



INTERNATIONAL JOURNAL OF  
RESEARCH IN COMPUTER  
APPLICATIONS AND ROBOTICS  
ISSN 2320-7345

## SIGN LANGUAGE INTERPRETER USING MACHINE LEARNING

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### Abstract

Sign language interpreters play a crucial role in facilitating communication between deaf or hard-of-hearing individuals and those who do not use sign language. Their work extends across various settings, including educational institutions, healthcare facilities, legal proceedings, and public events. This abstract explores the importance of sign language interpretation, highlighting the linguistic, cultural, and ethical considerations involved. Additionally, it examines the skills required for effective interpretation, such as fluency in sign language, cognitive processing speed, and adaptability in diverse environments. The document also discusses challenges interpreters face, including maintaining accuracy, conveying emotions, and ensuring inclusivity. As society moves toward greater accessibility, the role of sign language interpreters remains indispensable in fostering equal communication opportunities for all.

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## CHAPTER I

### INTRODUCTION

#### 1.1 Background of study

A background study on sign language interpretation typically explores the historical development, significance, and current practices within the field. Here's an overview:

##### 1. Historical Context:

Sign languages have been in use for centuries, evolving within deaf communities worldwide. The formalization of sign language interpretation gained prominence in the 20th century, particularly with increased advocacy for accessibility and equal communication rights.

##### 2. Importance of Sign Language Interpretation:

Sign language interpreters play a vital role in bridging communication gaps between deaf individuals and the hearing population. Their work ensures inclusivity across various sectors, including education, healthcare, legal proceedings, and public services.

### 3. Linguistic and Cultural Considerations:

Sign languages are distinct, fully developed languages with their own grammar, syntax, and regional variations. Interpreters must be proficient in sign language and understand cultural nuances to ensure effective and respectful communication.

### 4. Skills and Training:

Sign language interpreters require extensive training, including language proficiency, cognitive processing speed, and ethical considerations. Many countries have certification programs to ensure high standards of interpretation.

### 5. Challenges and Future Directions:

Interpreters often face challenges such as maintaining accuracy in real-time translation, conveying emotions, and adapting to different contexts. The integration of technology, such as AI-assisted interpretation and video relay services, is shaping the future of the profession.

## 1.2 OBJECTIVES

1.To Analyze the Role of Sign Language Interpreters – Examine their impact on communication accessibility in various settings, such as education, healthcare, and legal proceedings.

2.To Identify Key Skills Required for Effective Interpretation – Investigate the linguistic proficiency, cognitive abilities, and ethical considerations necessary for interpreters to perform their duties effectively.

3. To Explore Challenges Faced by Sign Language Interpreters – Assess difficulties such as maintaining accuracy, conveying emotions, and adapting to different communication contexts.

4.To Evaluate the Importance of Cultural Sensitivity – Understand how cultural nuances influence sign language interpretation and its effectiveness in diverse communities.

5.To Examine Technological Advancements in Interpretation – Investigate the role of AI-assisted interpretation, video relay services, and digital platforms in shaping the future of sign language interpretation.

6.To Propose Strategies for Improving Accessibility– Develop recommendations to enhance interpreter training, certification, and integration into various professional fields.

## 1.3 SYSTEM DESCRIPTION

### 1. System Overview

The sign language interpreting system facilitates communication between individuals who use sign language and those who rely on spoken or written language. It ensures accessibility in various environments, such as education, healthcare, legal settings, and public services.

### 2. Components of the System

- Human Interpreters: Trained professionals fluent in sign language who interpret conversations in real time.
- Technological Tools: Video relay services (VRS), AI-powered interpretation software, and real-time captioning.
- Input & Output Modalities: Sign language, spoken language, text-based communication, and facial expressions for contextual meaning.

### 3. Interpretation Process

1. Recognition: The interpreter or system captures the sign language input via visual observation or motion sensors.
2. Processing & Translation: Converts sign language into spoken or written language (or vice versa) while maintaining accuracy, emotional intent, and cultural nuances.
3. Delivery: The interpreted message is conveyed either through speech, text, or sign language, depending on the recipient's needs.

### 4. Challenges & Considerations

- Accuracy & Speed: Ensuring real-time interpretation without losing meaning.
- Cultural Sensitivity: Understanding different dialects and contextual expressions.
- Technology Limitations: AI interpretation is evolving but not yet as nuanced as human interpreters.
- User Accessibility: Systems must be designed to accommodate diverse needs, including different sign language variants and regional adaptations.

### 5. Future Enhancements

- AI-powered gesture recognition to improve interpretation accuracy.
- Wearable devices that provide real-time language translation.
- Integration with augmented reality (AR) for immersive communication experiences.

## 1.4 LITERATURE REVIEW

### 1. Introduction

The literature review provides an overview of academic and professional research on sign language interpretation. It explores historical developments, linguistic theories, challenges, and innovations that shape the profession today.

### 2. Historical Perspectives

- Early documentation of sign languages, such as studies on American Sign Language (ASL), British Sign Language (BSL), and other regional sign languages.
- The recognition of sign languages as fully developed languages with unique grammar and syntax.

- Growth of interpreter certification programs and accessibility regulations over time.

### 3. Linguistic & Cognitive Frameworks

- Studies on the cognitive processing required for simultaneous interpretation.
- Research on how sign languages differ structurally from spoken languages.
- The role of facial expressions and non-manual markers in sign language communication.

### 4. Challenges in Interpretation

- Accuracy in real-time translation and the risk of misinterpretation.
- The impact of dialectal variations and regional sign language differences.
- Emotional and cultural considerations when interpreting sensitive topics.

### 5. Technological Advancements

- Use of Artificial Intelligence (AI) for automated sign language translation.
- Development of wearable devices and motion-sensing gloves for sign recognition.
- Video relay services (VRS) improving remote accessibility for deaf individuals.

