Easy Communication Interface for the Vocally and Hearing Impaired: EZCOMM

Capstone Project Report

End-Semester Evaluation

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ABSTRACT

Gesture recognition is an effort towards studying the challenges in the classification of characters in Indian Sign Language(ISL). A lot of research has already been done in the corresponding field of American Sign Language(ASL), but unfortunately the same cannot be said for ISL. This project deals with the recognition and detection of hand gestures. Images of the hand gestures are taken using a web camera and matched with the dataset and the best match is returned. Lack of standard datasets, occluded features and variation in the language with locality have been the major barriers which have led to a little research being done in Indian Sign Language. Our project aims to reduce the communication gap between the vocally and hearing disabled people and the normal people who do not know sign language at all.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled "Easy Communication Interface for the Vocally and Hearing Impaired: EZCOMM" is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr. Sunita Garhwal during 7th semester (2019).

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Lastly, we would also like to thank our families for their unyielding love and encouragement. They always wanted the best for us and we admire their determination and sacrifice.

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LIST OF ABBREVIATIONS

ISL	Indian Sign Language
ASL	American Sign Language
CNN	Convolutional Neural Networks
OH	Orientation Histogram
PCA	Principal Component Analysis
HTML	Hyper Text Markup Language
SVM	Support Vector Machine
CSS	Cascading Style Sheets
PC	Personal Computer
INR	Indian National Rupee
API	Application Programming Interface
NLP	Natural Language Processing
AI	Artificial Intelligence
ML	Machine Learning

INTRODUCTION

1.1 Project Overview

Motion of body parts like face, hand is a form of gesture. Here for gesture recognition we are using image processing, computer vision and deep learning. Gesture recognition enables computer to understand human actions and also acts as an interpreter between computer and human. This could provide a potential to humans to interact naturally with the computers without any physical contact of the mechanical devices. Gestures are performed by the deaf and dumb community to perform sign language. This community used sign language as means of communication when broadcasting the audio is impossible, or typing and writing is difficult, but there is the vision possibility. At that time sign language was the only way for exchanging information between people. Normally sign language is used by everyone when they do not wish to speak, but this is the only way of communication for deaf and dumb community. Sign language also serves the same meaning as spoken language does. This has been used by deaf and dumb community all over the world but in their regional form like ISL, ASL. Sign language can be performed by using Hand gesture either by one hand or two hands. It can be categorized into Isolated sign language and continuous sign language. Isolated sign language consists of a single gesture having single word while continuous ISL or Continuous Sign language consists of a sequence of gestures that generate a meaningful sentence. We performed isolated ISL gesture recognition technique.

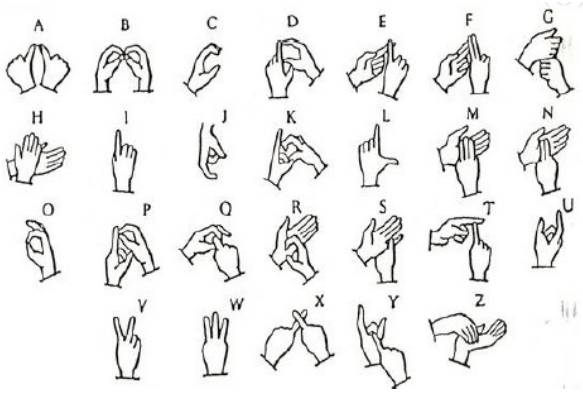

Fig 1.1: Alphabet Chart of the Indian Sign Language [3]

1.1.1 Technical Terminology

Hand gesture recognition system involves the following steps:

- Pre-processing and hand segmentation: Data preprocessing is a data mining technique. It is used for the transformation of raw data into understandable and clean format. Efficient hand tracking and segmentation is the key of success towards any gesture recognition. To overcome the challenges of vision based methods, such as varying lighting condition, change in background and skin color detection, variation in human skin color complexion required the robust development of algorithm for natural interface. Color is very powerful descriptor for object detection. So color information was used for the segmentation purpose. Color information is invariant to rotation and geometric variation of the hand. The system first learns the color histogram and after learning the histogram, the model converts it into a grey image with black and white pixels.

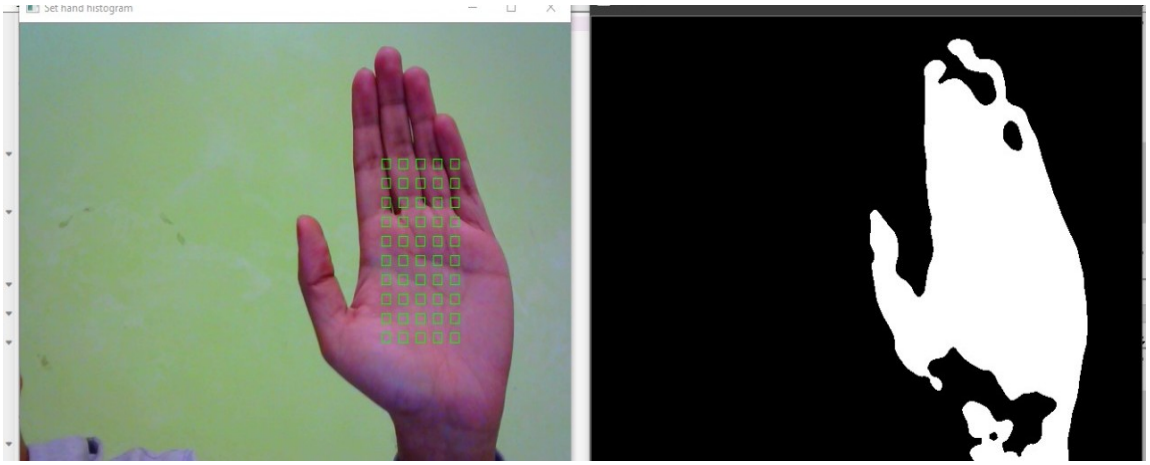

Fig 1.2: Hand Segmentation

- Hand detection: After hand segmentation is done, hand detection algorithm works. The live video now appears black and white. The part recognizing the segmented part of the hand appears white and all the other features appear black.

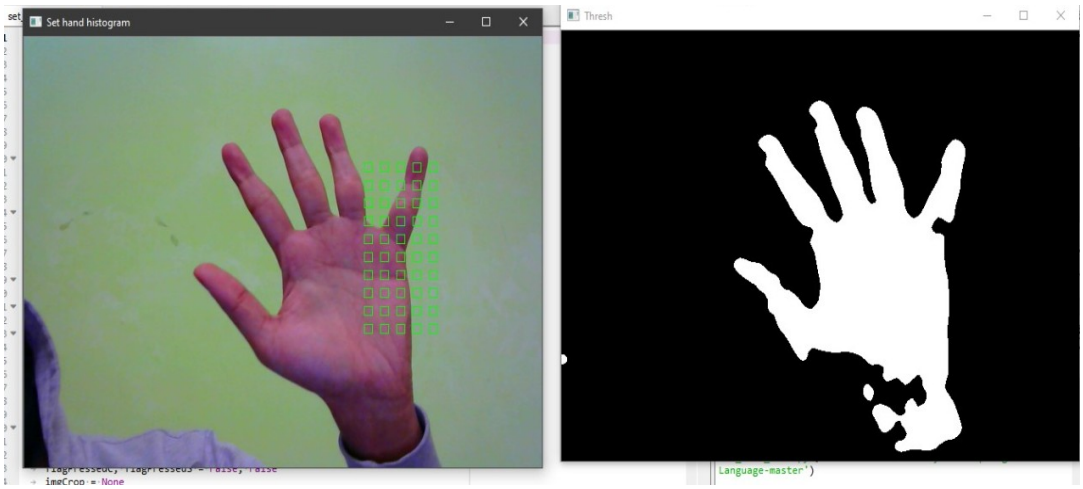

Fig 1.3: Hand Detection

- Hand gesture recognition: Frames are captured from the live video. The keras model builds a CNN model to recognize the gesture. Dataset of 26 alphabets (A-Z) and numbers (0-9) with 2000 images of each letter is created using OpenCV and is used to train the model. The frames extracted from the live video are tested on the model and the corresponding hand gesture is recognized.

