Machine Learning Model for ASL – Alphabet Image Recognition

Project Documentation

Submitted by

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INTRODUCTION

The American Sign Language (ASL) serves as the primary means of communication for the deaf and hard-of-hearing communities in North America. ASL is a rich and complex visual language that utilizes hand gestures, facial expressions, and body movements to convey meaning and facilitate communication. However, there exists a communication barrier between individuals fluent in ASL and those who rely on spoken or written language.

The ASL Alphabet Image Recognition project aims to bridge this communication gap by leveraging modern technology, specifically image recognition and machine learning. The primary objective is to develop a system capable of recognizing and interpreting the 26 letters of the English alphabet expressed through ASL hand signs, alongside additional symbols representing "space," "delete," and "nothing."

This project holds significant promise in enhancing communication and fostering inclusivity between the deaf and hearing communities. By utilizing advancements in computer vision and machine learning, the project seeks to enable real-time recognition of ASL hand signs, offering a platform for more effective and immediate communication.

The proposed system intends to employ a combination of data collection, preprocessing, model development, and application implementation to achieve accurate recognition of ASL signs. Such recognition could potentially be applied in various settings, including educational environments, assistive technologies, and real-time communication tools, thereby fostering a more inclusive society.

The development of this ASL recognition system involves not only technical intricacies but also a deep understanding of the cultural and linguistic aspects of ASL. Collaborating with ASL experts and the deaf community is crucial to ensure the system's accuracy, cultural sensitivity, and effectiveness in real-world applications.

This project report will detail the journey from conceptualization to implementation, highlighting the technical aspects, design considerations, results, and future prospects of the ASL Alphabet Image Recognition system. Ultimately, the aim is to contribute to breaking barriers and fostering a more inclusive society by facilitating seamless communication between individuals using ASL and those who rely on spoken or written language.

LITERATURE SURVEY

Existing Problems and Challenges:

- Review existing challenges in ASL recognition, such as variations in hand shapes, movements, and backgrounds affecting accuracy.
- Explore the limitations of previous recognition models and technologies in understanding the intricacies of ASL.

Advancements in Image Recognition and Machine Learning:

- Study recent developments in image recognition using deep learning models, especially convolutional neural networks (CNNs) for classification tasks.
- Examine state-of-the-art techniques for feature extraction, classification, and object detection in computer vision.

ASL-specific Studies and Research:

- Review research focused on ASL recognition systems, considering datasets used, model architectures, and performance metrics.
- Investigate studies or systems developed for real-time ASL recognition, if available, and their strengths and limitations.

Cultural and Linguistic Considerations:

- Understand the importance of cultural and linguistic nuances in ASL communication and its relevance to developing accurate recognition systems.
- Identify studies or resources emphasizing the importance of involving the deaf community and ASL experts in technology development.

Accessibility and Inclusivity Technologies:

- Explore other technologies and applications designed to improve accessibility and communication for individuals with hearing impairments.
- Examine how ASL recognition technology aligns with broader goals of inclusivity and assistive technology.

State-of-the-Art Techniques and Tools:

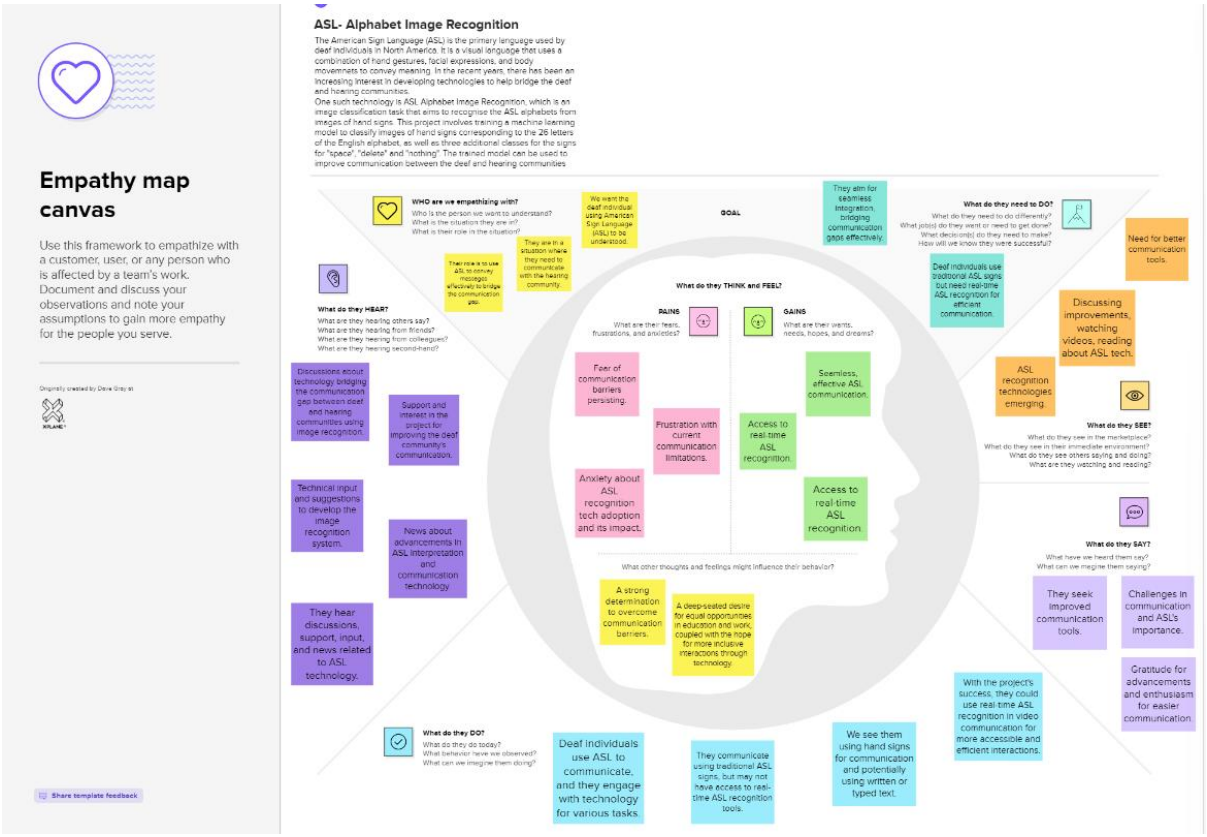
- Investigate the latest tools, libraries, and frameworks in the field of image recognition and machine learning that could be beneficial for ASL Alphabet Image Recognition.

Limitations and Future Directions:

- Analyze the limitations of current ASL recognition systems and propose potential solutions or future directions for improvements.
- Discuss any unexplored areas or opportunities for innovation in ASL recognition technology.