### 6. Future Directions & Research Gaps

- The need for improved AI-assisted interpretation that captures nuances of human emotion and dialectal differences.
- More research on interpreter training methods to enhance cognitive speed and accuracy.
- The exploration of immersive technologies like augmented reality (AR) in facilitating sign language interpretation.

## CHAPTER II SYSTEM ANALYSIS

### 2.1 Introduction

System analysis plays a critical role in evaluating the effectiveness, efficiency, and adaptability of sign language interpretation systems. It involves examining various components, including human interpreters, technological tools, communication processes, and accessibility mechanisms. Through system analysis, researchers and developers can identify challenges, optimize existing methods, and propose enhancements for better communication between deaf and hearing individuals.

This analysis explores key aspects such as linguistic accuracy, real-time processing, cultural considerations, and technological advancements, including AI-powered interpretation and video relay services. By understanding the interaction between interpreters, users, and assistive technologies, system analysis aims to improve accessibility and inclusivity in diverse environments.

## 2.2 PROBLEM DEFINITION

Effective communication between deaf or hard-of-hearing individuals and those who do not use sign language is crucial for accessibility and inclusivity. Despite advancements in sign language interpretation, several challenges persist, including accuracy, real-time translation, cultural sensitivity, and technological limitations.

The problem arises due to the complexity of sign languages, which involve distinct grammatical structures, facial expressions, and regional variations. Human interpreters face difficulties in maintaining speed, precision, and emotional nuance, while automated systems struggle with full linguistic and contextual comprehension. Additionally, accessibility gaps remain in education, healthcare, and legal settings, limiting equal opportunities for deaf individuals.

This study aims to analyze existing interpretation methods, identify shortcomings, and explore potential solutions, such as improved interpreter training, AI-powered interpretation tools, and integrated technological frameworks to enhance communication equity.

## 2.3 EXISTING SYSTEM

The current systems for sign language interpretation rely on two primary approaches: human interpreters and technological solutions. These methods enable communication between deaf individuals and those who do not use sign language, but each has its own strengths and limitations.

### 1. Human Interpretation

**Professional Sign Language Interpreters:** Trained individuals who interpret spoken language into sign language and vice versa in real-time.

**Video Relay Services (VRS):** Remote interpretation services where users connect with interpreters via video calls.

**Limitations:** Availability of interpreters, interpretation accuracy in specialized fields (e.g., medical or legal contexts), and fatigue in real-time communication.

### 2. Technological Solutions

**AI-Based Sign Language Translators:** Machine learning models trained to recognize signs and translate them into text or speech.

**Motion-Sensing Devices:** Wearable technology and gloves equipped with sensors to capture hand movements and translate them into words.

**Automated Captions:** Speech recognition software that transcribes spoken content in real time to aid communication.

**Limitations:** AI struggles with complex grammar, facial expressions, and emotional nuances critical to sign language communication.

### 3. Challenges in the Existing System

**Accuracy Issues:** AI-based solutions have difficulty understanding regional sign language variations.

**Limited Accessibility:** Many public institutions lack adequate interpretation services.

**Cultural Sensitivity:** Interpreters must grasp context, tone, and cultural nuances to ensure meaningful communication.

## 2.4 FEASIBILITY STUDY

A feasibility study evaluates the practicality and viability of implementing or improving a sign language interpretation system. It considers technical, economic, legal, operational, and scheduling aspects to determine if the system can be successfully developed and sustained.

### 1. Technical Feasibility

**Technology Availability:** Assessing existing tools like AI-powered interpretation, motion-sensing devices, and video relay services.

**System Integration:** Compatibility with various platforms (e.g., healthcare, education, and legal institutions).

**Challenges:** AI's ability to recognize gestures, facial expressions, and emotional nuances accurately.

### 2. Economic Feasibility

**Cost of Implementation:** Evaluating expenses for interpreter training, technology acquisition, and system maintenance.

**Funding Sources:** Government grants, corporate sponsorships, and non-profit initiatives.

**Return on Investment (ROI):** The long-term benefits of improved communication accessibility.

### 3. Legal Feasibility

**Compliance with Accessibility Laws:** Ensuring the system meets disability rights and communication accessibility regulations.

**Data Privacy Concerns:** Addressing security issues in AI-based interpretation services.

**Standardization:** Developing universal guidelines for sign language translation systems.

### 4. Operational Feasibility

**User Adoption:** Evaluating how deaf individuals, interpreters, and organizations will interact with the system.

**Training Requirements:** Preparing professionals to use advanced interpretation tools effectively.

**Scalability:** Ensuring the system can expand to meet growing demand.

### 5. Scheduling Feasibility

**Project Timeline:** Estimating the duration required for research, development, testing, and deployment.

**Milestones & Deliverables:** Setting achievable goals within realistic timeframes.

## 2.5 PROPOSED SYSTEM

### System Components

#### 1. Gesture Recognition Module

- Utilizes cameras or sensors to capture hand movements, facial expressions, and body gestures.
- Machine learning models trained to recognize various signs in different sign language dialects.

#### 2. Translation Engine

- Converts recognized signs into spoken or written language.
- Can include contextual understanding for improved accuracy.

#### 3. Speech-to-Sign Module

- Converts spoken or written language into sign language animations or holographic representations.
- Offers real-time feedback to ensure fluid communication.

#### 4. User Interface

- Intuitive interface for both signers and non-signers.
- Could include mobile, web, or wearable devices for accessibility.

#### 5. Cloud-based Processing & AI Training

- Continuous learning to improve accuracy over time.
- Cloud-based storage allows for updates and expansion of vocabulary.

## 2.6 SYSTEM OBJECTIVE

The objective of a Sign Language Interpreter System is to facilitate seamless communication between sign language users and non-signers by leveraging technology. Here are the key objectives:

#### 1. Accessibility & Inclusivity

- Ensure deaf and hard-of-hearing individuals can communicate effectively with non-signers.
- Enable broader participation in education, workplaces, healthcare, and public services.

#### 2. Real-time Translation

- Provide instant conversion of sign language into text or speech.
- Allow spoken or written language to be transformed into sign language animations.