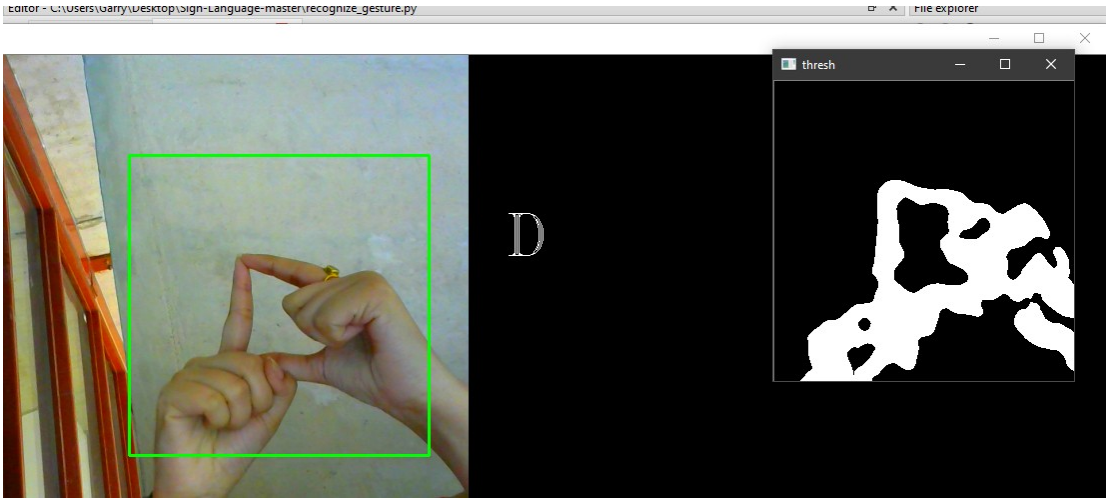

Fig 1.4: Hand Gesture Recognition

1.1.2 Problem Statement

About nine million people in the world are considered to be deaf or dumb or both. Communication between the deaf-dumb and a normal person have always been a challenging task. There is a need for an interpretation system which could act as a bridge between the deaf and dumb and those who do not know the sign language.

1.1.3 Goal

The goal of this project is to reduce the communication gap between the vocally impaired and normal people. This would result in a lot easier communication between both sides.

1.1.4 Solution

The proposed solution for the problem is to develop a web application software for automatic translation of Indian sign language into text in English and vice-versa to assist the communication between speech and/or hearing impaired people and normal people. The language translator should be able to translate two handed finger spelling input of Indian Sign language alphabets A-Z and numbers 0-9 into English text output.

1.2 Need Analysis

In majority of the communication through sign languages, much of the semantic content lies in movement, facial expressions and stress placed on the sign. Thus there is scope for development of a complete system which could be used as an accompaniment for the disabled to communicate, in which all elements of a sign language would be used. Gesture recognition could also be used in recognition of Cued Speech – a sign system in which both lip reading and hand gestures are used in conjunction. About nine million people in the world are considered to be deaf or dumb or both. Communication between deaf-dumb and a normal person has always been a challenging task. People with speech disabilities communicate in sign language and thus have trouble in mingling with the able-bodied. There is a need for an interpretation system which would act as a bridge between them and those who do not know the sign language. Hand gestures are a strong medium of communication for the hearing impaired society. There is a need for a portable interpretation system which could act as a bridge between the deaf and dumb and those who do not know the sign language. Our project aims at taking the basic step in bridging the communication gap between normal people, deaf and dumb people using sign language. The main focus of this work is to create a vision based system to identify sign

language gestures from the video sequences. The main reason for choosing a system based on vision relates to the fact that it can provide a simpler and more intuitive way of communication between a human and a computer.

1.3 Research Gaps

Gesture Recognition using sign language is a field which has not been explored to its fullest. Lack of standard datasets, occluded features and variation in the gestures with regions have been the major barriers which have led to a little research being done on the Indian Sign Language. Hand gestures are done either by one hand or two hands. The major requirement is of a high quality depth sensing camera which can easily capture the static hand gestures as in case of dynamic gestures, it is difficult to extract the accurate signs from the frames. Hand orientation, image noise, lighting and background conditions have major effects on the accuracy of the prediction. Due to these reasons a lot of research is being carried out in this field to build an effective communication system to help the deaf and dumb people.

1.4 Problem Definition and Scope

- In majority of the communication through sign languages, much of the semantic content lies in movement, facial expressions and stress placed on the sign. Thus there is scope for development of a complete system which could be used as an accompaniment for the disabled to communicate, in which all elements of a sign language would be used.
- Gesture recognition could also be used in recognition of Cued Speech – a sign system in which both lip reading and hand gestures are used in conjunction.
- This system could be ported to run on a portable embedded system that could be taken by a disabled person and used anywhere for interpretation.

1.5 Assumptions and Constraints

Some assumptions that we made before moving forward with the project are shown in the table below.

Table 1: Assumptions and Constraints

S. No.	Assumptions and Constraints
1	Possibility of misinterpretation of closely related gestures.
2	Possibility of misinterpretation of words of similar pronunciation.
3	System is trained on a limited database.
4	Facial expressions are not considered.
5	Background subtraction for robust usage. • Making the system user independent. • Pattern matching training.
6	Image noise, ambient light intensity and color of the object are appropriate for the system to operate.
7	Sign languages have their own morphological structure and grammatical nuances.
8	Less availability of ISL dataset and more complexity as compared to American sign language.
9	Variation in sign language with locality and the usage of different symbols for the same alphabet by the same person.
10	System is highly dependent on: • Lighting and background conditions. • Speed and velocity of motion of hand. • Position, posture and orientation of hand.

1.6 Approved Objectives

- Implementing the conversion of hand gestures to text using deep learning algorithms.
- Design a model to convert speech/text input into Indian Sign Language gestures using NLP.
- To develop a web application software for automatic translation of Indian sign language into text and vice-versa to assist communication between speech and/or

hearing impaired people with normal people.

- Analyzing and verifying the test results.

1.7 Methodology Used

For gesture recognition, efficient hand tracking and segmentation is required. The input image is segmented for processing. Color is very powerful descriptor for object detection. So color information was used for the segmentation purpose. Color information is invariant to rotation and geometric variation of the hand. The system first learns the color histogram and after learning the histogram, the model converts it into a grey image with black and white pixels.

After hand segmentation, hand detection algorithm is used. The part recognizing the segmented part of the hand appears white and all the other features appear black.

Spatial features for individual frames using inception model (CNN) are extracted. Frames are captured from the live video. Each video (a sequence of frames) is then represented by a sequence of predictions made by CNN for each of the individual frames. The keras model builds a CNN model to recognize the gesture. The frames extracted from the live video are tested on the model and the corresponding hand gesture is recognized.

Methodology

- First, we will extract the frames from the multiple video sequences of each gesture.
- After the first step, noise from the frames i.e. background, body parts other than hand are removed to extract more relevant features from the frame.
- Video frames are given to the CNN model for training on the spatial features. Inception model has been used for this purpose which is a deep neural net.
- Store the train and test frame predictions. We'll use the model obtained in the above step for the prediction of frames.

Frame Extraction and Background Removal

Each gesture video is broken down into a sequence of frames. Frames then are processed to remove all the noise from the image that is everything except hands. The final image consists of grey scale image of hands to avoid color specific learning of the model.

Train CNN (Spatial Features) and Prediction

The first row in the below illustration is the video of a gesture of sign language. The second row depicts the set of frames extracted from it. The third row shows the sequence of predictions for each frame by CNN after training it.

