Technical Report

Hand Gestures Translation System Integrated with Robotic Arm

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1. Project Overview

This project presents an assistive technology system designed to help individuals who are non-verbal or have difficulty communicating, especially those who use sign language. It integrates a real-time hand gesture recognition module with a robotic arm that mimics human hand gestures. The goal is to enable clear, intuitive interaction between sign language users and those unfamiliar with the language.

The system captures gestures, translates them into letters using machine learning, displays them on LCD screens, and allows the robotic arm to physically mimic the recognized gesture. It combines computer vision, embedded systems, and electromechanical actuation to form a robust and scalable solution for gesture-based interaction.

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2. System Components

2.1 Hand Gesture Recognition System

- **Functionality: Captures and interprets hand gestures in real-time and translates them into corresponding alphabetic characters.**
- **Technologies Used:**
  - **MediaPipe: For accurate, real-time hand landmark detection.**
  - **OpenCV: To process webcam video feed.**
  - **Machine Learning Classifier: Recognizes gestures and maps them to specific characters.**
  - **LCD Display: Shows the recognized gesture as visual feedback.**

2.2 Robotic Arm System

- **Functionality: Physically replicates recognized hand gestures using servo motors.**
- **Components:**
  - **Arduino Uno: Controls the servos and LCD display.**
  - **Servo Motors:**
    - **SG90: Controls individual finger and thumb movements.**

        - **MG995: Provides forearm rotation to imitate wrist-like motion.**
    - **LCD Module: Displays the received gesture character.**
    - **Power Supply: Includes a buck converter and lithium batteries for voltage regulation and portability.**
    - **Mechanical Elements: Uses nylon threads for finger bending and elastic cords for returning fingers to their original position.**

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3. Integration Workflow

Step 1: Gesture Recognition

- **The user makes a gesture (e.g., signing the letter "A").**
- **MediaPipe detects hand landmarks, and the system uses a trained classifier to identify the corresponding letter.**
- **The letter is displayed on the recognition system's LCD screen.**

Step 2: Robotic Arm Mimicry

- **Letters can be entered manually via a keyboard to instruct the robotic arm to mimic sign language gestures.**

- **The Arduino Uno maps the letter to predefined servo positions.**
- **The robotic hand replicates the gesture through coordinated movement of fingers and forearm.**

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4. System Architecture

Hardware Overview

Component	Purpose
Webcam	Captures live hand gestures
PC	Processes video and classifies gestures
Arduino Uno	Controls servo motors and LCDs
SG90 Servos	Control individual fingers
MG995 Servo	Controls forearm rotation
Buck Converter	Ensures proper voltage levels
Lithium Battery	Portable power source
LCD Module	Displays recognized letters

Software Overview

- **MediaPipe: Hand landmark detection**
- **OpenCV: Camera input and preprocessing**

- **Machine Learning Classifier: Maps hand landmarks to specific characters**
- **Arduino Code: Maps gesture data to servo angles**
- **LCD Library: Displays character output**

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5. Key Benefits

- **Enhanced Communication for Non-Verbal Individuals: Allows users to express themselves using sign language, which is recognized and visualized on screens.**
- **Physical Replication of Gestures: The robotic arm adds a tangible, interactive layer to communication, bridging the gap between digital recognition and physical interaction.**
- **Real-Time Feedback: Immediate LCD updates ensure clarity and confirmation of interpreted gestures.**
- **Therapy & Rehabilitation: Can assist patients in relearning hand movements through interactive repetition and visual confirmation.**
- **Interactive Exhibits: Ideal for educational or museum settings to demonstrate gesture recognition and robotics interactively.**

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6. Future Enhancements

- **Gesture-Based Gripping: Introduce more complex hand movements for grasping and object manipulation.**
- **Full Sign Language Interpretation: Extend recognition beyond individual letters to full words or phrases.**
- **Expanded Device Integration: Connect to other assistive technologies such as screen readers or mobile apps.**

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7. Conclusion

This project delivers a highly interactive, intelligent system that supports non-verbal communication using real-time hand gesture recognition and robotic mimicry. It combines machine learning, embedded hardware, and electromechanics into an accessible and expandable solution, with promising applications in accessibility, education, therapy, and robotics research.