#### 3. Accuracy & Context Awareness

- Employ AI to understand context, emotions, and nuances in sign language.

- Reduce translation errors by refining recognition models.

#### 4. Multi-language Support

- Accommodate different sign language variations (e.g., ASL, BSL, ISL).
- Enable cross-language communication for international interactions.

#### 5. Device Compatibility & User-Friendliness

- Develop solutions for mobile, web, and wearable devices.
- Ensure an intuitive and adaptive interface for ease of use.

### 2.7 SYSTEM SPECIFICATION

#### 1. Hardware Requirements

- Camera/Sensors: High-resolution cameras or depth sensors (e.g., LiDAR, infrared) for gesture recognition.
- Processing Unit: Dedicated GPU (e.g., NVIDIA RTX series) or TPU for AI-driven real-time processing.
- Microphone (for speech-to-sign module): High-quality noise-filtering microphone for voice input.
- Display: Touch screen, wearable display (AR glasses), or holographic projector for sign visualization.
- Storage: Cloud or local storage for learned sign language models and real-time data caching.

#### 2. Software Requirements

- Operating System: Windows, Linux, macOS, or mobile OS (Android, iOS) for cross-platform use.
- Programming Languages: Python (TensorFlow, OpenCV), C++ (Computer Vision), JavaScript (Web Integration).
- AI & ML Frameworks: TensorFlow, PyTorch, MediaPipe, OpenAI Whisper for sign recognition.
- Natural Language Processing (NLP): Transformer-based models (GPT, BERT) for context aware translations.
- Cloud Services: AWS, Google Cloud, Azure for model training and data processing.

#### 3. Network & Connectivity

- Internet: Cloud-based AI processing requires stable internet connection.
- Bluetooth/Wi-Fi: For wearable device communication (e.g., smart gloves).
- Edge Computing: Local AI processing for offline functionality.

#### 4. Security & Privacy

- Data Encryption: Secure transmission of sign language data.
- User Authentication: Biometric authentication for personalized settings.
- Ethical AI Compliance: Fair and bias-free model training for inclusivity.

## CHAPTER III SYSTEM DESIGN

### 3.1 INTRODUCTION

A Sign Language Interpreter System is designed to bridge communication between sign language users and non-signers using technology. The system employs artificial intelligence, computer vision, and natural language processing to recognize, translate, and generate sign language gestures.

#### Purpose of the System

The goal is to create an inclusive communication tool that provides real-time translation of sign language into text or speech and vice versa. This can be useful in various settings, including education, healthcare, customer service, and social interactions.

#### Key Design Consideration

1. User-Centric Interface – The system should be intuitive and easy to use for both signers and non-signers.
2. Gesture Recognition – Accurate and efficient sign language detection using cameras or sensors.
3. Translation Accuracy– AI models must understand context, grammar, and variations in sign language.
4. Multi-platform Accessibility – Available on mobile, web, and wearable devices for convenience.
5. Privacy & Security – Ensuring user data and interactions are protected.

### 3.2 SYSTEM ARCHITECTURE

#### System Architecture for a Sign Language Interpreter

The architecture of a Sign Language Interpreter System consists of multiple components that work together to recognize, translate, and generate sign language gestures. Below is an overview of its layered architecture:

#### 1. Input Layer (Gesture & Speech Capture)

- Camera/Sensors – Captures hand movements, facial expressions, and body gestures.
- Microphone – Records spoken language to convert into sign language.
- Touch/Text Input – Allows users to enter text for sign translation.

#### 2. Processing Layer (AI & NLP Model Execution)

- Computer Vision Module – Uses deep learning models (CNN, MediaPipe) for gesture recognition.
- Natural Language Processing (NLP) Engine – Context-aware AI for sign language translation.
- Speech-to-Sign Converter – Translates audio into sign animations or holograms.

### 3. Database Layer (Sign Language Dataset & Training Models)

- Sign Language Knowledge Base – Stores sign vocabulary, grammar, and contextual meanings.
- Training & Adaptation Models – AI continuously refines sign recognition accuracy.
- User Preferences & Profiles – Saves custom settings for personalized interactions.

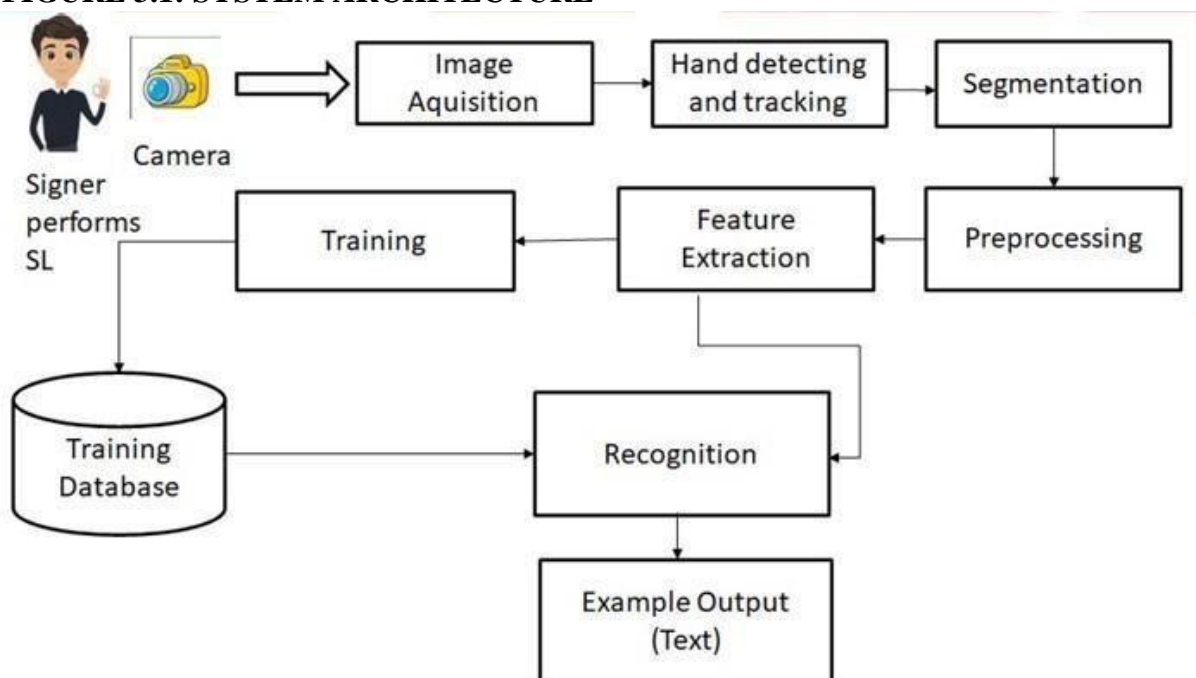
### 4. Output Layer (Translation & Visualization)