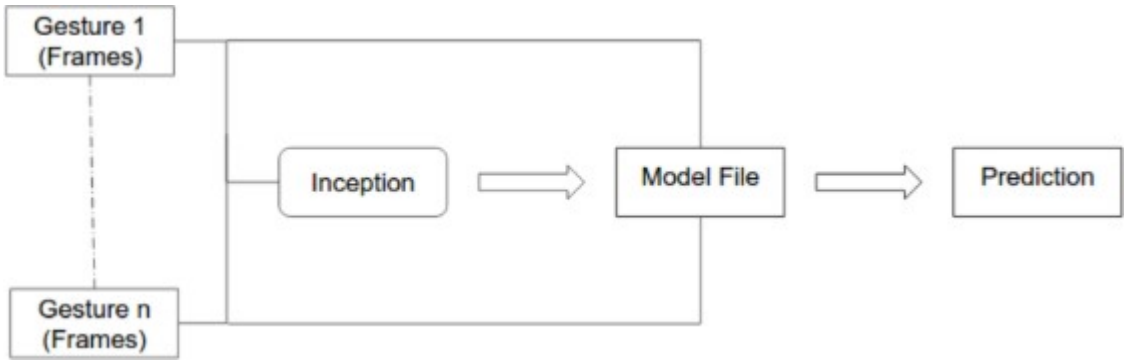

Fig 1.5: Training the CNN model [17]

1.8 Project Outcomes and Deliverables

- Eliminates the need for an interpreter for communication between sign language and speech language.
- Easy to execute in any supporting operating system.
- Real time translation.
- Does not require any additional hardware.
- The feature vectors which include the image frames containing all the aspects of the sign are considered.
- The geometric features which are extracted from the dominant hand of the signer, improve the accuracy of the system to a great degree.
- An interpretation system which should act as a bridge between the deaf and dumb and those who do not know the sign language. This system can be deployed at various facilities to aid deaf and dumb people.
- Applications are mainly communication based like managing day-to-day activities, schooling, etc.

1.9 Novelty of Work

There is a separate sign language in America that uses only one hand for picturing the gestures. But the Indian sign language is totally different. It uses both the hands for representing the alphabets. While there are lot of efforts going into American Sign Language detection the same cannot be said about Indian Sign Language due to lack of standard datasets, occluded features and variation in the language with regions.

Our project aims to develop a robust application software for automatic translation of Indian sign language into speech in English and vice-versa with high accuracy rates.

2.1 Literature Survey

2.1.1 Theory associated with Problem Area

Sign Language enhances the understanding ability for the challenging persons in speech and hearing all over the world. It employs sign which is made with hand, facial expression and other parts of our body. Every country uses its own native language as per sign language is concerned about its own syntactical and grammatical meaning. Like British Sign Language and American Sign Language the language which is being used in India is called Indian Sign Language.

2.1.2 Existing Systems and Solutions

In the recent years, there has been tremendous research on the hand sign language gesture recognition. The technology for gesture recognition is given below.

Vision-based

In vision-based methods camera is the input device for observing the information of hands. These methods require only a camera, thus realizing an interaction between humans and computers without the use of any extra devices. These systems tend to complement the biological vision by describing artificial vision systems that are executed in software and/or hardware. This poses a problem as these systems should be background insensitive, light invariant, person and camera independent to achieve real time performance. Moreover, such systems should be optimized to meet the requirements, including accuracy and robustness [11].

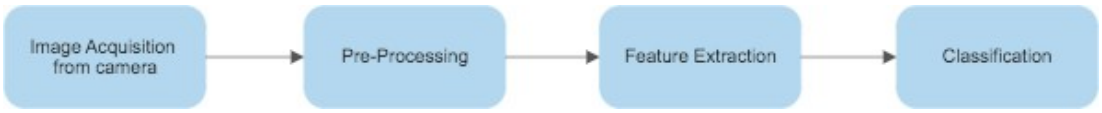

Fig 2.1: Block diagram of vision based recognition system [11]

Vision based analysis, is based on how humans perceive information about their surroundings, yet it is probably the most difficult to implement in a satisfactory manner. Several different approaches have been tested so far.

1. One is to build a three-dimensional model of the human hand. The model is matched to the images of the hand in the dataset by one or more cameras, and the parameters corresponding to palm orientation and joint angles are estimated. These parameters are then used to perform gesture classification.
2. Second is to capture the image using a camera then extract some features and use them input in a classification algorithm for classification.

Automatic Indian Sign Language Recognition for Continuous Video Sequence [2]

The proposed system comprises of 4 major modules: Data Acquisition, Pre-processing, Feature Extraction and Classification.

Pre-processing stage involves Skin Filtering and histogram matching after which Eigen-vector based Feature Extraction and Eigen value weighted Euclidean distance based Classification Technique is used.

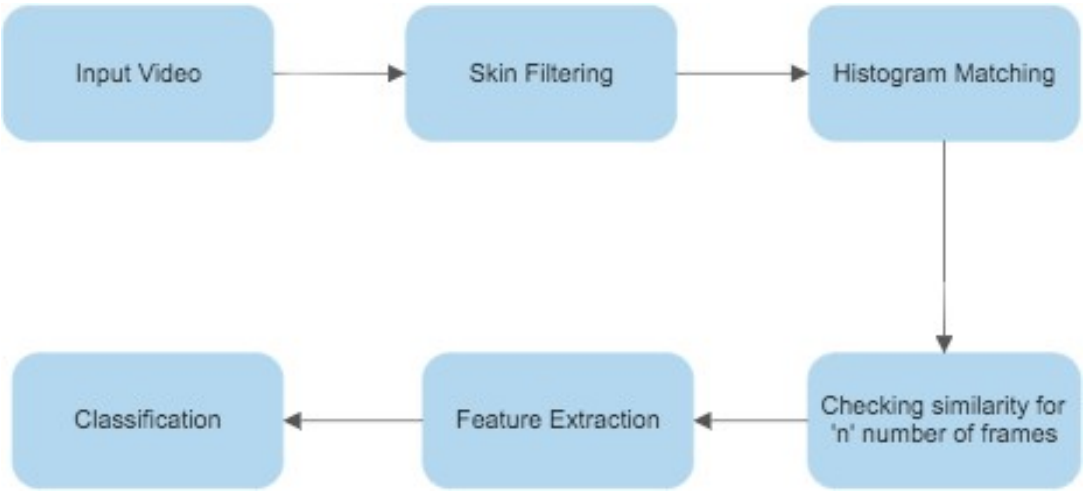

Fig 2.2: System overview [2]

Recognition of isolated Indian Sign Language Gesture in Real Time [1]

The statistical techniques for recognition of ISL gestures in real time are demonstrated which comprises both the hands. A video database is created and utilized which might contain several videos for large number of signs. Direction histogram is the feature used for classification due to its appeal for orientation invariance and illumination. Two different approaches which can be utilized for recognition are Euclidean distance and K-nearest neighbor metrics.

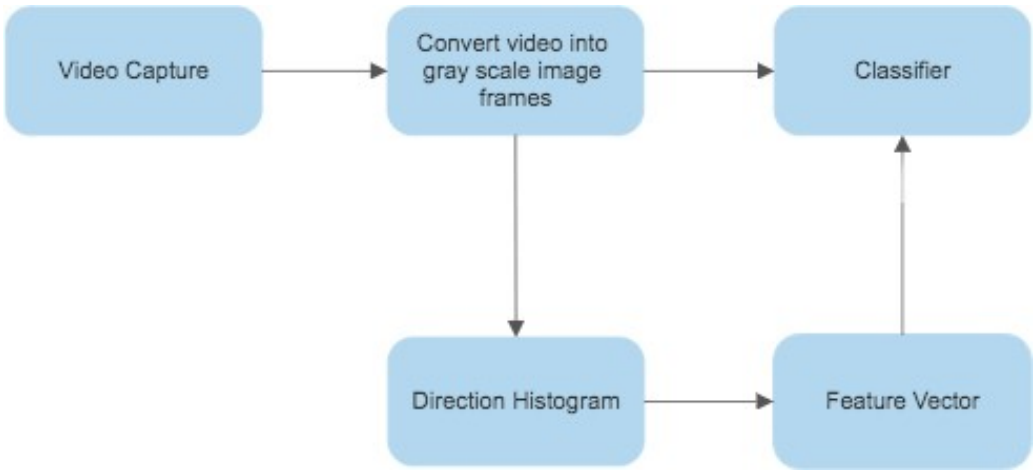

Fig 2.3: Methodology for real time ISL classification [1]

Continuous Indian Sign Language Gesture Recognition and Sentence Formation [6]

Recognizing sign language gestures from continuous gestures is a very challenging research issue. For this, the gradient based key frame extraction method is used. These key frames are helpful in splitting continuous sign language gestures into sequence of signs as well as for removing uninformative frames. After splitting of gestures each sign is treated as an isolated gesture. Then features of pre-processed gestures are extracted using Orientation Histogram (OH) with Principal Component Analysis (PCA) which is applied for reducing dimension of features obtained after OH. Testing of probes is done using various types of classifiers like Euclidean distance, Correlation, Manhattan distance, city block distance etc. Comparative analysis of their proposed scheme is performed with various types of distance classifiers.