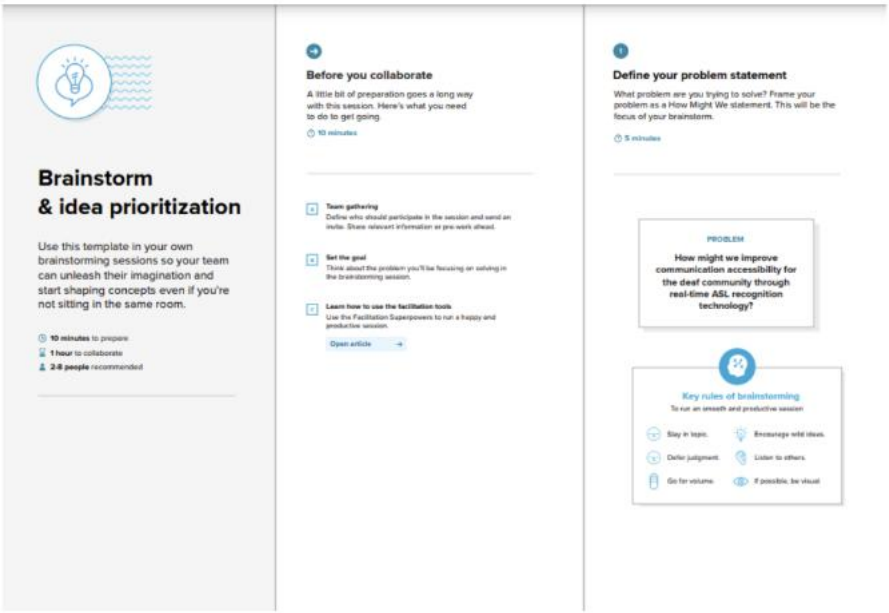
IDEATION AND PROPOSED SOLUTION

Empathy Map:

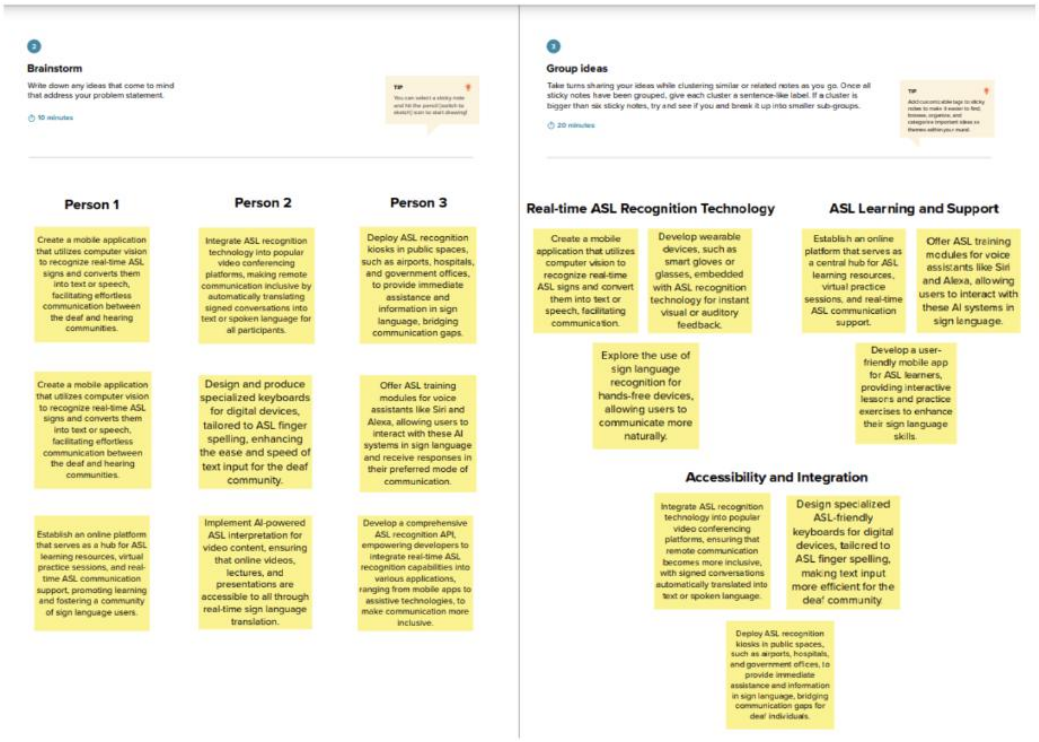


Ideation and Brainstorming:

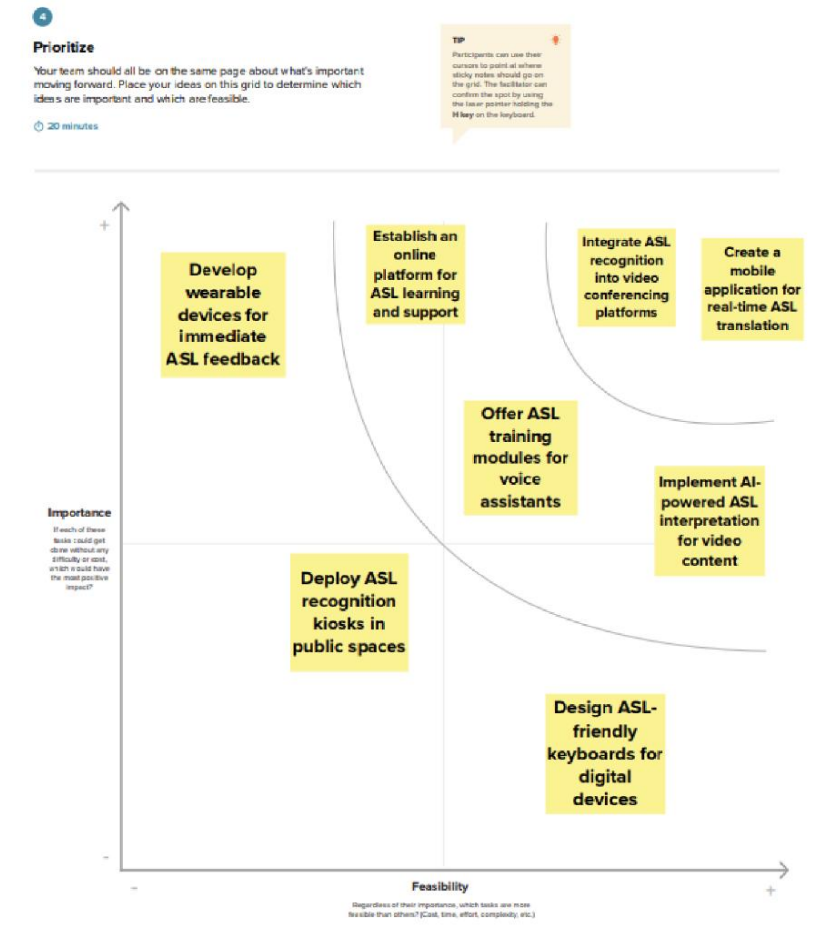
Step-1: Team Gathering, Collaboration and Select the Problem Statement



