Humanoid Robotic Arm Using Computer Vision

Project Report

by N Narayan

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Abstract

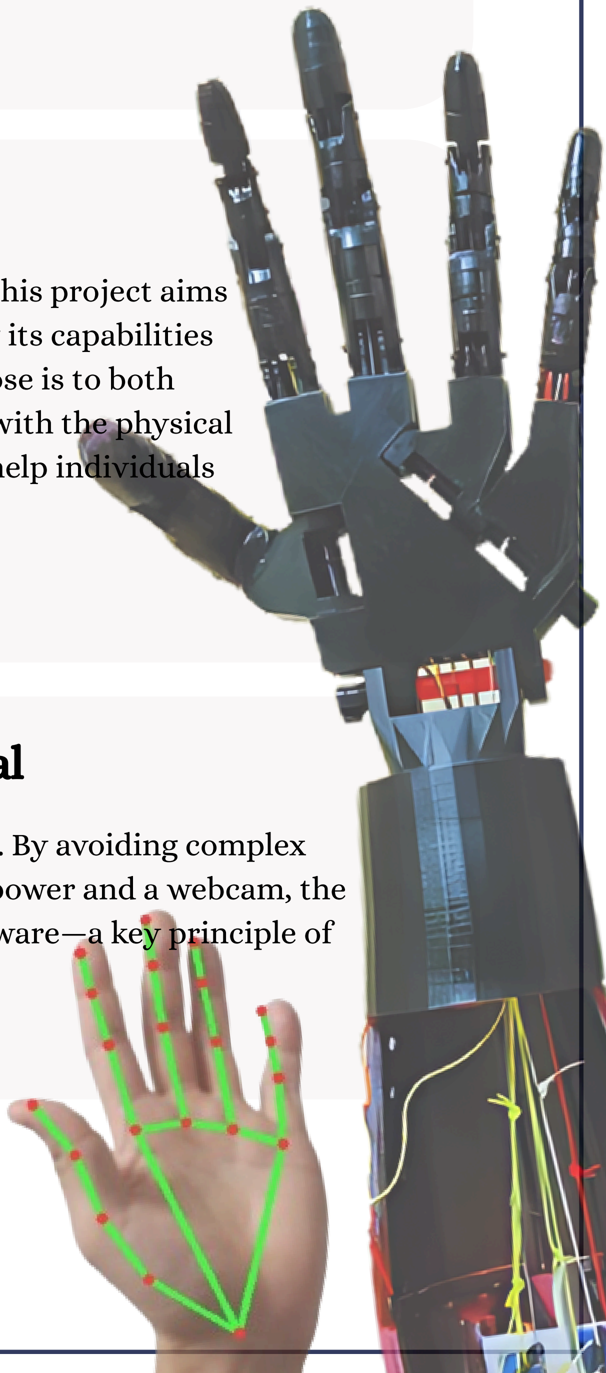
This document details a low-cost, sensor-less humanoid robotic arm controlled by computer vision and deep learning. It interprets real-time hand gestures from a standard camera to mimic human motion, demonstrating a practical and accessible application of machine learning in robotics. By simplifying hardware in favor of a software-driven approach, the project serves as both an educational platform and a prototype for advanced assistive technology, successfully bridging digital intelligence with physical action.

Introduction

Motivated by the high barrier to entry in robotics and AI, this project aims to demystify applied machine learning by demonstrating its capabilities with minimal, cost-effective hardware. The core purpose is to both educate, by offering a tangible example of ML interacting with the physical world, and innovate, by prototyping an assistive limb to help individuals with disabilities.

Core Principle & Goal

The project prioritizes simplicity and accessibility. By avoiding complex sensors and instead relying on a laptop's processing power and a webcam, the focus shifts from costly hardware to intelligent software—a key principle of modern robotics.