2.1.3 Research findings for Existing Literature

Table 2: Existing Techniques

S. No.	Roll Number	Name	Paper Title	Tools/ Technology	Findings	Citation
1	101603057	Arshit Goel	Real-time American Sign Language Recognition with Convolutional Neural Networks	Convolutional neural networks, Transfer learning, Caffe and GoogLeNet, HTML and Javascript	American Sign Language fingerspelling translator using Convolutional neural networks. A pre-trained GoogLeNet architecture was used by applying transfer learning to classify letters a-k correctly.	Garcia and Viesca [4]
2	101603057	Arshit Goel	Recognition of isolated Indian sign language gesture in real time	Direction Histogram, K-nearest neighbor, Euclidean distance metric	A video database was created and the signs were classified using Direction histogram due to its appeal for illumination and orientation invariance.	Nandy *et. al.* [1]
3	101603058	Arushi Aggarwal	Nearest neighbor classification of Indian sign language gestures using kinect camera	MeshLab, OpenKinect, Neural networks, K-means clustering, nearest neighbor classification	The system was implemented using Microsoft Kinect camera for gesture recognition on a vocabulary of 140 symbols.	Ansari and Harit [7]
4	101603058	Arushi Aggarwal	Continuous Indian Sign Language Gesture Recognition and Sentence Formation	Orientation histogram, Feature extraction, Classification, Principal component analysis, Correlation	Features of sign language gestures were extracted from continuous gestures using Orientation Histogram with PCA as a dimensionality reduction technique.	Tripathi *et. al.* [6]

5	101610017	Asees	Computer vision based approach for Indian Sign Language character recognition	Distance transform method, Hidden Markov model, Eigen vectors, SVM	The hand is segmented and the state of fingers is used to recognize the alphabet. The features such as angle made between fingers, number of fingers that are fully opened, closed and semi-closed are used for recognition.	Shangeetha *et. al.* [11]
6	101610017	Asees	Automatic Indian Sign Language Recognition for Continuous Video Sequence	MATLAB, Skin filtering, Histogram Matching, Eigen vector, Euclidean Distance classification	A system to recognize 24 different alphabets of Indian sign language using four modules- Data Acquisition, Pre-processing, Feature Extraction and Classification.	Singha and Das [2]
7	101610089	Sukruth G	Hand Segmentation Techniques to Hand Gesture Recognition for Natural Human Computer Interaction	MATLAB, OpenCV, Hand tracking and Segmentation, Edge traversal algorithm	Hand segmentation using different color spaces with required morphological processing was used to handle the challenges such as complex background removal, variable lighting condition and skin color detection.	Ghotkar and Kharate [5]
8	101610089	Sukruth G	A research gap on automatic Indian Sign Language recognition based on hand gesture datasets and methodologies	Support vector machine, K-nearest neighborhood, Hidden Markov model, Fuzzy interface system	Recognizing gestures under parameters like multiple hands as background, left handed person, right handed person, size of finger etc. helps remove research gaps in existing systems.	Dangarwala and Hiran [9]

2.1.4 The Problem that has been Identified

To develop an application software for automatic translation of Indian sign language into text in English and vice-versa to assist the communication between speech and/or hearing impaired people with normal people. This language translator should be able to translate one handed spelling input of Indian Sign language alphabets A-Z and numbers 0-9 into spoken English text output and vice versa.

2.1.5 Survey of Tools and Technologies Used

- Spyder**,** Tensorflow and keras
- Web camera
- Image processing and computer vision for gesture recognition.
- Natural Language Processing for converting speech to text and vice versa.
- Machine learning and Deep Learning algorithms.
- Flask, HTML, CSS

2.2 Standards

1. IEEE 23026-2015 ISO/IEC 25010:2011

IEEE 23026-2015 ISO/IEC 25010:2011 defines:

1. A quality in use model composed of five characteristics (some of which are further subdivided into sub characteristics) that relate to the outcome of interaction when a product is used in a particular context of use. This system model is applicable to the complete human-computer system, including both computer systems in use and software products in use.
2. A product quality model composed of eight characteristics (which are further subdivided into sub characteristics) that relate to static properties of software and dynamic properties of the computer system. The model is applicable to both computer systems and software products.

The characteristics defined by the models are relevant to all software products and computer systems. The characteristics and sub characteristics provide consistent

terminology for specifying, measuring and evaluating system and software product quality. They also provide a set of quality characteristics against which stated quality requirements can be compared for completeness.

The models can, for example, be used by developers, acquirers, quality assurance and control staff and independent users, particularly those who want to use it on daily basis. Activities during product development that can benefit from the use of the quality models include:

- Identifying software and system requirements;
- Validating the comprehensiveness of a requirements definition;
- Identifying software and system design objectives;
- Identifying quality control criteria as part of quality assurance;
- Identifying acceptance criteria for a software product and/or software-intensive computer system;
- Establishing measures of quality characteristics in support of these activities.

2. IEEE 29148:2011(E)

This standard replaces IEEE 830-1998, IEEE 1233-1998, IEEE 1362-1998. ISO/IEC/IEEE 29148:2011 contains provisions for the processes and products related to the engineering of requirements for systems and software products and services throughout the life cycle. It defines the construct of a good requirement, provides attributes and characteristics of requirements, and discusses the iterative and recursive application of requirements processes throughout the life cycle. ISO/IEC/IEEE 29148:2011 provides additional guidance in the application of requirements engineering and management processes for requirements-related activities in ISO/IEC 12207 and ISO/IEC 15288. Information items applicable to the engineering of requirements and their content are defined. The content of ISO/IEC/IEEE 29148:2011 can be added to the existing set of requirements-related life cycle processes defined by ISO/IEC 12207 or ISO/IEC 15288, or can be used independently.

2.3 Software Requirement Specification(SRS)

2.3.1 Introduction

The software requirements section explains the system requirements. This document should show functionality, constraints, supportability, performance and usability.

2.3.1.1 Purpose

The purpose of this document is to describe the functional and non-functional requirements that our project "Easy communication interface for vocally and hearing impaired: EZCOMM" need. This is to ensure that our product has the same requirements as the customer wanted it to have, so there is no misinterpretation between the customer's needs and the team's thoughts on those needs. The goal of this document is to give a detailed description of system constraints and interactions with users.

2.3.1.2 Intended Audience and Reading Suggestions

The intended audience is as follows:

- Developers who can review project's capabilities and more easily understand where their efforts should be targeted to improve or add more features to it (design and code the application – it sets the guidelines for future development).
- End users of this application who wish to read about what this project can do. These are:
  "Normal" user: a user that can use the application as another video/audio interface for communication with a deaf/dumb person.
  "Sign language" user: a user who will communicate through his hand by gestures. Movement detection and recognition is especially done for this user.
- Project testers can use this document as a base for their testing strategy as some bugs are easier to find using a requirements document. This way testing becomes more methodically organized.

2.3.1.3 Project Scope

"Easy communication interface for vocally and hearing impaired: EZCOMM" is designed especially for speech and hearing impaired people, but all other users can use it. The main function is to allow the user to use sign language in front of a camera and then the application is recognizing the gesture. Each movement recognized is translated for easier communication between a normal and a deaf/dumb user.

2.3.2 Overall Description

2.3.2.1 Product Perspective

EZCOMM is a very useful web application for effective communication between speech and hearing impaired people and the normal people. Our software is divided in two main parts. The first one is about the gesture recognition and its textual translation. The second part is conversion of speech/text to signs (gestures).

2.3.3.2 Product Features

The main features of our application are:

- Gesture Recognition and translation: Our software will be able to detect and recognize gestures from the user. It will have a lot of data about sign language in a special dictionary. If the movement is not recognized, it will just do nothing. If the gesture is recognized, the translation will be displayed on the screen.
- Speech/text to sign conversion: Our application will convert the input audio or text into the corresponding sign language gestures. The signs will be displayed on the screen to form the words where each word will be differentiated with a dot in between.