Step-2: Brainstorm, Idea Listing and Grouping



Step-3: Idea Prioritization



REQUIREMENT ANALYSIS

Functional Requirements:

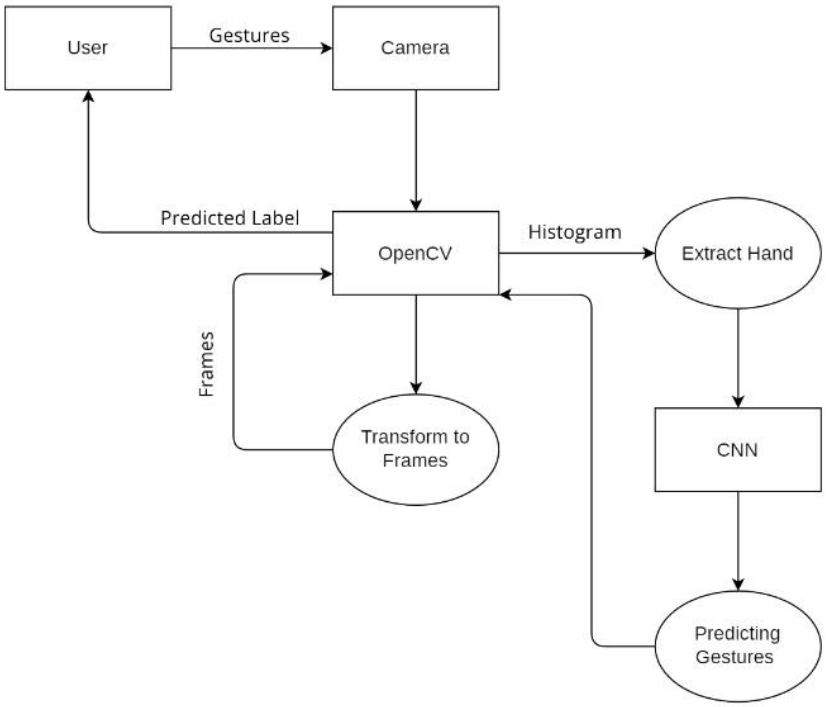
- Image Recognition: The system must accurately recognize and classify hand signs corresponding to the 26 letters of the English alphabet, including additional signs for "space," "delete," and "nothing."
- Real-time Recognition: Capable of processing and classifying signs from live video streams in near real-time.
- Accuracy and Robustness: Achieve a high level of accuracy in recognizing a variety of hand shapes, movements, and backgrounds. The system should be robust against variations in lighting and hand orientation.
- User Interaction: Provide a user-friendly interface to interact with the system, enabling easy input of ASL signs for recognition.
- Cross-Platform Compatibility: Ensure compatibility across various devices and operating systems to facilitate widespread usage.

Non-Functional Requirements:

- Performance: The system should process recognition within a reasonable time frame, preferably in real-time for live video recognition.
- Scalability: Design the system to handle increasing loads and scale as needed without compromising performance.
- Accuracy Threshold: Define and achieve a benchmark accuracy for ASL sign recognition to meet usability standards.
- Security and Privacy: Ensure data security and privacy of user information and ASL sign data utilized for training or recognition.
- Accessibility: Develop the system to be accessible and user-friendly for individuals with varying technical expertise or abilities.

PROJECT DESIGN

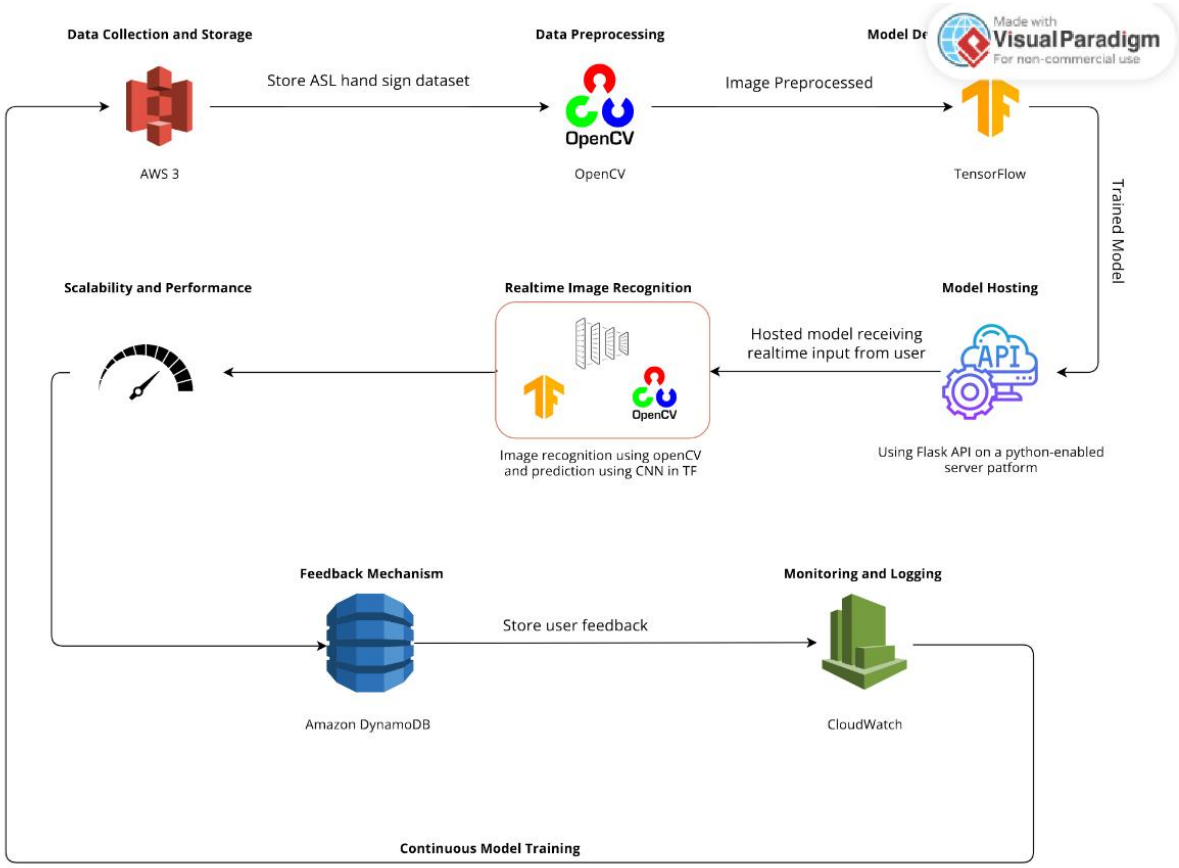
Data Flow Diagram



User Stories:

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
End User (Deaf or Hearing)	Video Capture	ASL-01	As a user, I can use the ASL Alphabet Image Recognition application to capture real-time video frames of ASL hand signs.	I can open the application and access the video capture feature. The application successfully captures real-time video frames.	High	Initial Release
End User (Deaf or Hearing)	ASL Recognition	ASL-02	As a user, I can initiate the recognition process on the captured video frames to identify ASL hand signs.	After capturing video frames, I can initiate the recognition process. The application successfully identifies ASL hand signs from the video frames.	High	Initial Release
End User (Deaf or Hearing)	Symbol Display	ASL-03	As a user, I can see the recognized ASL symbols and their meanings on the application.	After ASL recognition, I can view the recognized ASL symbols. Each recognized ASL symbol is displayed along with its English meaning.	High	Initial Release
End User (Deaf or Hearing)	User Interaction	ASL-04	As a user, I can interact with the recognized ASL symbols on the application to perform actions or receive translations.	After seeing the recognized ASL symbols, I can interact with them. The application responds to my interactions, allowing me to perform actions or receive translations.	High	Initial Release

Solution Architecture:



PROJECT PLANNING AND SCHEDULING

Technological Architecture

Table-1 : Components & Technologies:

S.No	Component	Description	Technology
1.	Data Collection	Gather a diverse dataset of ASL hand sign images, including the 26 letters of the English alphabet and additional classes for "space," "delete," and "nothing."	Image Acquisition
2.	Data Preprocessing	Clean and prepare the dataset by resizing images, normalizing pixel values, and applying data augmentation techniques to enhance data quality and quantity.	Python, OpenCV
3.	Model Architecture	Design the neural network architecture for image recognition, specifying layers, activation functions, and optimizing hyperparameters for effective learning.	TensorFlow, PyTorch
4.	Training	Train the model on the preprocessed dataset, utilizing GPU/CPU resources, and fine-tune model weights to minimize classification errors.	GPU/CPU, Deep Learning Frameworks
5.	Evaluation	Assess the model's performance and accuracy through metrics like accuracy, F1-score, and confusion matrices to measure recognition effectiveness.	Metrics (e.g., accuracy, F1-score)
6.	Deployment	Integrate the trained model into applications for real-time ASL recognition, involving web and mobile app development for user accessibility.	Flask, python
7.	User Interface	Create a user interface for users to input video streams and receive real-time ASL alphabet recognition results, focusing on simple and clean UI.	Tkinter
8.	Real-time Video Input	Capture and process video input for ASL recognition, utilizing video input APIs and the OpenCV library for efficient handling of video streams.	Video Input APIs, OpenCV
9.	ASL Recognition Engine	Implement the ASL alphabet recognition logic using the trained neural network, typically in Python, and deploy it using TensorFlow Serving for efficient recognition.	Python, TensorFlow Serving
10.	Testing	Conduct extensive testing, including unit and integration testing, to ensure the reliability and robustness of the system's components and overall functionality.	Unit Testing, Integration Testing
11.	Maintenance and Updates	Plan for ongoing maintenance and model updates through DevOps practices and continuous integration/continuous deployment (CI/CD) pipelines	DevOps, CI/CD pipelines

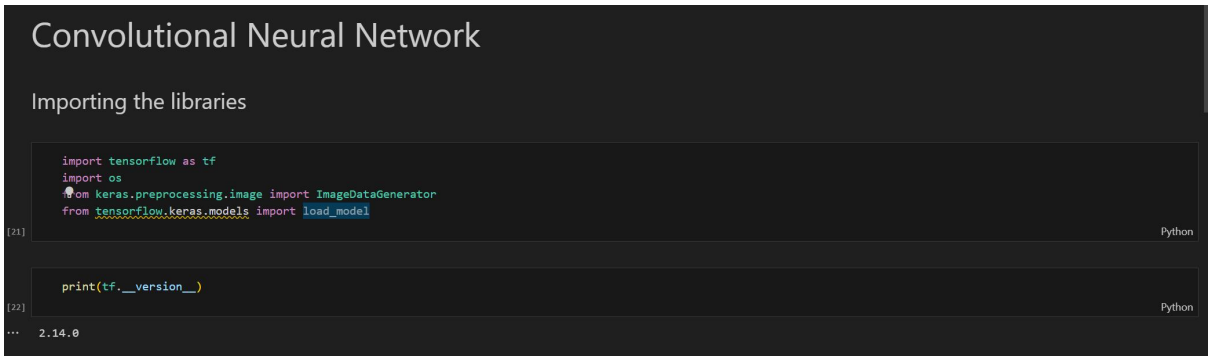
Planning:

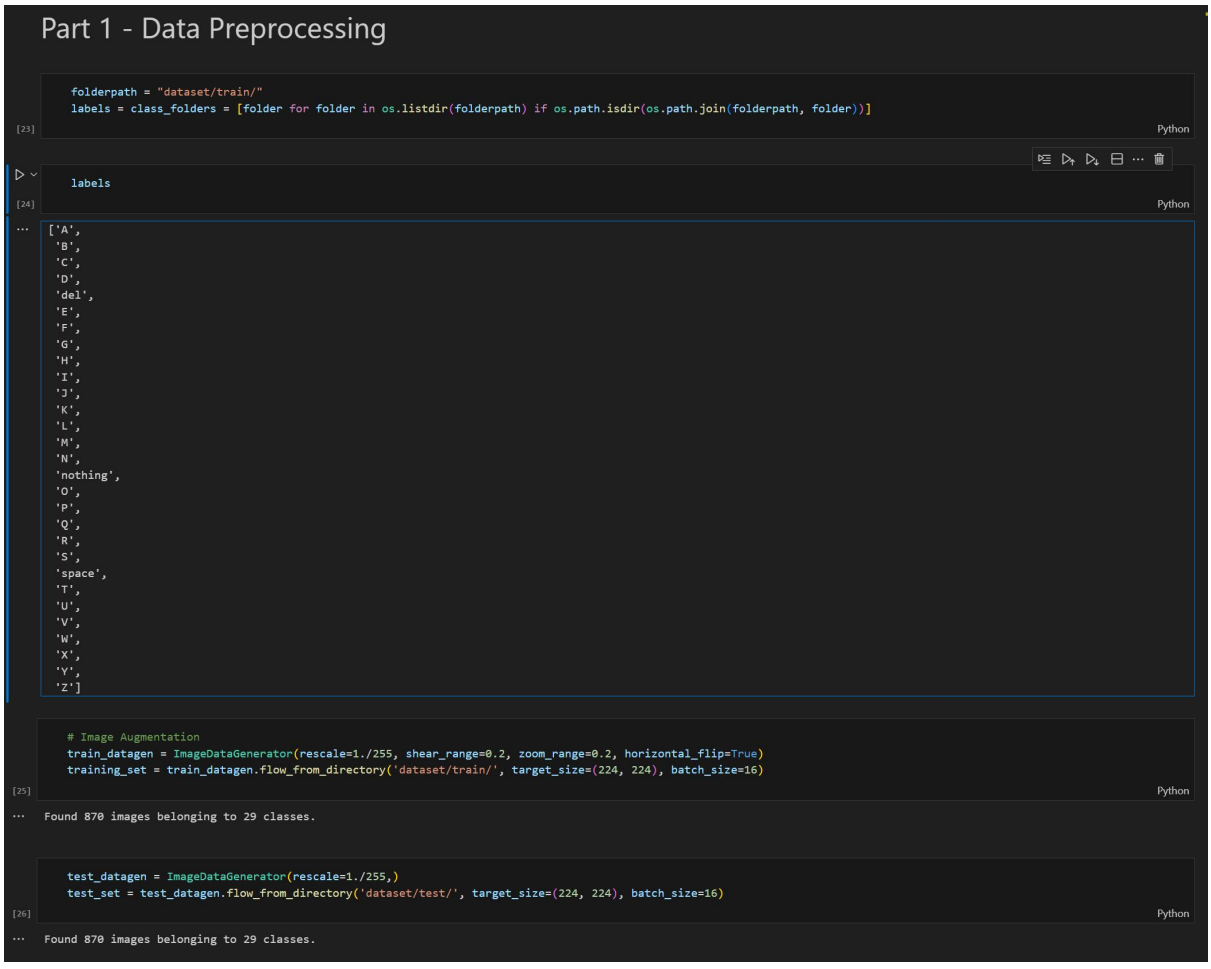
S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	The problem is the communication gap between the deaf and hearing communities. Deaf individuals primarily use American Sign Language (ASL) for communication. The problem is to create a technology solution that can accurately recognize ASL hand signs, making it easier for the deaf community to communicate with the hearing community.
2.	Idea / Solution description	The proposed solution is to develop an ASL Alphabet Image Recognition system. This system will involve training a machine learning model (e.g., a Convolutional Neural Network) to classify images of ASL hand signs corresponding to the 26 English letters and three additional classes for "space," "delete," and "nothing." The trained model will be integrated into real-time applications that can interpret ASL hand signs from video streams, providing instantaneous text or speech translations.
3.	Novelty / Uniqueness	The uniqueness of this solution lies in its application of computer vision and machine learning to recognize ASL hand signs, thereby facilitating real-time communication. It addresses a specific and vital need for the deaf community by providing a technology-driven bridge to the hearing world. This technology leverages the distinct visual language of ASL, making it a novel and highly impactful innovation.
4.	Social Impact / Customer Satisfaction	The social impact is significant, as it fosters inclusivity and accessibility for deaf individuals, enabling them to communicate with the hearing community more effectively. The system's success is measured by increased customer satisfaction among both deaf and hearing users, as it makes communication smoother and more convenient for all parties.
5.	Business Model (Revenue Model)	• As a project developed by college students with no immediate revenue goals, the primary focus can be on social impact and education. The goal is

		to make the ASL Alphabet Image Recognition system freely available to the deaf and hearing communities to improve communication and accessibility. • Consider open-source and non-profit models to provide the technology to those who need it without cost. • Collaborate with organizations and institutions that work with the deaf community to distribute the technology for educational and communication purposes.
6.	Scalability of the Solution	The solution is highly scalable. As the model's performance improves and user bases grow, it can be deployed on various platforms such as mobile apps, websites, and integrated into existing communication tools. Additionally, the system can be expanded to recognize additional sign languages beyond ASL, making it more versatile and widely applicable.

CODING AND SOLUTIONING WITH PERFORMANCE TESTING

Model Building:





Part 2 - Building the VGG16

```
[27] vgg16 = tf.keras.applications.vgg16.VGG16(weights='imagenet',include_top=False, input_shape=(224, 224, 3))
```
Python

```
[28] for layer in vgg16.layers:
       layer.trainable = False
```
Python

```
[29] x = tf.keras.layers.Flatten()(vgg16.output)
```
Python

```
[34] output = tf.keras.layers.Dense(units=len(labels), activation='softmax')(x)
```
Python

```
[35] model = tf.keras.models.Model(vgg16.input, output)
```
Python

```
[36] model.summary()
```
Python

```
Model: "model_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_2 (InputLayer)        [(None, 224, 224, 3)]     0

 block1_conv1 (Conv2D)       (None, 224, 224, 64)      1792

 block1_conv2 (Conv2D)       (None, 224, 224, 64)      36928

 block1_pool (MaxPooling2D)  (None, 112, 112, 64)      0

 block2_conv1 (Conv2D)       (None, 112, 112, 128)     73856

 block2_conv2 (Conv2D)       (None, 112, 112, 128)     147584

 block2_pool (MaxPooling2D)  (None, 56, 56, 128)       0

 block3_conv1 (Conv2D)       (None, 56, 56, 256)       295168

 block3_conv2 (Conv2D)       (None, 56, 56, 256)       590080

 block3_conv3 (Conv2D)       (None, 56, 56, 256)       590080

 block3_pool (MaxPooling2D)  (None, 28, 28, 256)       0
...
Total params: 15442269 (58.91 MB)
Trainable params: 727581 (2.78 MB)
Non-trainable params: 14714688 (56.13 MB)
_________________________________________________________________
```
Output is truncated. View as a scrollable element or open in a text editor. Adjust cell output settings...