- Text/Speech Output – Displays translated sign language as spoken or written language.
- Sign Animation/Holographic Display – Converts text/speech into animated sign gestures.
- Multi-language Support – Handles variations of sign languages (ASL, BSL, ISL).

### 5. Connectivity Layer (Cloud &IoT Integration)

- Cloud-based AI Training – Updates models in real time for improved accuracy.
- IoT& Wearables – Allows smart gloves, AR glasses, or mobile applications for accessibility.
- Edge Computing– Enables offline processing for real-time translation without internet dependency.

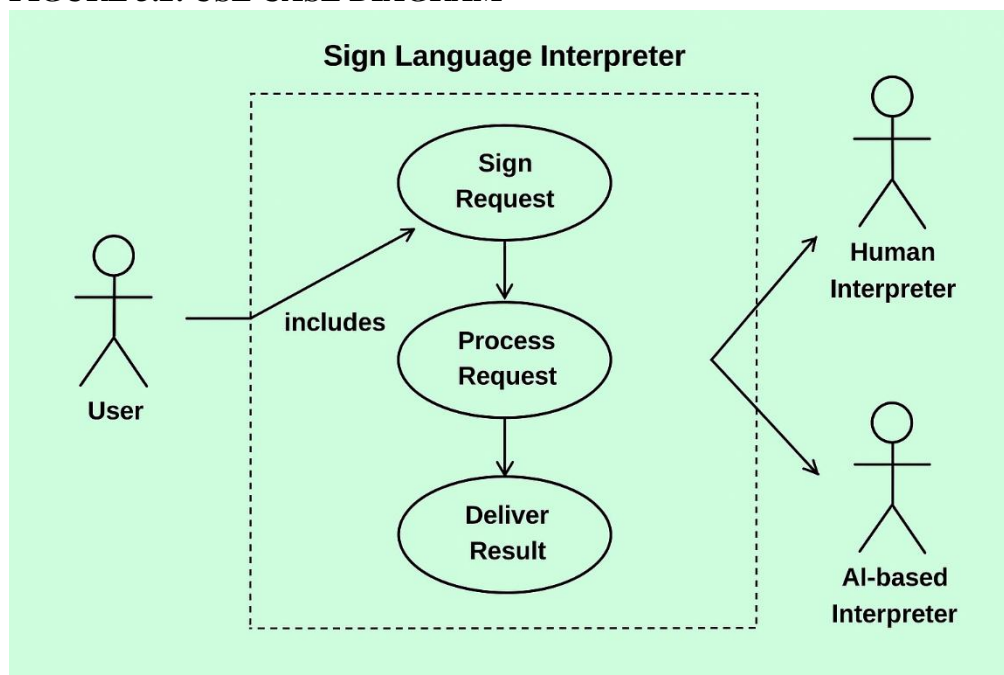
**FIGURE 3.1: SYSTEM ARCHITECTURE**



### 3.3 USE CASE DIAGRAM

Use case for representing system performance between the explanation and analysis of requirements. Use case examples to describe how the system works and how it helps the actor see outcomes. By instructing on the system's boundaries and representing the work they have done as well as the entire environment, actors and their issue cases may be identified. Actors are not included in the system, but instances are. The use case explains the system using the actor's behavior as an example. It represents the work done by the system as a series of actions that give the actor tangible outcomes.

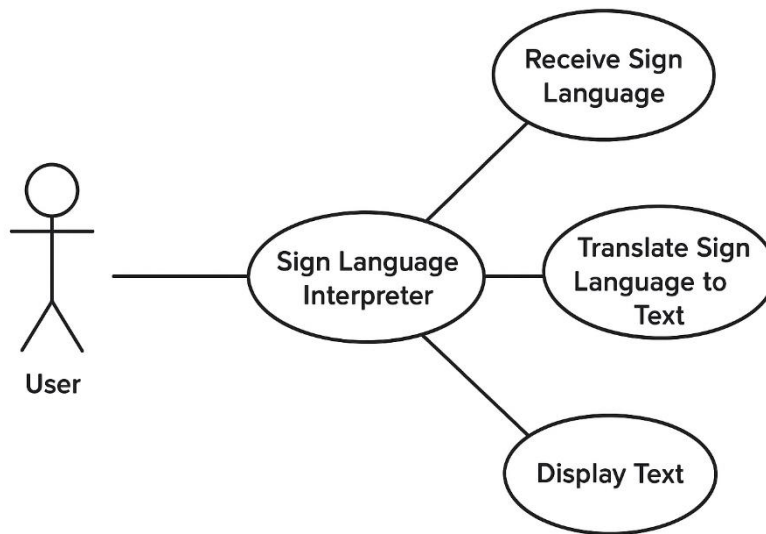
FIGURE 3.2: USE CASE DIAGRAM



### 3.4 DATA FLOW DIAGRAM

A data flow (DFD) diagram enhances the process characteristics by graphically outlining the movement of information or data. In order to create a holistic overview without getting into too much detail—which may be described later—DFD is frequently utilized as the first stage. Data processing is visualized using DFDs. The DFD outlines the kinds of data that will be input into and retrieved from the system, as well as how and where the data will be created inside the system. In contrast to a systematic flow chart that emphasizes control flow or the UML function flow diagram, which introduces both control and data flow, this graphic does not include information on the process time or whether the processes will operate sequentially or similarly.