2.3.3 External Interface Requirements

2.3.3.1 User Interfaces

Our project has two main parts, i.e. conversion of hand gestures to text and conversion of speech/text to the corresponding hand gesture. All this is incorporated in the web application. The user’s application part will perform by his choice. If the user wants to convert gestures to text, the web camera will be connected and particular image of the hand

gesture will be taken which will then be recognized by our model and be converted to text. If the user wants to convert speech to gesture, the microphone will be connected and the speech or text entered by the person will be converted to the particular gesture in sign language.

2.3.3.2 Hardware Interfaces

The hardware required for the proposed system is a laptop or a tablet with a good resolution web camera so that images with as less noise as possible can be taken and the gestures can be recognized properly and accurately.

2.3.3.3 Software Interfaces

Machine Learning algorithms like SVM, Naive Bayes Classification etc. have been used, Deep Learning algorithms like CNN using Tensorflow and keras, Android Studio for web application development.

2.3.4 Other Non-functional Requirements

2.3.4.1 Performance Requirements

Performance is essentially for how fast your app works whereas Responsiveness ensures that your app is ready to respond to a user's input or an external event no matter what it's doing currently.

2.3.4.2 Safety Requirements

Software safety can be applicable to a variety of systems, but the most often it is associated with system-critical systems. Any errors in these types of systems can have a profound negative impact. The number and complexity of safety critical interfaces have been minimized.

2.3.4.3 Security Requirements

The system should give privacy for user data using database encryption and local encryption to protect data in the event of device theft. The system's back-end servers shall only be accessible to authenticated administrators. Sensitive data will be encrypted before being sent over insecure connections like the internet.

2.4 Cost Analysis

We opted for the use of a web camera to test our model on a PC. The overall cost incurred while implementing our project is shown in the table below:

Table 3: Cost Structure

ITEM	QUANTITY	COST (INR)
Web Camera	1	1500

2.5 Risk Analysis

The biggest concern in our system is system's dependency on external environment and conditions which can result into misclassification. Our system is highly sensitive to external lighting conditions, postures, orientation and angles of hand. This dependency can lead to misinterpretation of signs which will lead to misunderstanding between users.

The other disadvantage is that Indian sign language varies in different parts of country and it is very much possible for different users to use different symbols for the same sign.

METHODOLOGY ADOPTED

3.1 Investigative Techniques

In research we conduct many different types of investigations. There are three main types of investigations: descriptive, comparative and experimental. In our project, Experimental investigative techniques have been used with the initial idea of contributing to society using our engineering skills. An Experimental Investigative Technique involves coming up with a plan, designing the required procedure for executing the program and then coming up with the final hypothesis for the desired project. We want to revolutionize the way we communicate with impaired people. There have been a lot of research done in this field but no particular method stands out.

In this project, we aim towards recognizing and analyzing various alphabets from a dataset of sign images. Dataset consists of various images with each image clicked in different light condition with different hand orientation. With such a wide range of data set, we are able to train our system to good levels and thus obtain good results.

We will investigate different machine learning techniques like Support Vector Machines (SVM), Logistic Regression, K-nearest neighbors and a neural network technique, Convolution Neural Network (CNN) for detection of sign language.

3.2 Proposed Solution

For gesture recognition, efficient hand tracking and segmentation is required. The input image is segmented for processing. Color is very powerful descriptor for object detection. Color information is invariant to rotation and geometric variation of the hand. The system first learns the color histogram and then the model converts it into a grey image with black and white pixels. After hand segmentation, hand detection algorithm is used. Then the spatial features for individual frames using CNN are extracted. Frames are captured from the live video. Each video is then represented by a sequence of predictions made by CNN for each of the individual frames. The keras model builds a CNN model to recognize the

gesture. The frames extracted from the live video are tested on the model and the corresponding hand gesture is recognized.

3.3 Work Breakdown Structure

This is the overview of the work plan we decided to follow during the course of this project.

Table 4: Gantt chart of proposed work plan

3.4 Tools and Technologies used

- Spyder
- Web Camera
- Tensorflow object detection API
- Keras
- Notepad++
- Computer Vision
- Deep Learning
- Flask
- CSS
- HTML

4.1 System Architecture

A system architecture is the conceptual model which defines the behavior, structure and views of a system. The architecture shown below depicts the working of our model. The web app converts hand gesture to text and text/speech to sign language.

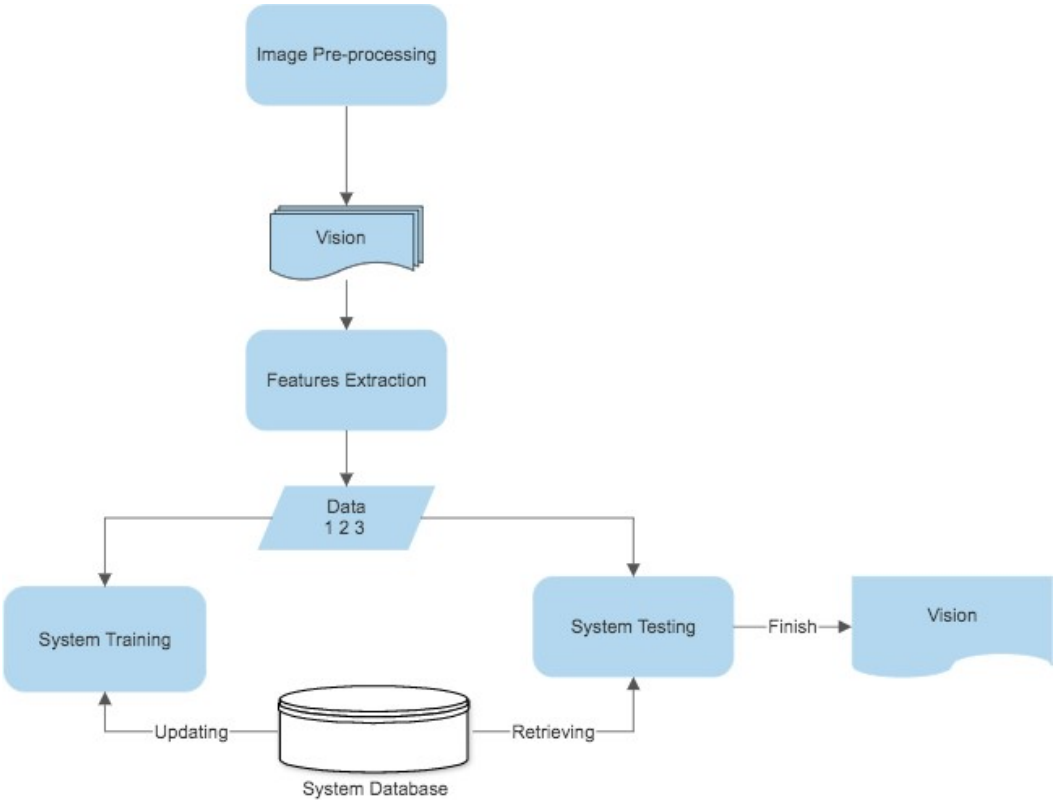

Fig 4.1: System Architecture

4.2 Design Level Diagram

- Activity Diagram: It is a diagram that depicts the behavior of the system. It portrays the control flow from start to finish showing various decision paths that might exist when an activity is performed.