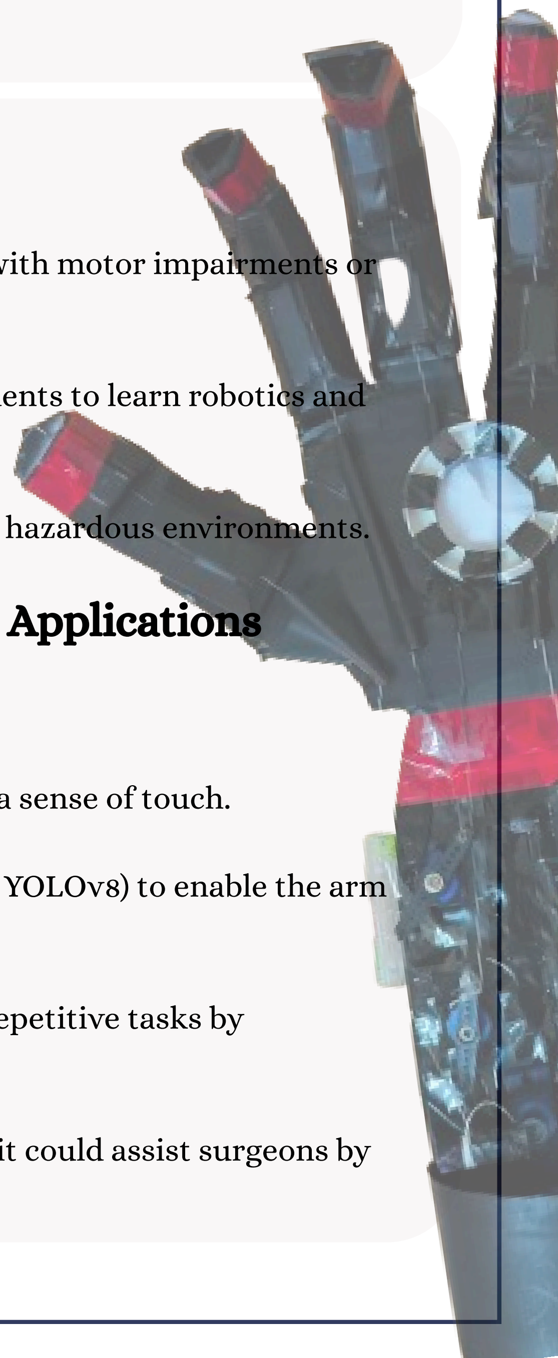


Project Architecture

The project consists of a physical arm and a digital control system.

1. The Physical Model: Design and Construction
The physical arm is a 3D-printed replica of a human arm, allowing for rapid prototyping. Assembled components are actuated by a tendon and pulley system connected to five SG90 micro servos, which mimic muscle movements for actions like finger flexion.

2. The Digital Brain: Computer Vision and Control
The arm's intelligence is a software system running on a laptop. Using Python and computer vision libraries, a pre-trained deep learning model processes a webcam feed to track 21 key landmarks on a human hand in real-time. An Arduino Uno board acts as the interface, receiving control data from the Python script via Serial Communication and directing the servos.



Use Cases

Intuitive Assistive Technology: Acts as a "third arm" for users with motor impairments or anyone needing assistance with simple tasks.

Educational Kits: A low-cost, hands-on platform for STEM students to learn robotics and computer vision.

Telerobotics: Allows for safe remote manipulation of objects in hazardous environments.

Future Enhancements and Advanced Applications

Future development could vastly expand its capabilities:

Haptic Feedback: Integrating sensors to provide the user with a sense of touch.

Autonomous Grasping: Adding object recognition models (e.g., YOLOv8) to enable the arm to autonomously identify and grab objects.

Industrial Automation: Using the system to "teach" the robot repetitive tasks by performing them once.

Medical Assistance: With upgrades in precision and materials, it could assist surgeons by controlling instruments.

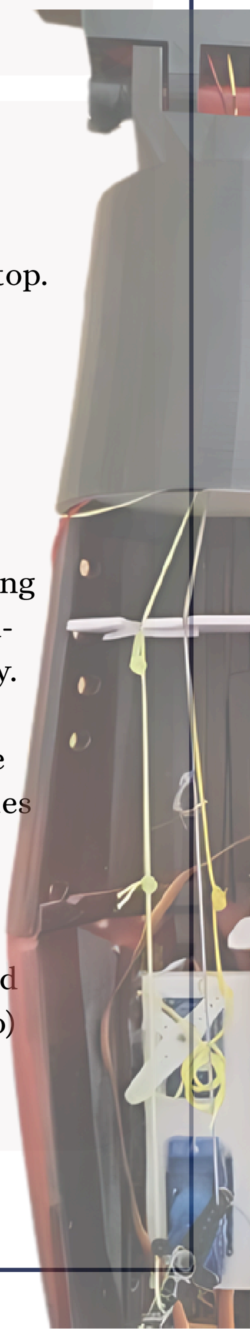
The Physical Model: Design and Construction

The physical manifestation of the project is a 3D-printed humanoid arm, designed to replicate the basic structure and articulation of a human arm.

3D Modeling & Printing: A 3D model of a human arm was designed and then fabricated using 3D printing technology, with support from our university's labs. This allows for rapid prototyping and easy replacement of parts.

Assembly & Mechanics: The printed components (fingers, palm, forearm) were assembled to create the final structure.

Actuation System: To enable movement, a pulley-like system using tendons (high-strength strings) is integrated. These tendons are connected to five SG90 micro servos, which act as the muscles of the arm. Each servo controls a specific degree of freedom, such as the flexion of a finger or the wrist's rotation.



The Digital Brain: Computer Vision and Control

The intelligence of the arm lies entirely in the software, which runs on a standard laptop. This "brain" is responsible for seeing the user, understanding their intent, and commanding the arm.

Core Technology: The system is built using Python, leveraging powerful open-source libraries for computer vision and media processing.

Hand Tracking Module: At the heart of the control system is a pre-trained deep learning model for hand tracking. This module processes the video feed from a webcam in real-time to identify 21 different landmarks (joints) on the human hand with high accuracy.

Hardware Interface: An Arduino Uno board serves as the bridge between the software and the physical hardware. It receives commands from the Python script and translates them into precise electrical signals to control the SG90 servos.

Communication Protocol: The laptop and Arduino communicate via Serial Communication over a standard USB connection. This is a reliable and straightforward method for transmitting the control data (specifically, the target angles for each servo) from the ML model to the arm's actuators.

Final Thoughts

This project proves that you don't need a huge budget to build something smart and functional. By combining simple hardware with intelligent software, we've created a sensor-less arm that's a real step towards more intuitive and accessible robotics. It shows that using computer vision to control robots is a powerful idea with a very exciting future.

A Project for Aspiring Innovators

This robotic arm is a great project for anyone who wants to learn and try applied computer science by solving a real-world problem. Developing such an intuitive project will give you a good understanding of the field and make your concepts much stronger.

So let us do science!