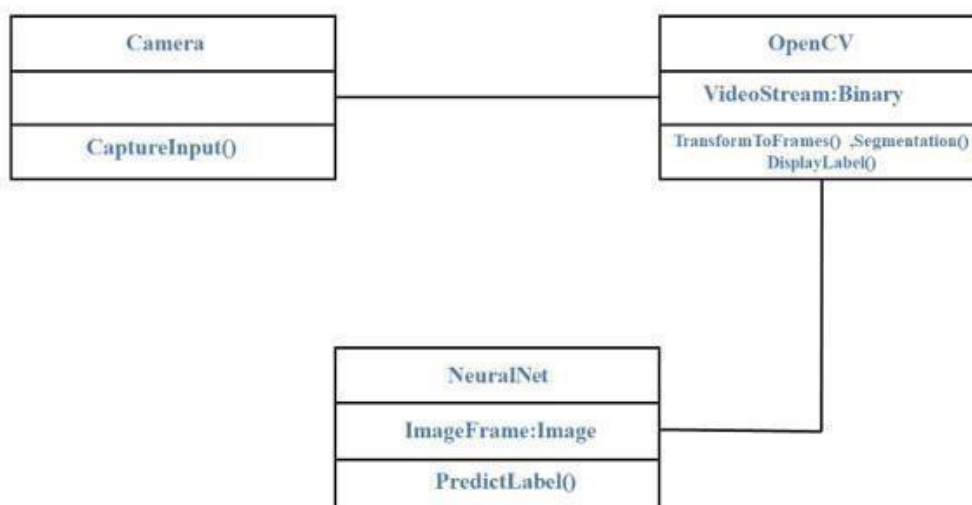
**FIGURE 3.3: DATA FLOW DIAGRAM**



**3.5 CLASS DIAGRAM**

Create the class's structure and content components using the class drawing, package, and object marked designs. When building the technique, concept, result, and outcome, the class outlines how it approached the figure. The three components of a class are its name, its attributes, and its actions. Relationships like inheritance, cohabitation, and so on are also shown in class diagrams. The most typical relation in a class diagram is relationship. The term "association" describes the connection between class instances.

**FIGURE 3.4: CLASS DIAGRAM**

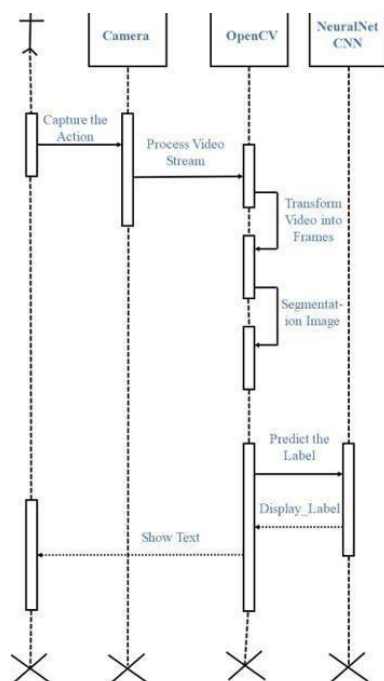


**Sequence Diagram**

The sequence diagram depicts how several things interact when they are chronologically presented. It refers to the sequence in which messages must be sent and received by view

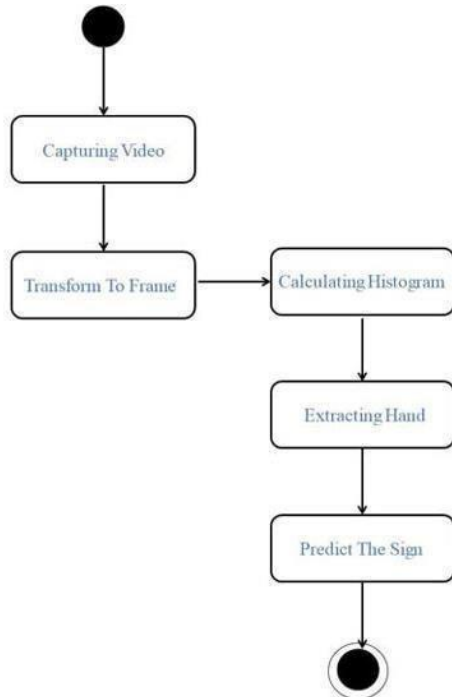
included objects and other objects required to accomplish class and visual functionality. In the case of a logical method, the system under development  $k$  is obtained and sequence diagrams are frequently employed. Events, or events that happen, are happenings. Interactions are shown when messages are entered with horizontal arrows, with the message name above. Asynchronous communications are represented by open arrows, synchronous calls are represented by solid arrow tops, and reply messages are represented by dashed lines. If the caller delivers a synchronous message, one must wait for the message to finish before doing an action, such as issuing a subroutine instruction. It can go on processing without stopping if the caller delivers an asynchronous message. Applications with several threads, those that are event-driven, and middleware that uses messages all use asynchronous calls. An execution statement (message response in UML) is being processed when an opaque rectangle called an activation box or a method-call box is drawn on the lifeline.

**FIGURE 3.5: SEQUENCE DIAGRAM**



### State Diagram

To signal the level of the next process, object calling methods add additional activation boxes to the second vertex and utilize messages. The lifeline will have an X and a dash line written beneath it if an item is destroyed (removed from memory). It must be the outcome of the communication, whether it came from the item or anything else. Extrinsic message sequences (gates in the UML) or circles (queries in the UML) can be used to exhibit extraordinary messages. Extrinsic message sequences (gates in the UML) or circles (queries in the UML) can be used to exhibit extraordinary messages. Links between several pieces are used to simulate parallelism, conditional branching, and alternative interactions.