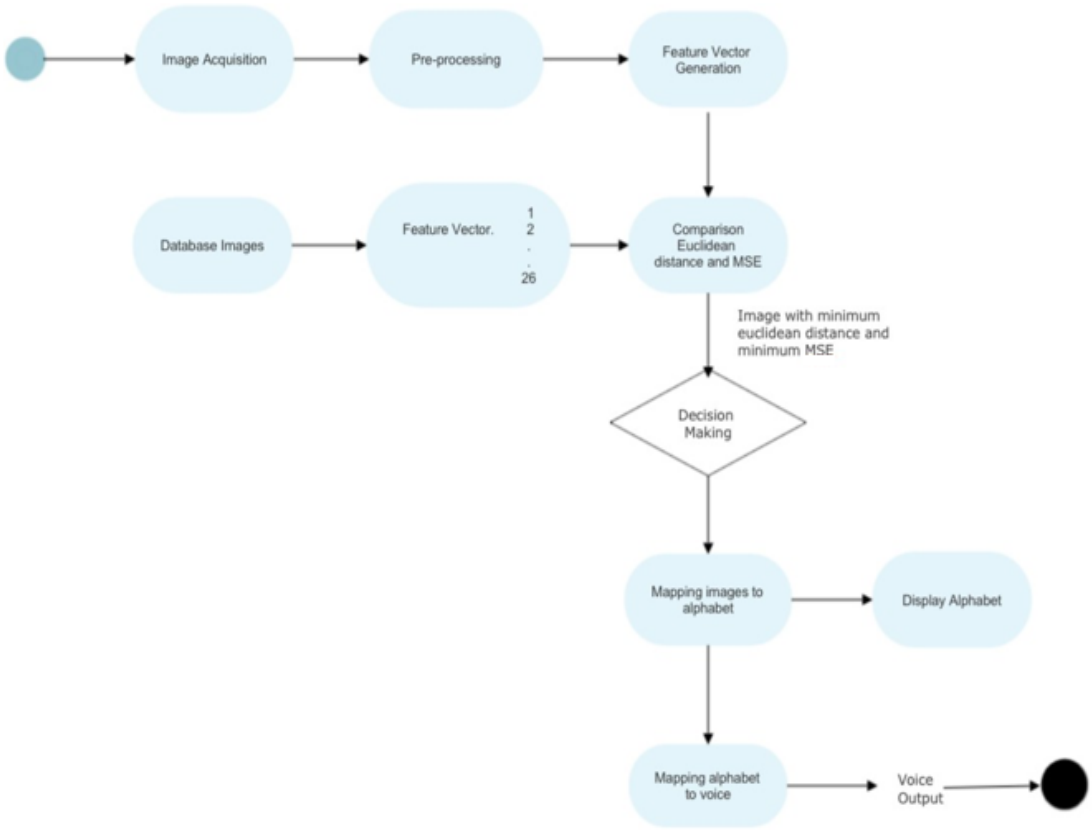

Fig 4.2: Activity Diagram

4.3 User Interface Diagrams

A use case diagram is a representation of a user's interaction with the system that shows the relationship between the user and the different use cases in which the user is involved. The use case diagram below shows the interaction between the user and the system that converts hand gesture to text.

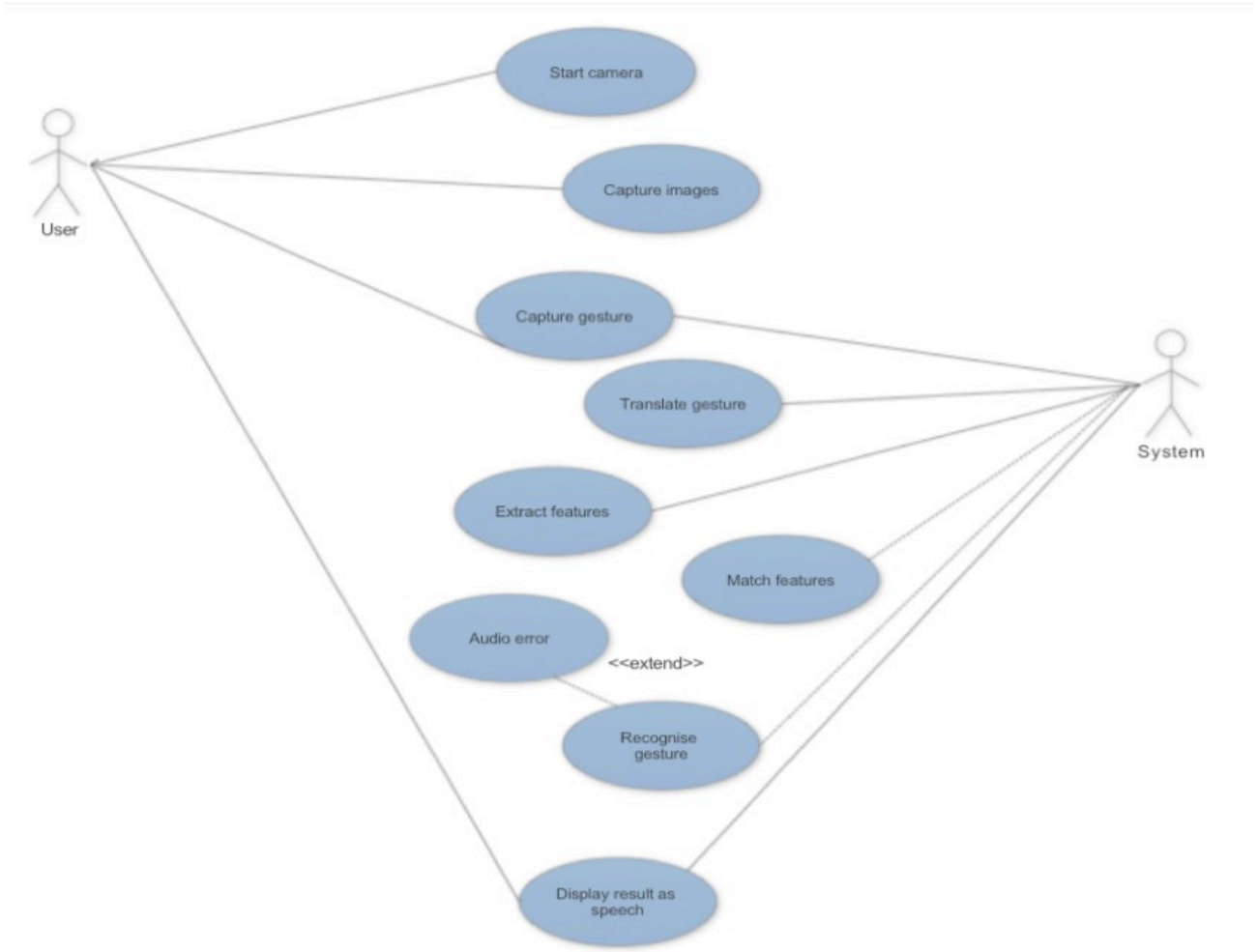

Fig 4.3: Gesture recognition use case diagram

The use case diagram below shows the interaction between the user and the system that converts speech to sign language.

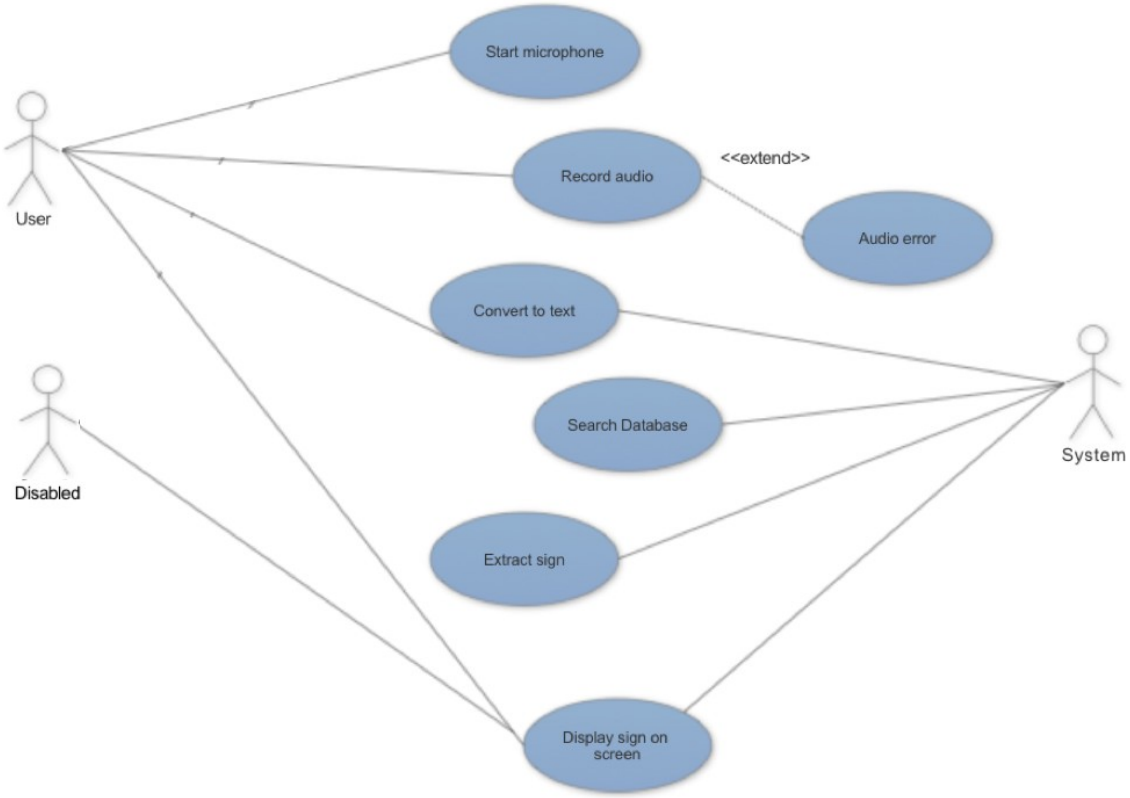

Fig 4.4: Speech to sign conversion use case diagram

IMPLEMENTATION AND EXPERIMENTAL RESULTS

5.1 Experimental Setup (or simulation)

The setup includes an efficient system that uses skin segmentation and object detection algorithms to first differentiate between hand and rest of the objects in that frame. The hand gesture detected is taken as an input to our trained model and several features are extracted through various deep learning algorithms to finally recognize the input gesture correctly. Various libraries like keras, numpy, opencv have been used to implement this project.