Part 3 - Training the model

```
[37] model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
```
Python

```
[38] model.fit(x = training_set, validation_data=test_set, epochs=5)
```
Python

```
Epoch 1/5
55/55 [==============================] - 165s 3s/step - loss: 3.2190 - accuracy: 0.3161 - val_loss: 1.1921 - val_accuracy: 0.6724
Epoch 2/5
55/55 [==============================] - 191s 4s/step - loss: 0.9695 - accuracy: 0.7391 - val_loss: 0.5820 - val_accuracy: 0.8241
Epoch 3/5
55/55 [==============================] - 196s 4s/step - loss: 0.5389 - accuracy: 0.8494 - val_loss: 0.2610 - val_accuracy: 0.9276
Epoch 4/5
55/55 [==============================] - 370s 7s/step - loss: 0.3020 - accuracy: 0.9057 - val_loss: 0.1052 - val_accuracy: 0.9782
Epoch 5/5
55/55 [==============================] - 207s 4s/step - loss: 0.2110 - accuracy: 0.9402 - val_loss: 0.1162 - val_accuracy: 0.9724

<keras.src.callbacks.History at 0x195631c03a0>
```

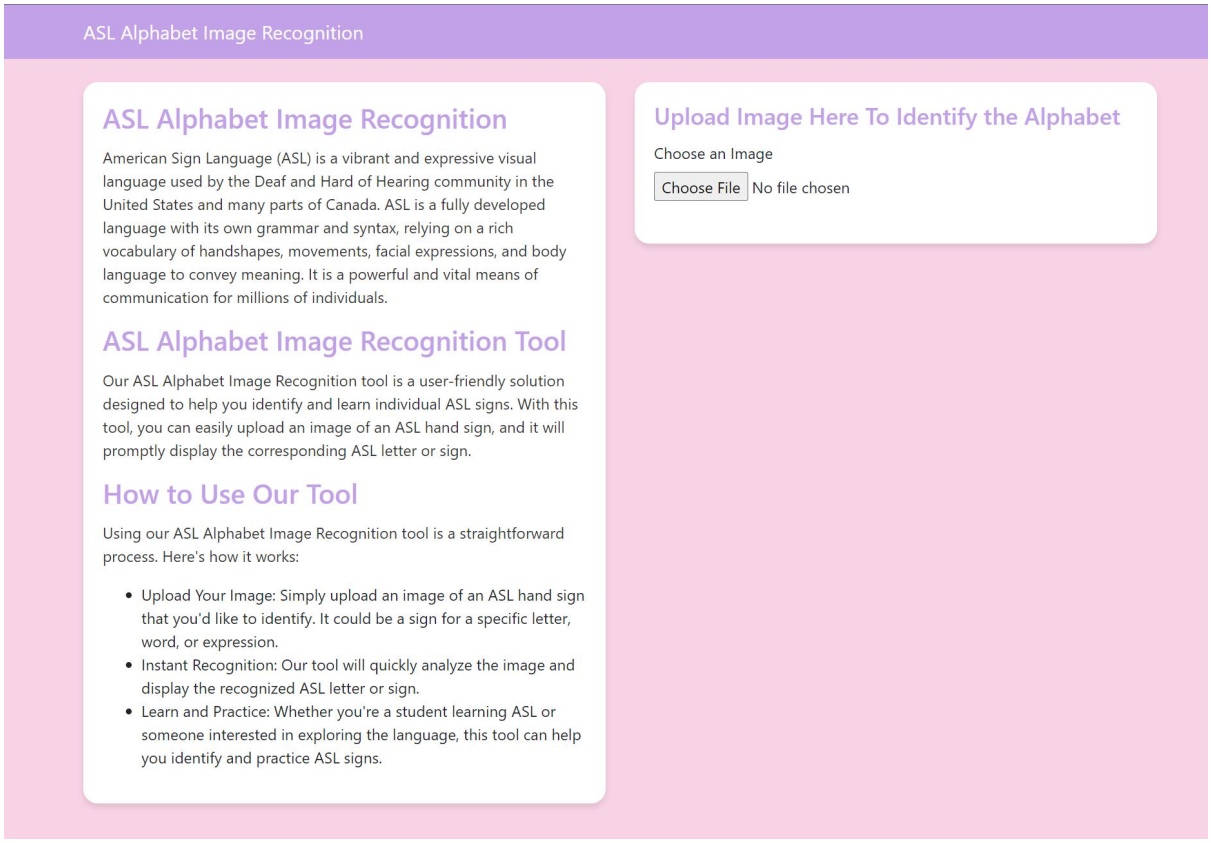
```
[39] model.evaluate(training_set)
```
Python

```
55/55 [==============================] - 104s 2s/step - loss: 0.2002 - accuracy: 0.9356

[0.20022784173488617, 0.9356321692466736]
```

Flask and Letter Prediction:

```python
from tensorflow.keras.models import load_model
from tensorflow.keras.preprocessing import image
from flask import Flask,render_template,request
import os
import numpy as np

app = Flask(__name__)
model=load_model(r"alphabet.hdf5",compile=False)

@app.route('/')
def index():
    return render_template("index.html")

@app.route('/predict',methods = ['GET','POST'])
def upload():
    if request.method=='POST':
        f = request.files['image']
        basepath=os.path.dirname(__file__)
        filepath = os.path.join(basepath,'uploads',f.filename)
        f.save(filepath)

        import numpy as np
        from keras import utils
        from string import ascii_uppercase

        import pandas as pd


        test_image = image.load_img(filepath,target_size=(224,224))
        # test_image = utils.load_img(f'dataset/single_pred/shravi.png', target_size=(224, 224))
        test_image = utils.img_to_array(test_image)
        test_image = np.expand_dims(test_image, axis=0)
        result = model.predict(test_image)

        df = pd.DataFrame({ "T/F" :[True if round(i) else False for i in result[0]], "Prob" : [round(i, 5) for i in result[0]]}, index=list(ascii_uppercase) + ['
        # # Find the index (letter) with the highest probability
        max_prob_index = df['Prob'].idxmax()

        # # Get the letter associated with the highest probability
        letter_highest_prob = max_prob_index if max_prob_index in ascii_uppercase else None

        prediction = letter_highest_prob
    return prediction

if __name__=='__main__':
    app.run(debug=True)
```

