Design and Development of a Low-Cost Myoelectric Prosthetic Arm Utilizing Camera- Based Sensing

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Abstract

This paper aims to develop an advanced prosthetic arm control system using object detection technology to enhance user engagement and functionality. The technology uses a camera module to take real-time images of the user's environment. The Raspberry Pi microprocessor interprets these images through advanced object detection algorithms to identify and analyze objects in the field of view. When it senses objects, the Raspberry Pi sends relevant data to an Arduino Uno microcontroller. The Arduino Uno interprets this information and drives servo motors in the prosthetic arm, providing precise and responsive movements based on the detected objects. This unified approach allows patients to interact naturally with their surroundings, enhancing their ability to perform daily tasks and improving overall quality of life. The proposed system offers an inexpensive and efficient method for controlling prosthetic arms and has the potential for applications in assistive technology and rehabilitation engineering.

Keywords: Prosthetic arm control, object detection technology, Raspberry Pi, Arduino Uno, assistive technology

1.Introduction

The incorporation of camera module technology into myoelectric prosthetic limbs presents a dramatic improvement, responding to issues that have plagued the field for years regarding accessibility, cost, and functionality. This innovative solution significantly reduces the cost of production while enhancing the user experience by providing natural, intuitive control of the prosthetic arm. The system substitutes standard EMG sensors with a cost-effective solution that uses a camera module, Raspberry Pi, and Arduino Uno by taking visual data to interpret the user's gestures and movements of their muscles in this technology. By not requiring special sensors, this noninvasive technology offers accurate feedback about the user's desired activities. The Raspberry Pi interprets the images that are being captured by the

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camera and recognizes objects and movements in real-time, while Arduino Uno serves as a link to drive the servo motors of the prosthetic arm to facilitate accurate, coordinated movement. The seamless integration between the Raspberry Pi and Arduino Uno ensures smooth and efficient performance, enabling users to perform a variety of activities with ease and accuracy. The device not only offers a more cost-effective option to traditional myoelectric prosthetic limbs but also increases user satisfaction through greater comfort and control, making advanced prosthetic technology affordable to more people.

2.Literature review

2.1 Advancements in Prosthetic Control:

From Myoelectric to Camera-Based Systems Early breakthroughs in prosthetic control were mainly based on myoelectric systems, which relied on electromyography (EMG) inputs to interpret muscle activity and control prosthetic motions. Myoelectric control has evolved from simple switch-based mechanisms to more advanced techniques, such as proportional control and pattern recognition, which significantly improve the accuracy along with the electromyography inputs of all the prosthetic motions of natural[2020].

The development of 3D printing technologies has enabled prostheses to be lighter, flexible, and less costly [2021]. Nevertheless, even with these advancements, low-cost prostheses tend to have limited functioning, which can significantly impact user satisfaction [2018]. Recent studies have also shown that high-accuracy biosignal classifiers are still a challenge, as obtaining reliable [2022].Several open-source projects, such as Open Bionics, Inmoved, and Enable, aim to make prosthetic technology more affordable and accessible [2017]. However, EMG-based systems, such as the Myo Armband, continue to face challenges regarding signal quality and stability in everyday environments [2020].

3.Proposed System

The suggested solution targets only taking advantage of the camera module technology for object detection to facilitate user-friendly control of the myoelectric prosthetic arm. The prosthetic arm would identify and detect objects from the user's surroundings, which would allow for seamless interaction as well as handling. This method circumvents the need for involved electromyography sensors and thus concentrates on optical cues for commands. The ease and inexpensiveness of this technology render it extremely promising for those with limb in a render differences, providing a cost-effective and efficient method of prosthesis control. The block Diagram consists of included microcontroller/microprocessor, display screen, and prosthetic limb. The camera takes visual input, such as images of different objects. The microcontroller interprets this visual information using sub-components like the Raspberry Pi, Arduino Uno, and servo motor. . Economically, the goal is to redu The feasibility study is based on five critical areas: economic, technological, operational, environmental, and regulatory compliance. The operational feasibility emphasizes the need for proper signal interpretation, cost-effectiveness, accessibility, durability, and user-friendly designce prices compared to conventional prosthetic devices while offering scalability for mass production.

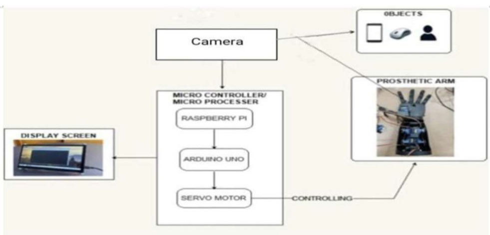


Figure 3.1 :Block Diagram of Prosthetic Arm

The display screen takes output from the microcontroller, potentially showing a graphical user interface with text and graphics. Lastly, the prosthetic arm is controlled by commands from the microprocessor, which could allow for accurate movement.