5.2 Experimental Analysis

5.2.1 Data

The dataset for Indian Sign Language has been created manually using a web camera. Total number of gestures involved are 36 (26 alphabets A-Z and 10 numbers 0-9). 1000 images were taken for each gesture under different light conditions and with different orientation. Each image was further flipped vertically to generate 1000 more images in the dataset so as to introduce diversity and improve the accuracy of the model.

Fig 5.1: Dataset of generated Numerals (0-9)

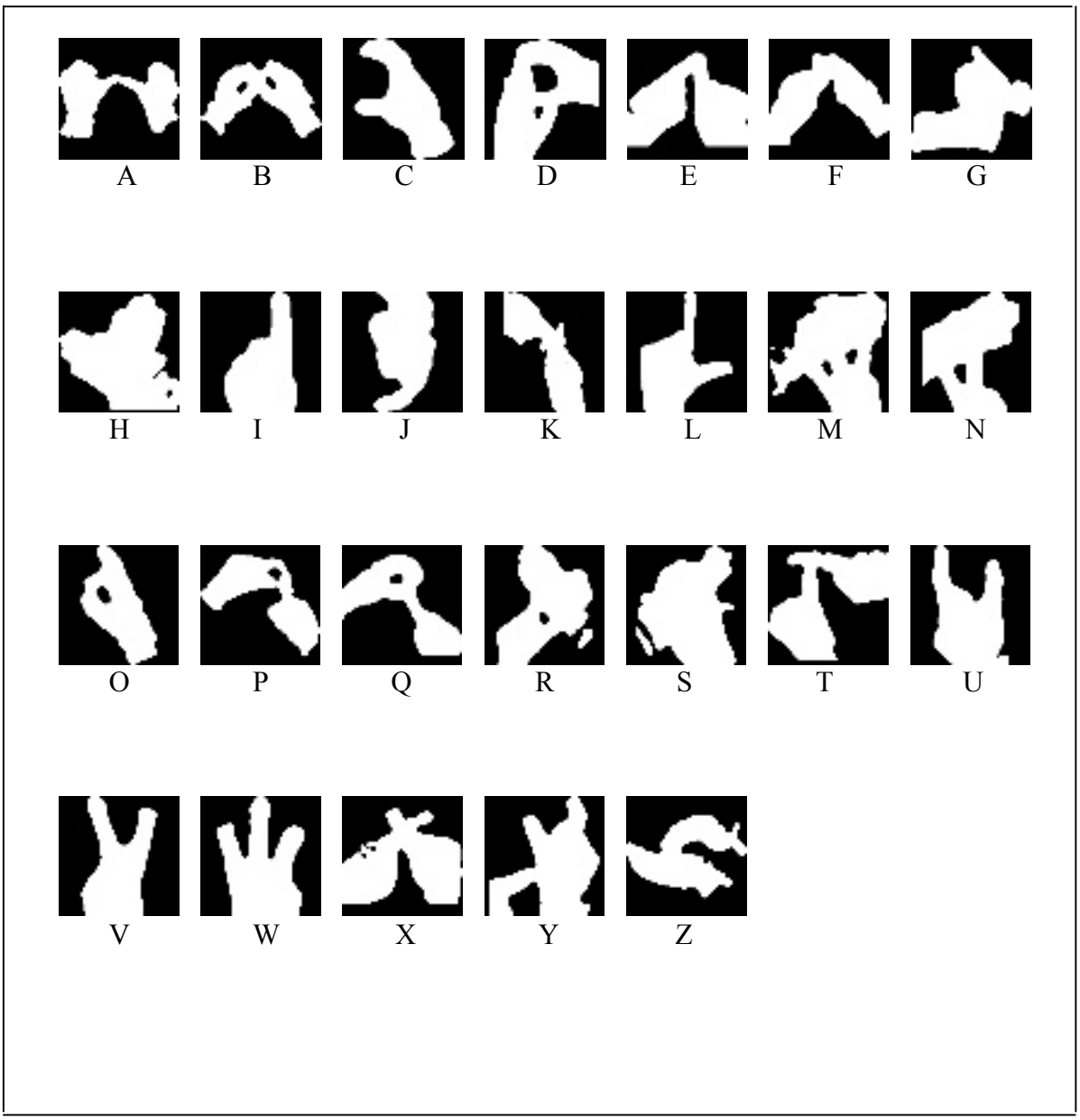

Fig 5.2: Dataset of generated Alphabets (A-Z)

5.2.2 Performance Parameters

- App Load Period: Application should be able to handle multiple requests without affecting the performance of app.
- API Latency: The app should have low latency time for being successful. The ideal duration of latency is 1 sec.
- App Crashes: Crash rate is number of crashes per app load and this should be low for better performance of application.

- Retention Rate: It determines how engaging, interesting and useful your app is to audience and it should be high.
- Application Availability: Monitoring and measuring if the application is online and available is a key metric to be tracked.

5.3 Working of the Project

5.3.1 Procedural Workflow

Procedural workflow uses control-flow methods which are found in procedural languages. These workflows use constructs like if and while, and can be composed using flow control activities like Flowchart and Sequence.

