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Bionic Hand Using Voice And Vision Controller

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Abstract: The development of bionic hands has significantly improved the quality of life for individuals with limb loss by restoring essential hand functions. This project presents a bionic hand controlled using vision and voice recognition technologies, offering a more natural and intuitive mode of interaction. The system integrates computer vision to identify objects and determine the appropriate grip type, while voice commands allow the user to control hand movements such as opening, closing, or selecting specific gestures. The hand is powered by microcontrollers, servo motors, and sensors, ensuring precise motion and feedback. By combining artificial intelligence with human–machine interaction, this design enhances the usability, flexibility, and accessibility of prosthetic devices. The proposed model demonstrates how vision and voice-based control can make prosthetic hands more responsive, user-friendly, and adaptive to real-world environments

***Keywords* –** ESP32, MG996 Servo Motor, Machine Learning, Jumped Wire.

I. INTRODUCTION

Revolutionizing Prosthetics with Brain-Controlled Robot Hands A bionic hand with voice and vision control is a prosthetic limb that can be manipulated through spoken commands and eye movements, providing a more intuitive and accessible way for users to control its functions. The system uses a microcontroller as the "brain" to process inputs from a microphone and a camera, translating them into actions like opening, closing, or rotating the hand. This dual-control approach offers a flexible solution, with voice providing direct command input and vision control offering an alternative, especially when speaking is not an option.

1.1 Need for Smart Prosthetic Systems

Traditional prosthetic hands offer limited motion and require manual or muscle-based control, making them less efficient and natural for users. They lack adaptability and precise control in real-world situations. To overcome these issues, smart prosthetic systems integrate vision and voice control to provide intuitive, accurate, and adaptive movement. Vision helps in object detection and grip selection, while voice commands enable easy, hands-free operation. Such intelligent systems greatly enhance user comfort, independence, and functionality.

1.2 Overview of Vision and Voice-Controlled Systems

Vision and voice-controlled systems combine artificial intelligence, image processing, and speech recognition to create intelligent interaction between humans and machines. In a bionic hand, vision control uses a camera to detect and identify objects, allowing automatic selection of suitable grip patterns. Voice control enables the user to perform commands such as open, close, or hold through simple speech input. Together, these technologies provide a more natural, efficient, and user-friendly control method for prosthetic devices.

II. Related Work

2.1 Review of Vision-Based Control in Prosthetics:

Review of Vision-Based Control in Prosthetics is an important aspect of the proposed Bionic Hand Using Vision and Voice Control system. This section elaborates on how vision technology contributes to improving object detection, grip selection, and motion precision in prosthetic hands. Relevant examples, theoretical explanations, and technical insights are provided to strengthen the understanding of system design and implementation

2.2 Review of Voice Recognition in Prosthetic Systems:

Review of Voice Recognition in Prosthetic Systems is an important aspect of the proposed Bionic Hand Using Vision and Voice Control system. This section elaborates on how voice commands contribute to simplifying control mechanisms, enhancing accessibility, and providing a natural interface for users. Relevant examples, theoretical explanations, and technical insights are provided to strengthen the understanding of the system design and implementation.

2.3 Integration of AI and Embedded Systems in Bionics:

Integration of AI and Embedded Systems in Bionics is an important aspect of the proposed Bionic Hand Using Vision and Voice Control system. This section elaborates on how artificial intelligence and microcontrollers contribute to real-time processing, intelligent motion, and adaptive control. Relevant examples, theoretical explanations, and technical insights are provided to strengthen the understanding of the system design and implementation.

2.4 Research Motivation and Gap Analysis:

Research Motivation and Gap Analysis is an important aspect of the proposed Bionic Hand Using Vision and Voice Control system. This section elaborates on how integrating both vision and voice control addresses existing limitations in traditional prosthetics. Relevant examples, theoretical explanations, and technical insights are provided to strengthen the understanding of the system design and implementation.

III. Problem Statement

People with upper-limb disabilities face significant challenges in performing everyday tasks due to limited mobility and lack of functional prosthetic control. Traditional prosthetic hands often depend on mechanical or muscle-based input, which restricts natural movement and adaptability. These limitations result in reduced precision, slower response, and discomfort during use. There is a strong need for an intelligent prosthetic solution that combines advanced control methods to enhance accuracy, ease of use, and human-like performance.

- Limitations of Conventional Prosthetic Hands
- Need for Natural and Adaptive Control
- Integration of Smart Technologies for Better Assistance

IV. Objectives

The primary goal of this project is to design and develop a bionic hand that utilizes vision and voice control to achieve more natural and user-friendly movement. The system aims to interpret visual inputs from a camera for object recognition and grip selection, while voice commands allow the user to control hand actions efficiently. A key objective is the integration of Open CV for image processing and ESP32 for motor control, creating a reliable two-tier control system. Ultimately, the project seeks to provide amputees with improved precision, comfort, and independence through intelligent automation.