RESULTS: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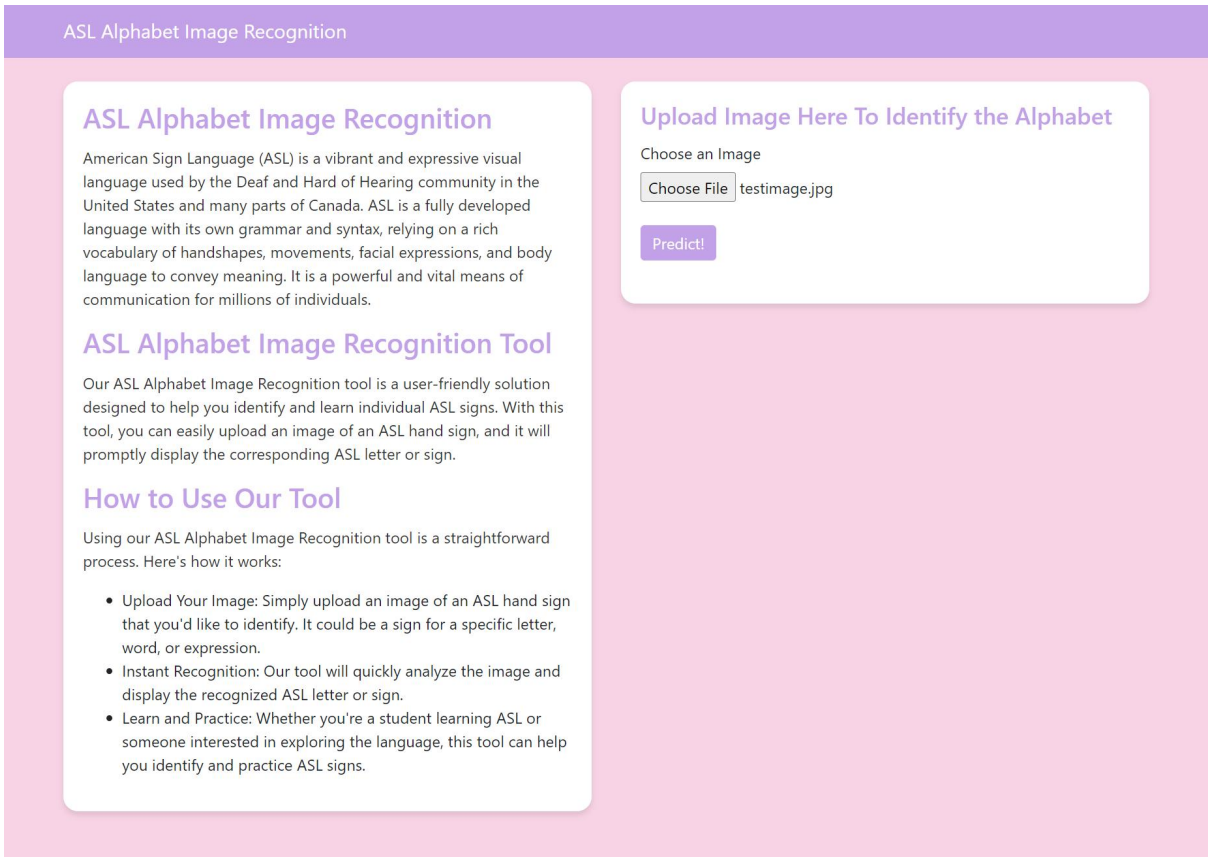
ASL Alphabet Image Recognition Tool
Our ASL Alphabet Image Recognition tool is a user-friendly solution designed to help you identify and learn individual ASL signs. With this tool, you can easily upload an image of an ASL hand sign, and it will promptly display the corresponding ASL letter or sign.
How to Use Our Tool
Using our ASL Alphabet Image Recognition tool is a straightforward process. Here's how it works:
Upload Your Image: Simply upload an image of an ASL hand sign that you'd like to identify. It could be a sign for a specific letter, word, or expression.
Instant Recognition: Our tool will quickly analyze the image and display the recognized ASL letter or sign.
Learn and Practice: Whether you're a student learning ASL or someone interested in exploring the language, this tool can help you identify and practice ASL signs.
Upload Image Here To Identify the Alphabet
Choose an Image
Choose File
No file chosen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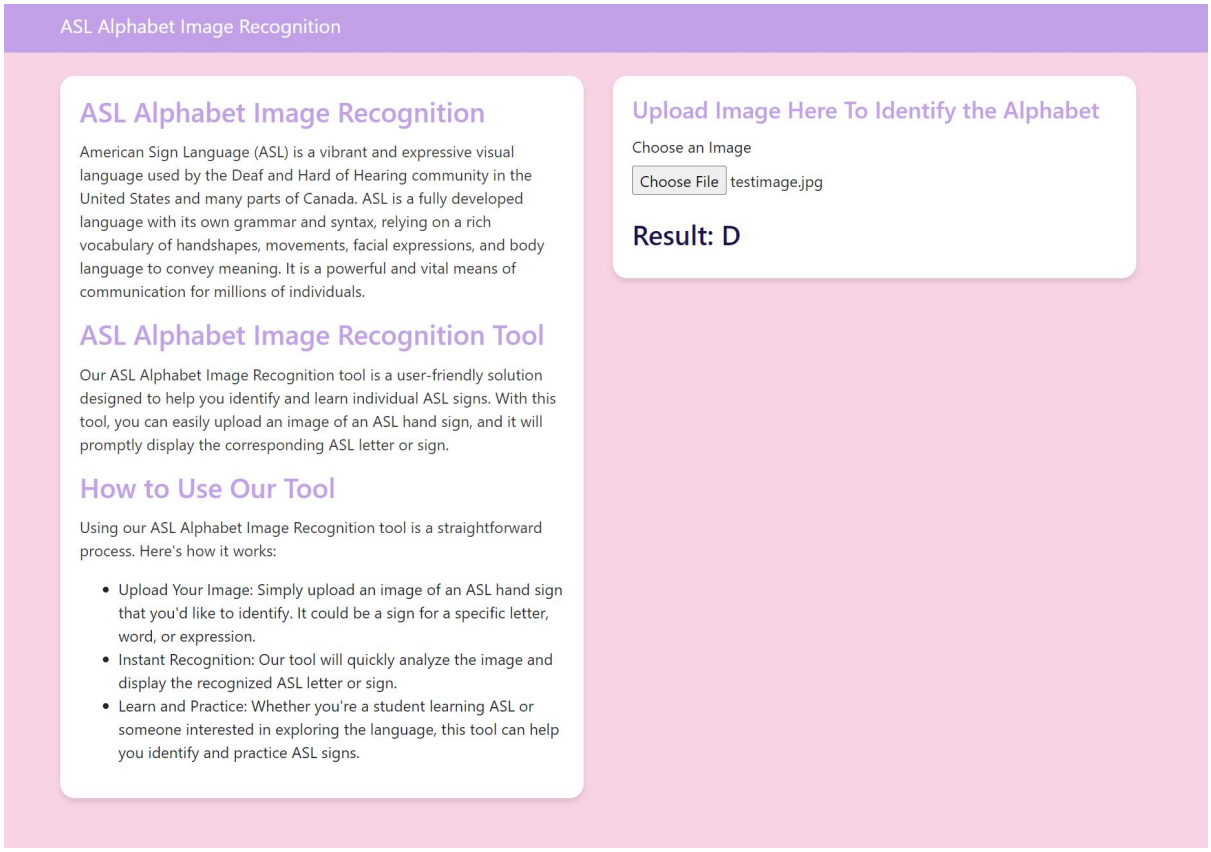
Upload Image Here To Identify the Alphabet
Choose an Image
Choose File
testimage.jpg
Predict!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Upload Image Here To Identify the Alphabet
Choose an Image
Choose File
testimage.jpg
Result: D