**FIGURE 3.6: STATE DIAGRAM**

## CHAPTER IV SYSTEM DEVELOPMENT

### METHODOLOGY

**TRAINING MODULE:** Supervised machine learning: It is one of the ways of machine learning where the model is trained by input data and expected output data. To create such a model, it is necessary to go through the following phases:

1. Model construction
2. Model training
3. Model testing
4. Model evaluation

#### **Model Construction:**

It depends on machine learning algorithms. In this projects case, it was neural networks. Begin with its object: `model = Sequential()` Then consist of layers with their types: `model.add(type_of_layer())` After adding a sufficient number of layers the model is compiled. At this moment Keras communicates with TensorFlow for construction of the model. During model compilation it is important to write a loss function and an optimizer algorithm. It looks like: `model.comile(loss = 'name of loss function', optimizer= 'name of opimazeralg' )` The loss function shows the accuracy of each prediction made by the model.

**Model Training:** After model construction it is time for model training. In this phase, the model is trained using training data and expected output for this data. It's look this way: `model.fit` (training data, expected output). Progress is visible on the console when the script runs. At the end it will report the final accuracy of the model.

**Model Testing:** During this phase a second set of data is loaded. This data set has never been seen by the model and therefore it's true accuracy will be verified. After the model training is complete and it is understood that the model shows the right result, it can be saved by: `model.save("name_of_file.h5")`. Finally, the saved model can be used in the real world. The name of this phase is model evaluation. This means that the model can be used to evaluate new data.

### **Pre-processing:**

**Understanding aspect ratios:** An aspect ratio is a proportional relationship between an image's width and height. Essentially, it describes an image's shape. Aspect ratios are written as a formula of width to height, like this: For example, a square image has an aspect ratio of 1:1, since the height and width are the same. The image could be 500px × 500px, or 1500px × 1500px, and the aspect ratio would still be 1:1. As another example, a portrait-style image might have a ratio of 2:3. With this aspect ratio, the height is 1.5 times longer than the width. So the image could be 500px × 750px, 1500px × 2250px, etc.

**Cropping to an aspect ratio:** Aside from using built in site style options , you may want to manually crop an image to a certain aspect ratio. For example, if you use product images that have same aspect ratio, they'll all crop the same way on your site. **Option 1 - Crop to a pre-set shape** Use the built-in Image Editor to crop images to a specific shape. After opening the editor, use the crop tool to choose from preset aspect ratios. **Option 2 - Custom dimensions** To crop images to a custom aspect ratio not offered by our built-in Image Editor, use a third-party editor. Since images don't need to have the same dimensions to have the same aspect ratio, it's better to crop them to a specific ratio than to try to match their exact dimensions. For best results, crop the shorter side based on the longer side. • For instance, if your image is 1500px × 1200px, and you want an aspect ratio of 3:1, crop the shorter side to make the image 1500px × 500px. • Don't scale up the longer side; this can make your image blurry.

**Image scaling:** In computer graphics and digital imaging, image scaling refers to the resizing of a digital image. In video technology, the magnification of digital material is known as upscaling or resolution enhancement. When scaling a vector graphic image, the graphic primitives that make up the image can be scaled using geometric transformations, with no loss of image quality. When scaling a raster graphics image, a new image with a higher or lower number of pixels must be generated. In the case of decreasing the pixel number (scaling down) this usually results in a visible quality loss. From the standpoint of digital signal processing, the scaling of raster graphics is a two-dimensional example of sample-rate conversion, the conversion of a discrete signal from a sampling rate (in this case the local sampling rate) to another.

## Modules

### TensorFlow

A library for dataflow and differentiable programming used for a variety of applications called TensorFlow is free and open source software.

### OpenCV

A collection of programming functions with a focus on real-time computer vision is called OpenCV

(Open Source Computer Vision collection). It was initially created by Intel, then backed by Willow Garage and Itseez (which Intel eventually purchased). Under the terms of the open-source BSD license, the library is free to use and cross-platform.

### Keras

Python-based Keras is an open-source library for neural networks. It may function on top of TensorFlow, Microsoft Cognitive Toolkit, R, Theano, or PlaidML, among other frameworks. It focuses on being user friendly, modular, and extendable in order to enable quick experimentation with deep neural networks. Its major inventor and maintainer is François Chollet, a Google engineer, and it was created as a component of the research effort of project ONEIROS (Open-ended Neuro-Electronic Intelligent Robot Operating System). The Xception deep neural network model was also created by Chollet.

### NumPy

A library for the Python programming language called NumPy adds support for big, multidimensional arrays and matrices as well as a ton of high-level mathematical operations that can be performed on these arrays. Jim Hugunin and a number of other developers worked together to produce Numeric, the predecessor to NumPy. By heavily altering Numeric and combining features from the rival Numarray, Travis Oliphant built NumPy in 2005. Numerous people contribute to NumPy, an opensource program.

## CHAPTER VI SYSTEM IMPLEMENTATION

### 6.1 INTRODUCTION

A hand sign interpreter system is designed to bridge communication gaps between individuals who use sign language and those who do not. The implementation of such a system typically involves hardware components (like cameras or motion sensors) and software using machine learning or deep learning techniques to recognize and translate gestures into text or speech.

The implementation of a hand sign interpreter system starts with understanding the user needs and selecting the appropriate technology stack. The main objectives are:

1. Capturing Hand Gestures – Using cameras or wearable sensors to record movements.
2. Processing Data – Applying image processing techniques to identify sign language gestures.

3. Recognition & Translation – Using trained AI models to classify signs and convert them into corresponding text or speech.
4. User Interface Design – Ensuring accessibility for both sign language users and non-sign language users.

