Hand Gesture Sign Language Recognition System

“When hands speak, technology listens.”

Project Overview

The **Hand Gesture Sign Language Recognition System** bridges the communication gap for individuals who are non-verbal or have speech impairments. It enables them to communicate using **hand gestures**, which are recognized in **real-time** and converted into text. The output can be displayed on-screen, on an IoT-powered LCD, or within a mobile app.

The system supports **Arabic and English alphabets** and **numerical digits**, ensuring inclusivity and accessibility.

Goals

The main goal of this project is to provide a way for people who are unable to speak to **communicate simply and effectively** with people who cannot understand sign language.

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1. Artificial Intelligence (AI) System

Technologies & Tools

- **Computer Vision**:
  - **MediaPipe** – real-time hand landmark detection.
  - **OpenCV** – image processing & camera handling.

- **Machine Learning**:

  - **Random Forest Classifier** – trained to recognize gestures (letters and numbers).
  - Data preprocessing with **normalization and augmentation**.

Why Random Forest?

We selected **Random Forest** because:

- It handles **non-linear relationships** well, suitable for complex hand gestures.
- It reduces **overfitting** through ensemble learning.
- It is **fast in training** and **efficient in real-time predictions** compared to deep learning approaches, making it ideal for lightweight hardware integration.

Code Structure

- **File 1**: Feature extraction with MediaPipe + training a Random Forest model.
- **File 2**: GUI + real-time prediction using the trained model with live camera input.

Prediction Handling

- Recognizes individual letters, **SPACE**, **DEL**, and **Nothing**.
- Accumulates characters into a sentence with auto-spacing and deletion support.
- Dynamically displays predictions and the evolving sentence.

Graphical Interface

- Shows a **live video stream** with hand landmark overlays.
- Uses a **neon-bordered canvas** for visual appeal.
- Includes buttons to **Reset** the sentence or **Speak it aloud**.

Text-to-Speech (TTS)

- Uses **pyttsx3** and **gTTS** libraries to convert recognized letters or sentences into speech.
- Users can press the **Speak button** to hear the translated output.

Keyboard Shortcuts (GUI Version)

- **Spacebar** → Add space
- **Backspace** → Delete character
- **Enter** → Speak sentence
- **Escape** → Exit application

Dataset

- Open-source sign language datasets.
- Custom images from webcam & mobile camera.
- Coverage:
    - **A–Z (English)**
    - **Arabic alphabet**
    - **0–9 (Numbers)**

Features

- Real-time recognition with camera.
- **Bilingual support** (Arabic + English).
- **text-to-speech**: after detecting a gesture and translating it into a letter, the user can hear the letter pronounced.

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2. Internet of Things (IoT) System

Components

- **LCD Display** – to show recognized letters.
- **ESP8266 Module** – acts as an integration hub, receiving results from Python and sending them to Arduino.
- **Arduino UNO** – controls the LCD display.

Special Considerations

- The LCD does not natively support **Arabic letters**.
- To overcome this, Arabic characters were manually written in code **bit by bit** for correct display.

How It Works

1. Recognized gesture output is sent from the AI system via **Python → ESP8266 → Arduino**.
2. Arduino drives the **LCD** to display the recognized character.
3. The system provides immediate **hardware feedback** alongside software output.

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3. Mobile Application

Platform & Tools

- Built using **MIT App Inventor** for rapid development.

Features

- Uses a camera to detect hand gestures.
- Translates gestures into **letters in real-time**.
- Integrated with the AI system: recognized letters are sent directly to the mobile app.
- Allows **on-the-go communication** for non-verbal users.

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4. Future Updates

- **Gesture-to-words translation**: extend beyond letters/digits to recognize complete words.
- **Expanded dataset** for more natural communication.
- Cloud syncing for **data storage and monitoring**.