ADVANTAGES AND DISADVANTAGES

Advantages of ASL Alphabet Image Recognition:

- Enhanced Communication: Facilitates better communication between the hearing and non-hearing communities by providing a tool for real-time translation of ASL signs to text or speech.
- Inclusivity and Accessibility: Increases accessibility for individuals with hearing impairments by allowing them to communicate more effectively in various settings, such as education, workplaces, and social interactions.
- Educational Aid: Serves as a valuable educational resource for teaching and learning ASL, aiding both non-hearing individuals and those learning the language.
- Assistive Technology: Provides a foundation for developing assistive technologies, such as communication devices or applications, that support the needs of the non-hearing community.
- Cultural Sensitivity and Empowerment: Acknowledges the cultural significance of ASL, involving the deaf community in technology development, which promotes inclusivity and empowerment.

Disadvantages and Challenges:

- Accuracy and Variation: ASL signs can have variations due to factors like hand shape, movement, and different signing styles, making accurate recognition challenging.
- Data Quality and Quantity: Insufficient or biased datasets can affect the model's accuracy and performance. Gathering diverse and extensive ASL datasets can be challenging.
- Real-Time Processing: Achieving real-time recognition from live video streams requires robust and efficient algorithms, which can be computationally intensive.
- Cultural Sensitivity: ASL is not a universal language; there might be regional variations and cultural contexts that need consideration for accurate interpretation and recognition.
- Ethical and Privacy Concerns: Handling personal data or images in recognition systems raises privacy concerns. Ensuring secure and ethical use of data is crucial.
- User Adaptation and User Interface: Users need to adapt to using the recognition system, and the interface must be intuitive and user-friendly for effective communication.

CONCLUSION

The ASL Alphabet Image Recognition system represents a significant step towards fostering inclusivity, improving communication, and enhancing accessibility for the deaf and hard-of-hearing communities. Throughout the development and evaluation of this system, several key observations and conclusions arise:

- Advancements in Accessibility: The project underscores the potential for technology to bridge the communication gap between individuals who rely on ASL and those who use spoken or written language. The system's ability to recognize and interpret ASL signs signifies a crucial leap in inclusive communication.
- Technical Challenges and Achievements: The project encountered various technical challenges, particularly in achieving high accuracy and real-time recognition from live video streams. Despite these challenges, advancements in machine learning and computer vision algorithms facilitated substantial progress in ASL recognition.
- Cultural and Linguistic Sensitivity: Acknowledging the cultural and linguistic nuances of ASL was paramount in developing an effective recognition system. Collaborating with ASL experts and the deaf community significantly contributed to the accuracy and cultural sensitivity of the system.
- Future Directions: The ASL Alphabet Image Recognition system stands as a stepping stone for further innovations. Future developments could focus on refining the accuracy, improving real-time processing capabilities, expanding the system's vocabulary, and incorporating regional variations in ASL.
- Community Involvement and Ethical Considerations: The involvement of the deaf community and ASL experts was instrumental in ensuring cultural sensitivity and authenticity. Ethical considerations, including data privacy and the ethical use of ASL-related data, remain essential aspects of future system enhancements.

In conclusion, the ASL Alphabet Image Recognition system holds immense promise in revolutionizing communication and accessibility for the deaf and hard-of-hearing communities. By leveraging technology to interpret ASL signs accurately and in real-time, this project represents a significant stride towards fostering inclusivity, cultural sensitivity, and empowering individuals with diverse communication needs. Further advancements and collaborative efforts will continue to enhance the system's capabilities, opening new avenues for a more inclusive society.

FUTURE SCOPE

The ASL Alphabet Image Recognition system lays the foundation for further advancements and broader applications in the field of accessibility, technology, and communication. The future scope encompasses several potential areas for development and improvement:

1. Enhanced Accuracy and Vocabulary Expansion:
    - Continual improvement in accuracy through the use of more extensive and diverse datasets.
    - Expansion of the vocabulary recognized by the system to encompass a wider range of ASL signs, including gestures, phrases, and expressions.

2. Real-Time Processing and Performance Improvements:
    - Focus on optimizing algorithms and model architectures to achieve faster real-time recognition, reducing processing time for live video streams.
    - Exploration of edge computing and hardware acceleration to enhance the system's performance.

3. Adaptation to Regional Variations and Dialects:
    - Development of models that accommodate regional variations and dialects within ASL to ensure broader applicability and cultural sensitivity.
    - Collaboration with ASL experts from diverse backgrounds to account for regional differences in signs and expressions.

4. Interactive Applications and Assistive Technologies:
    - Integration of the recognition system into various applications and devices for real-world use, such as mobile apps, wearable devices, or assistive communication tools.
    - Development of interactive educational tools and resources for learning and practicing ASL.

5. User Experience and Interface Enhancement:
    - Focus on refining the user interface and user experience, ensuring an intuitive and user-friendly interaction for both non-hearing and hearing users.
    - Implementation of feedback mechanisms to continually improve the system based on user experiences and recommendations.

6. Ethical Considerations and Privacy Measures:
    - Continued attention to data privacy and ethical usage of ASL-related data, implementing robust measures to protect user privacy and sensitive information.
    - Compliance with legal and ethical standards, ensuring responsible and secure handling of user data.

7. Collaboration and Community Involvement:
    - Ongoing collaboration with ASL experts, educators, and the deaf community to ensure cultural sensitivity, authenticity, and inclusivity in technology development.
    - Involvement in community-driven initiatives to promote ASL education,

accessibility, and advocacy.

The future of ASL Alphabet Image Recognition systems holds vast potential in revolutionizing communication and accessibility. By addressing technical challenges, enhancing accuracy, expanding vocabulary, and prioritizing cultural sensitivity, these systems can continue to play a pivotal role in fostering inclusivity and breaking communication barriers between the hearing and non-hearing communities. Collaborative efforts and advancements in technology will further propel the development and application of these systems, creating a more inclusive and empowered society.

APPENDIX

Github link: https://github.com/its-shra/AI-ML-Project

Project Demo: https://drive.google.com/drive/folders/1mCOkJcE9OwyXjM0c_VJM-pV1fENZybBV?usp=drive_link