	Computer / PC	USB Cable	Serial communication and power
3	Servo Motor 1	Arduino Uno	D4	Base rotation control
4	Servo Motor 2	Arduino Uno	D5	Shoulder movement
5	Servo Motor 3	Arduino Uno	D6	Elbow movement
6	Servo Motor 4	Arduino Uno	D7	Gripper / Wrist movement
7	Servo Motor 5 (Optional)	Arduino Uno	D9	Extra joint control
8	All Servo VCC	External 5V Supply	+5V	Power supply for motors
9	All Servo GND	Arduino GND + Supply GND	GND	Common ground connection
10	Python Program	Arduino Uno	PyFirmata via USB	Sends control commands
11	OpenCV + MediaPipe	Webcam Input	Software Interface	Detects hand gestures

Connection table

V. RESULT

The developed system successfully recognized hand gestures with an accuracy of approximately **85– 90%** under normal lighting conditions using MediaPipe and OpenCV. It also showed fast real-time performance, with an average response delay of around **100–150 milliseconds**. Python programs running on a computer were used along with the PyFirmata library to communicate with the ArduinoUno board. Based on the detected hand gestures, the Arduino controlled the connected servo motors, enabling smooth movement of the robotic arm. The project proved to be a **cost-effective and efficient solution** for intuitive robotic control. It can be applied in several fields such as **education, healthcare, automation, and assistive systems**

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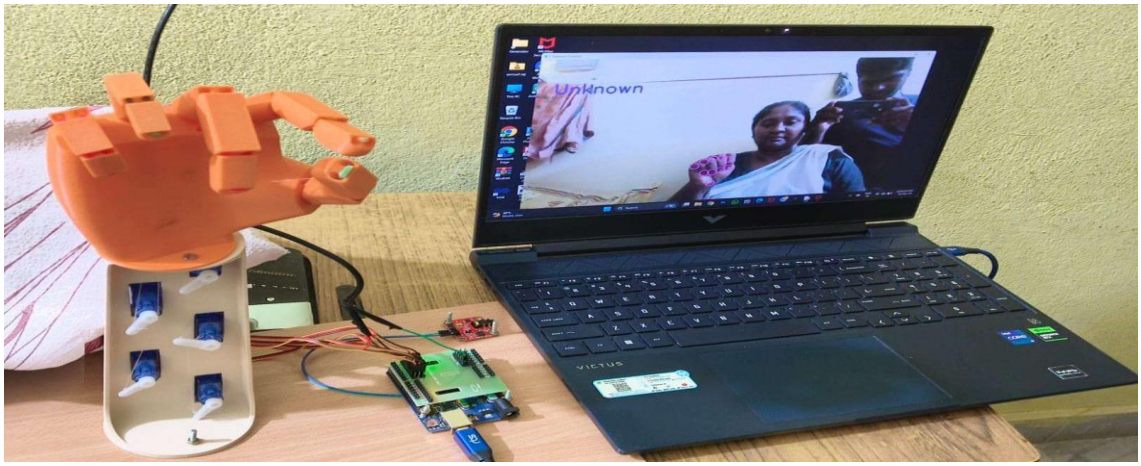

Project Implementation with hardware setup

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