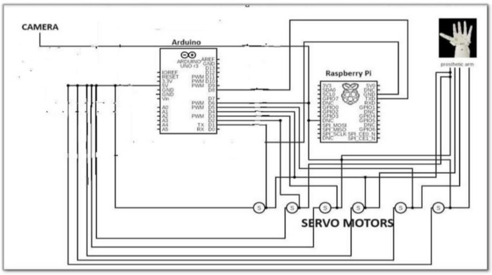


Figure 3.2 :Circuit Diagram of Prosthetic Arm

4.Methodology

4.1 Data Collection:

In order to develop a strong object detection system, the initial step is to determine the types of objects you need to detect, i.e., humans, cars, or animals. After determining the classes, the next step is to collect a varied set of images having these objects. This can be done through various sources such as online image databases such as ImageNet or Open photographs Dataset, web scraping tools, images taken with cameras or mobile phones, or even crowd-sourcing websites where people upload pictures. Once the photos are collected, quality and consistency of the dataset needs to be ensured. This includes confirming that all objects are labeled with the corresponding class, inspecting for the correct placement of bounding boxes, ensuring a ratio between object scales and postures, and removing duplicate or unwanted photos. It is also crucial to preprocess the dataset to condition it for training.

6.RESULTS

The prosthetic arm's fingers open and close based on inputs from the Arduino and Raspberry Pi serial monitor. Inputs like 2, 4, 6, 7, and 0 activate the fingers, with "0" closing all fingers simultaneously. This enables coordinated grasping and releasing, ensuring precise control and user-friendly operation.

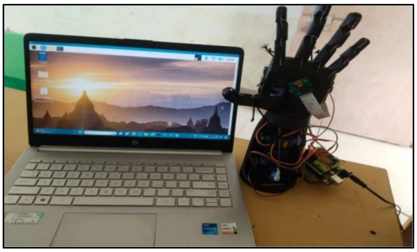
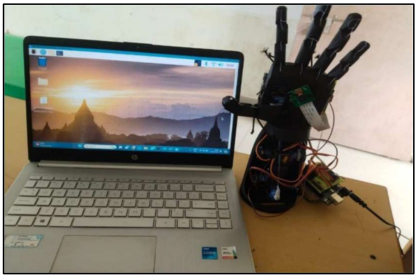


Fig 6.1 : Initial Set Up Of Prosthetic Arm

Fig 6.2 : Close all fingers at the same time



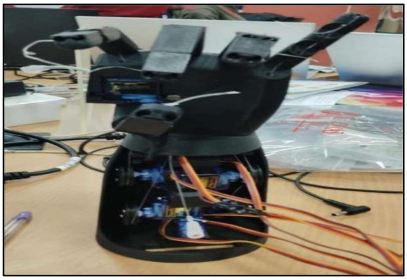
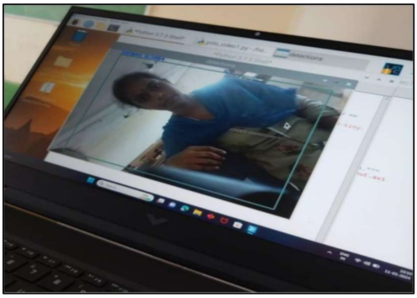


Fig 6.3 : Open all fingers at the same time

Fig 6.4 : Little finger Open and Close



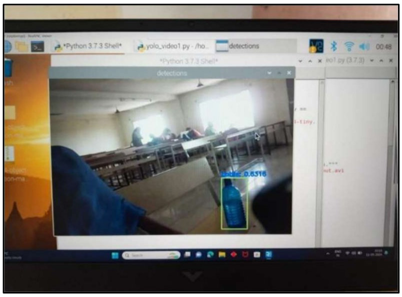


Fig 6.5 : Detecting Objects

Fig 6.6 : Detecting Water Bottle

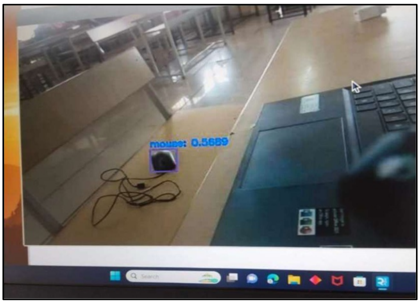


Fig 6.7 : Taking water bottle by detecting the bottle

Fig 6.8 :Detecting Mouse

7.Conclusion:

The Paper has well achieved the objective of developing a functional and effective prosthetic arm control system using object detection technology. Through the combination of a camera, Raspberry Pi, Arduino Uno, and servo motors, the system offers the user straightforward control of the prosthetic arm based on detected objects in their environment. With extensive testing, the system has shown consistent performance and continuous object identification, allowing for precise and timely movements of the prosthetic hand. This novel technology holds immense potential for enhancing the quality of life of upper limb amputation patients by offering them greater dexterity and control in everyday activities. In the future, additional optimizations and adjustments could be explored in order to open up the possibilities of the system and meet specific user needs. In general, the research constitutes an important stride towards the production of accessible and innovative prosthetic technology, providing new opportunities for assistive equipment in rehabilitative engineering.

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