### 6.2.2 CODING

FIGURE 3.7: CODE

```
class Application:
    usage

    def __init__(self):
        self.vs = cv2.VideoCapture(0)
        self.current_image = None
        self.model = load_model('cnn8grps_rad1_model.h5')
        self.speak_engine=pyttsx3.init()
        self.speak_engine.setProperty(name="rate", value=100)
        voices=self.speak_engine.getProperty("voices")
        self.speak_engine.setProperty(name="voice", voices[0].id)

        self.ct = {}
        self.ct['blank'] = 0
        self.blank_flag = 0
```

FIGURE 3.8: CODE

```

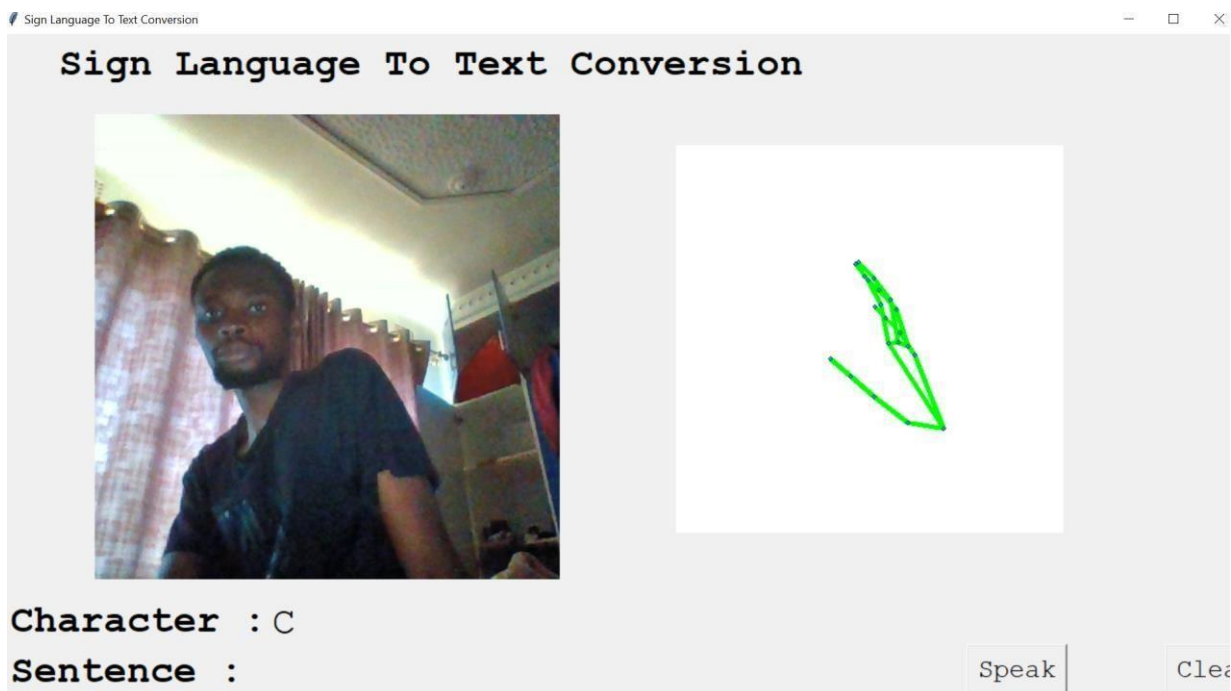
2         self.ct[i] = 0
3         print("Loaded model from disk")
4
5
6         self.root = tk.Tk()
7         self.root.title("Sign Language To Text Conversion")
8         self.root.protocol(name='WM_DELETE_WINDOW', self.destructor)
9         self.root.geometry("1300x700")
10
11        self.panel = tk.Label(self.root)
12        self.panel.place(x=100, y=3, width=480, height=640)
13
14        self.panel2 = tk.Label(self.root) # initialize image panel
15        self.panel2.place(x=700, y=115, width=400, height=400)
```

**FIGURE 3.9: CODE**

```
cv2.line(white, pt1: (self.pts[t][0] + os, self.pts[t][1] + os1), pt2: (self.pts[t + 1][0] + os, self.pts[t + 1][1] + os1), color: (0, 255, 0), thickness: 3)
for t in range(5, 8, 1):
    cv2.line(white, pt1: (self.pts[t][0] + os, self.pts[t][1] + os1), pt2: (self.pts[t + 1][0] + os, self.pts[t + 1][1] + os1), color: (0, 255, 0), thickness: 3)
for t in range(9, 12, 1):
    cv2.line(white, pt1: (self.pts[t][0] + os, self.pts[t][1] + os1), pt2: (self.pts[t + 1][0] + os, self.pts[t + 1][1] + os1), color: (0, 255, 0), thickness: 3)
for t in range(13, 16, 1):
    cv2.line(white, pt1: (self.pts[t][0] + os, self.pts[t][1] + os1), pt2: (self.pts[t + 1][0] + os, self.pts[t + 1][1] + os1), color: (0, 255, 0), thickness: 3)
for t in range(17, 20, 1):
    cv2.line(white, pt1: (self.pts[t][0] + os, self.pts[t][1] + os1), pt2: (self.pts[t + 1][0] + os, self.pts[t + 1][1] + os1), color: (0, 255, 0), thickness: 3)
```

### 6.2.1.1 FRONT END

**FIGURE 3.10: FROND END**



### 6.4.1.2 BACKEND

FIGURE 3.11: CODE

```
import csv

import numpy as np
import tensorflow as tf
from sklearn.model_selection import train_test_split

RANDOM_SEED = 42
```

FIGURE 3.12: CODE

```
X_dataset = np.loadtxt(dataset, delimiter=',', dtype='float32', usecols=list(range(1, (21 * 2) + 1)))

y_dataset = np.loadtxt(dataset, delimiter=',', dtype='int32', usecols=(0))

X_train, X_test, y_train, y_test = train_test_split(X_dataset, y_dataset, train_size=0.75, random_state=RANDOM_SEED)
```

FIGURE 3.13: CODE

```
model = tf.keras.models.Sequential([
    tf.keras.layers.Input((21 * 2, )),
    tf.keras.layers.Dropout(0.2),
    tf.keras.layers.Dense(20, activation='relu'),
    tf.keras.layers.Dropout(0.4),
    tf.keras.layers.Dense(10, activation='relu'),
    tf.keras.layers.Dense(NUM_CLASSES, activation='softmax')
])
```