V. Proposed System

The proposed Vision and Voice-Controlled Bionic Hand is designed to provide intuitive and adaptive hand movement for users with limb impairments. The system consists of two main controllers: a ESP32 . The ESP32 acts as the high-level controller, processing visual data from a camera to identify objects and determine suitable grip patterns. It also processes voice inputs through a microphone using speech recognition algorithms. The ESP32 functions as the hardware controller, receiving processed commands and driving servo motors to perform hand movements. The system thus integrates computer vision, voice control, and motor actuation to achieve precise, human-like hand functionality.

5.1 Role of ESP32:

The ESP32 acts as the main control unit of the bionic hand, handling wireless communication, voice command processing, and motor control. It connects with the Raspberry Pi or camera module to receive visual data and executes corresponding movements through servo motors. With built-in Wi-Fi, Bluetooth, and real-time processing, the ESP32 ensures smooth coordination between vision, voice, and actuation systems, making the bionic hand more intelligent and responsive.

5.2 Role of MG966:

The MG996 servo motor is responsible for providing precise movement and grip control in the bionic hand. It converts electrical signals from the ESP32 into mechanical motion to move the fingers and joints accurately. With its high torque and fast response, the MG996 ensures smooth and natural hand movements, enabling tasks like grasping, lifting, and releasing objects based on vision and voice commands

5.3 Role of Web Camera:

The web camera serves as the vision sensor of the bionic hand. It captures real-time images or video of the surrounding environment and sends the data to the ESP32 or Raspberry Pi for processing. Through image recognition and object detection, the system identifies objects and guides the hand's movements accordingly. This enables the bionic hand to visually recognize, locate, and interact with objects, enhancing precision and automation.

5.4 Block Diagram Representation: Block Diagram Representation is an important aspect of the proposed Smart Job Distribution and Quality Verification System.

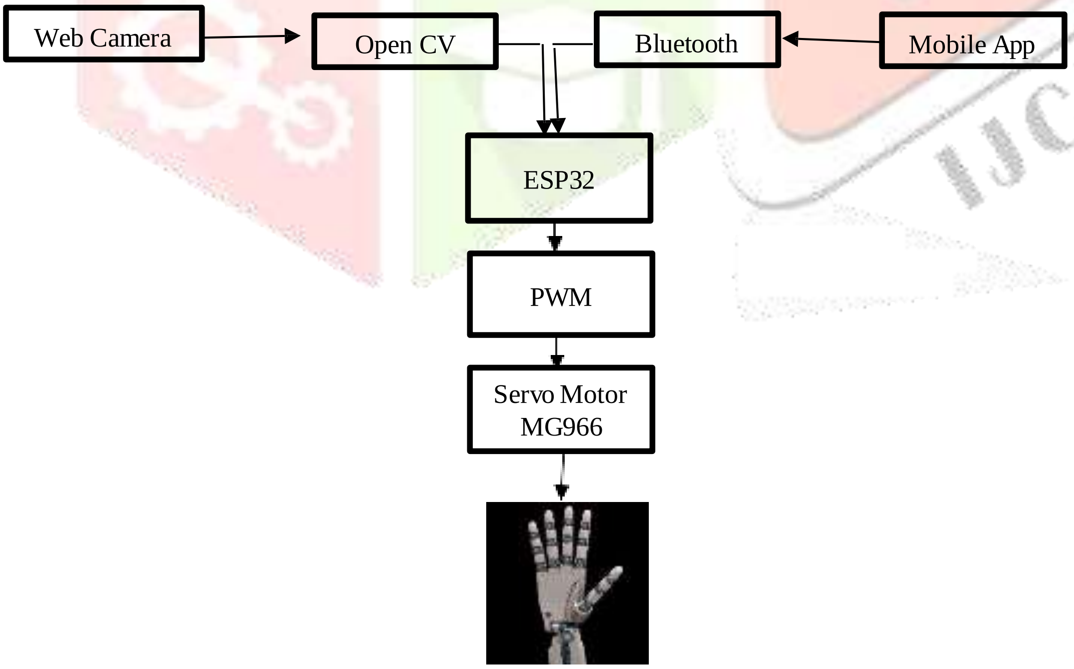

Fig. Block Diagram

VI. Hardware and Software Requirements

1. Hardware Requirements:

7.1.1 ESP32 : ESP32 is a low-cost, low-power microcontroller with built-in Wi-Fi and Bluetooth used for IoT and embedded applications.

7.1.2 MG966 : The MG996R is a high-torque metal gear servo motor commonly used in robotics and RC projects for precise movement control.

7.1.3 Jumped Wire : Jumper wires are short electrical wires used to connect components on a breadboard or between devices without soldering.

7.1.4 PWM : PWM (Pulse Width Modulation) is a technique used to control the speed of motors or brightness of LEDs by varying the width of electrical pulses.