**FIGURE 3.14: CODE**

```
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from sklearn.metrics import confusion_matrix, classification_report

def print_confusion_matrix(y_true, y_pred, report=True):
    labels = sorted(list(set(y_true)))
    cmx_data = confusion_matrix(y_true, y_pred, labels=labels)

    df_cmx = pd.DataFrame(cmx_data, index=labels, columns=labels)

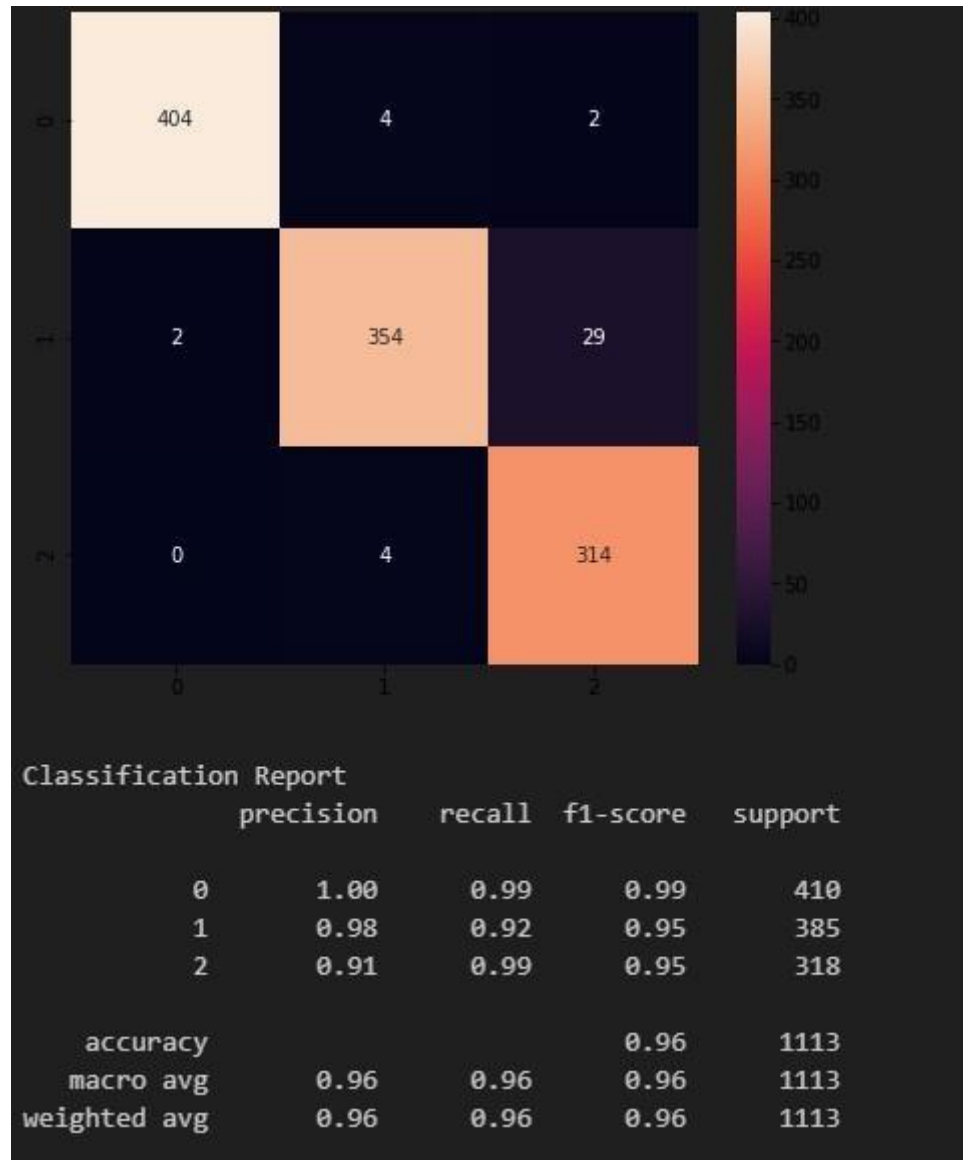
    fig, ax = plt.subplots(figsize=(7, 6))
    sns.heatmap(df_cmx, annot=True, fmt='g', square=False)
    ax.set_ylim(len(set(y_true)), 0)
    plt.show()

    if report:
        print('Classification Report')
        print(classification_report(y_test, y_pred))

Y_pred = model.predict(X_test)
y_pred = np.argmax(Y_pred, axis=1)

print_confusion_matrix(y_test, y_pred)
```

FIGURE 3.15: CODE



## CHAPTER VII CONCLUSION & FUTURE ENHANCEMENTS

### 7.1 CONCLUSION

A sign language interpreter plays a crucial role in bridging communication between deaf or hard of hearing individuals and the hearing world. Their work ensures accessibility, inclusion, and equal participation in various settings—whether in education, healthcare, legal proceedings, or daily interactions. By interpreting spoken language into sign language and vice versa, they empower individuals to connect, understand, and express themselves fully.

Ultimately, sign language interpreters are not just language facilitators; they are advocates for accessibility and inclusion. Their presence strengthens communities, fosters understanding, and helps break communication barriers, ensuring that everyone has the opportunity to be heard and understood.

## 7.2 FUTURE ENHANCEMENTS

Future enhancements for sign language interpretation could include AI-powered interpreters, improving accessibility through real-time digital translation. Advances in gesture recognition technology may enable more seamless communication, reducing the reliance on human interpreters in certain situations.

Wearable technology, like smart gloves that detect sign language movements and convert them into text or speech, could provide an innovative solution. Improvements in \*\*VR and AR\*\* could create immersive learning experiences for sign language users, making education and training more interactive.

Additionally, legislative advancements and broader awareness campaigns can ensure sign language interpretation becomes a standard in workplaces, education, and public services—strengthening inclusivity for the deaf and hard-of-hearing communities.

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