7.1.5 3D Printed Hand: The 3D printed hand forms the physical structure of the bionic hand, designed to mimic human finger movement. It provides a lightweight and customizable frame for mounting servo motors and mechanical parts controlled by vision and voice inputs.
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7.2 Software Requirements

7.2.1 sriTU Hobby : To use SriTu Hobby's voice control with Bluetooth, you need to build a project with a microcontroller (like an Arduino or ESP32) and a Bluetooth module (like HC-05).

7.2.2 Open CV in python : OpenCV in Python can be used for bionic hand control by processing live video streams to detect and interpret hand gestures. This visual input is combined with voice commands, processed by a speech recognition library, to provide a dual control mechanism. The interpreted gestures and voice commands are then translated into commands for the bionic hand's servo motors or other actuators, enabling precise and intuitive manipulation.

7.2.3 3D CAD Software using Fusion 360 : The bionic hand was designed using fusion 360, a powerful 3D CAD Software to optimize the ergonomics and mechanical functionality.

VII. METHODOLOGY

1 **Voice Command Control:** The user gives voice commands captured by a microphone. The speech recognition system
interprets these commands and sends signals to the controller to move the bionic hand's motors accordingly.

2 **Vision-Based Feedback**: A camera provides visual input for object detection and tracking. Using OpenCV, the system identifies object shapes, positions, and distances to guide accurate gripping and manipulation.

3 **System Integration**: Voice, vision, and sensor modules work together. Voice initiates movement, vision assists with positioning, and sensors ensure grip precision and safety.\

4 **Image Processing:** The vision system uses image processing (edge detection, contour, and color analysis) to recognize objects
and adjust the hand's response for correct and adaptive interaction.

VIII. Implementation

A. **Hardware Setup and Interfacing:** The bionic hand was assembled with actuators, sensors, a camera, and a microphone, interfaced through Raspberry Pi and Arduino. Power management ensured stable operation of all components.

B. **Software Coding and Algorithms**: Vision and voice control algorithms were developed for gesture recognition and speech command processing. The Raspberry Pi handled image and audio analysis, while the Arduino controlled motor movements via serial communication.

C. **Testing and Debugging:** The system was tested for accurate hand response to visual and voice inputs.

Issues like lighting, noise, and sensor calibration were resolved through iterative debugging.
D. Snapshots of the Prototype: Photos of the final prototype show the integrated camera, microphone, and motorized hand assembly demonstrating vision and voice-controlled operation.

IX. Results and Discussion

This section evaluates the system's performance and discusses its broader implications.
A. Performance of Voice Control: The bionic hand responded accurately to voice commands with minimal delay. Tests showed reliable performance even in moderate background noise, outperforming traditional button-controlled systems.
B. Accuracy of Vision Detection: The vision module successfully identified and grasped objects with high precision. Detection accuracy remained consistent under varying lighting and object positions.
C. Implementation Challenges: Key issues included sensor calibration, voice recognition under noise, and signal synchronization. These were addressed through software optimization and improved hardware tuning.
D. Comparison with Existing Research: Unlike conventional EMG-based hands, this system combines voice and vision, offering more intuitive, adaptive, and user-friendly control for amputees with limited muscle movement.

X. Applications, Advantages, Limitations, Future Scope

1. Practical Applications:

The bionic hand with voice and vision control has wide-ranging applications in prosthetics and rehabilitation for amputees, as well as in assistive robotics for individuals with limited motor ability. By integrating automation and intelligent control, it aligns with Industry 4.0 and Healthcare 5.0 principles, promoting human–machine collaboration. The system can be adapted for medical rehabilitation centers, research laboratories, and personal assistive devices, providing users with a more natural and responsive method of control through speech and visual recognition.

2. Benefits of the Proposed System:

Implementing this system offers several advantages over conventional prosthetic devices. It enhances ease of use and accessibility, allowing users to control hand movements through simple voice commands and adaptive vision feedback. The combined system provides greater accuracy, faster response, and improved dexterity compared to manually operated prosthetics. Furthermore, the intelligent control reduces user strain, enhances object-handling precision, and improves overall comfort and confidence. Overall, it results in increased functionality, adaptability, and user satisfaction.

3. Limitations and Possible Errors:

Despite its advantages, the system has certain limitations and potential sources of error. The vision module's performance depends heavily on lighting conditions, object color, and background complexity, which may cause misidentification. Similarly, voice recognition can be affected by background noise, accent variations, or speech clarity. Hardware constraints such as motor delays, limited battery life, and processing speed can also impact real-time performance. These challenges require careful calibration, noise filtering, and system optimization to ensure consistent and reliable operation.

4. Future Scope and Improvements:

Future enhancements could include advanced AI and deep learning for better object detection and adaptive grip control. The voice system can be improved using NLP for multi-language and noise-resistant recognition. Integration with IoT dashboards could enable remote monitoring and performance tracking. Adding haptic feedback and optimizing power efficiency will further enhance usability. These developments aim toward a smarter, more responsive, and user-friendly bionic hand.

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