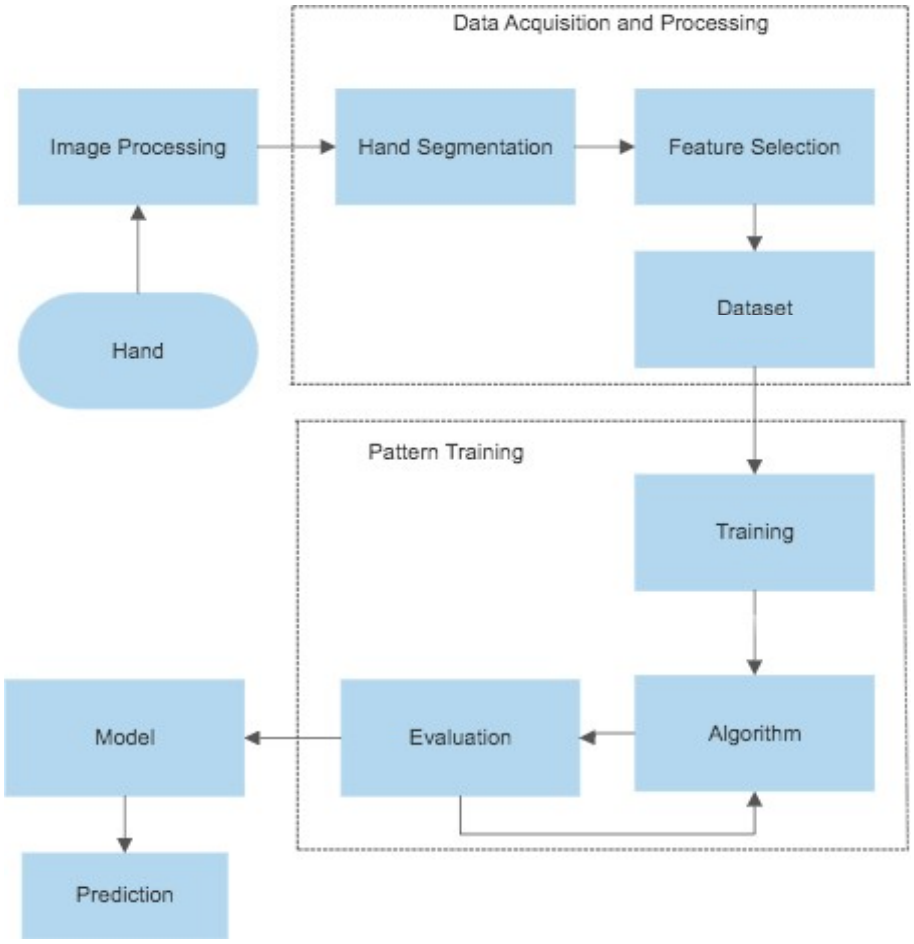

Fig 5.3: Workflow of Gesture Recognition

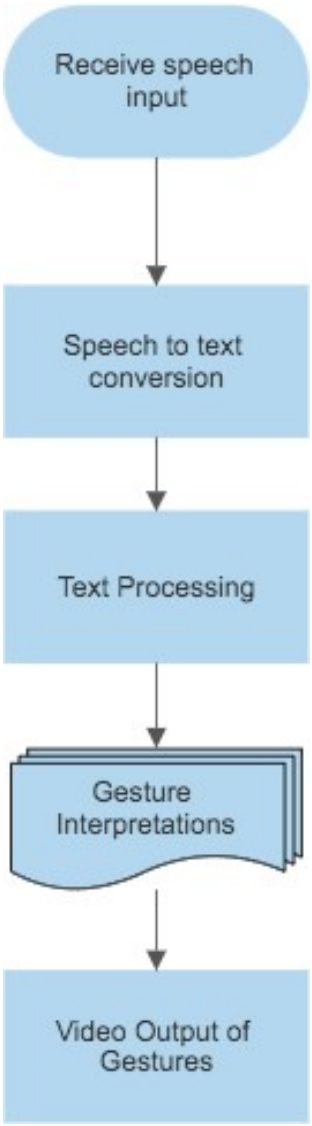

Fig 5.4: Workflow of Speech to Sign Language

5.3.2 Algorithmic Approaches Used

Hand segmentation is one of the approaches followed to build our model. Color is very powerful descriptor for object detection. So color information was used for the segmentation purpose. Color information is invariant to rotation and geometric variation of the hand. The system first learns the color histogram and after learning the histogram, the model converts it into a grey image with black and white pixels.

Other algorithm used in our model is CNN (Convolutional Neural Network). Convolutional neural network is a class of deep learning networks, most commonly applied to analyzing visual imagery. They are also known as shift invariant or space invariant artificial neural networks, based on their shared-weights architecture and Translational invariance characteristics. They have applications in image and video recognition, recommender systems, image classification, medical image analysis, and natural language processing.

Spatial features for individual frames are extracted using inception model (CNN). Frames are captured from the live video. Each video (a sequence of frames) is then represented by a sequence of predictions made by CNN for each of the individual frames. The keras model builds a CNN model to recognize the gesture. The frames extracted from the live video are tested on the model and the corresponding hand gesture is recognized.

5.3.3 Project Deployment

Project deployment includes all the processes that are involved in getting new software or hardware up and running properly in its environment, including the installation, configuration, running, testing, and making necessary changes in the project.

For the real time use of our project, a web app was deployed. The web app consists of all the modules that are a part of our model. The user can use the web app to convert sign to text and vice versa.

5.3.4 System Screenshots

Our system consists of a web application consisting of two main modules. They are:

- Sign language to text conversion: The input hand gestures are converted into corresponding alphabets and numbers.
- Speech to sign language conversion: This module first converts speech to text and outputs a video comprising of sign language symbols.

Following are some of the screenshots of our web application EZCOMM and its various modules.

Fig 5.5: Home Page of EZCOMM

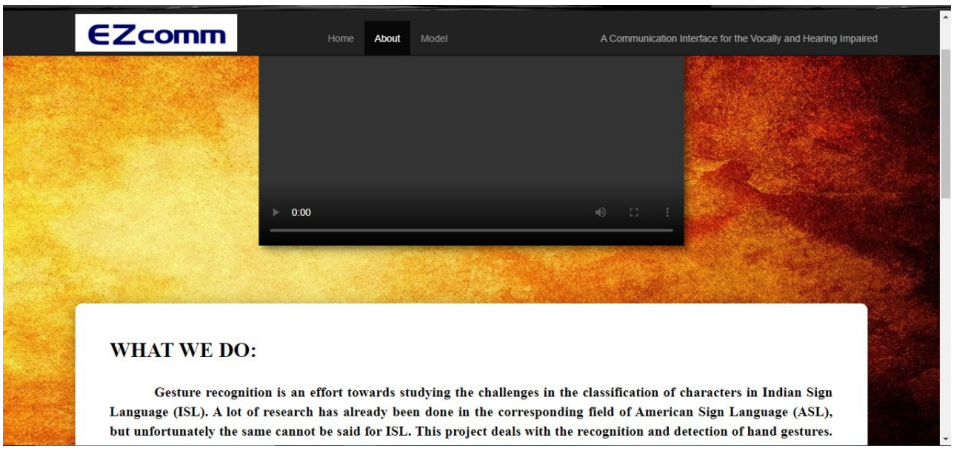

Fig 5.6: About EZCOMM

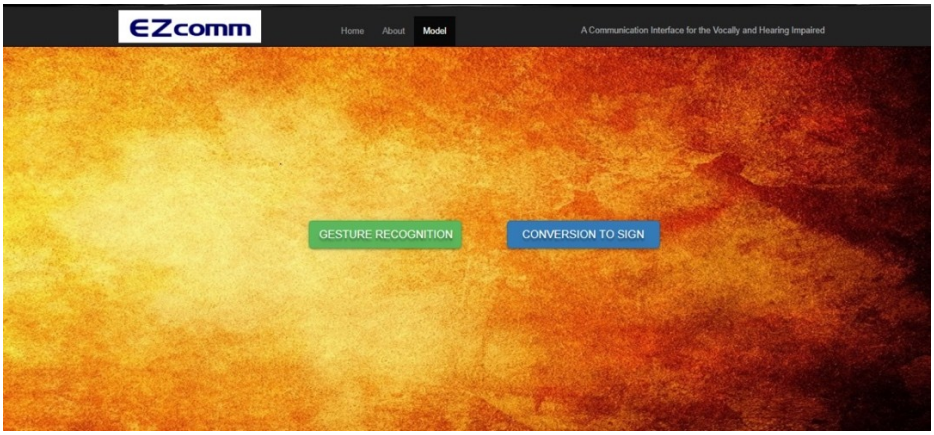

Fig 5.7: Modules of EZCOMM

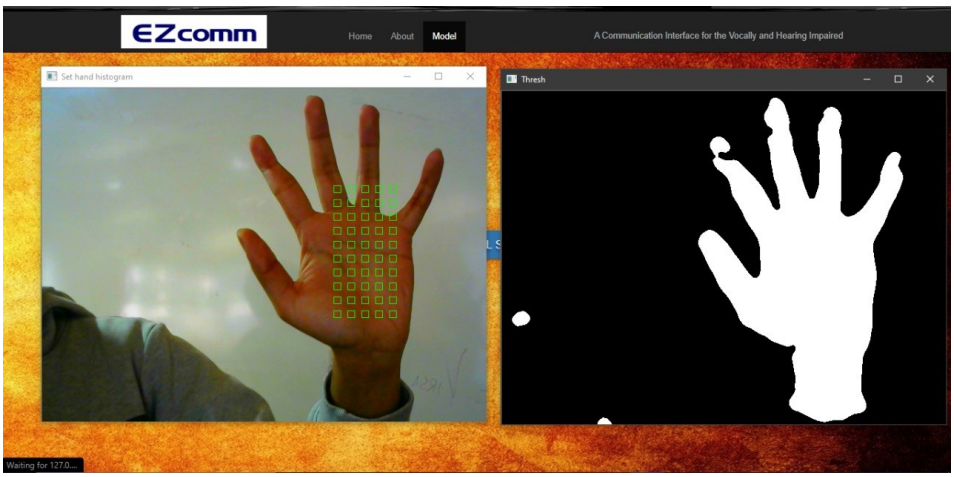

Fig 5.8: Hand Segmentation in EZCOMM

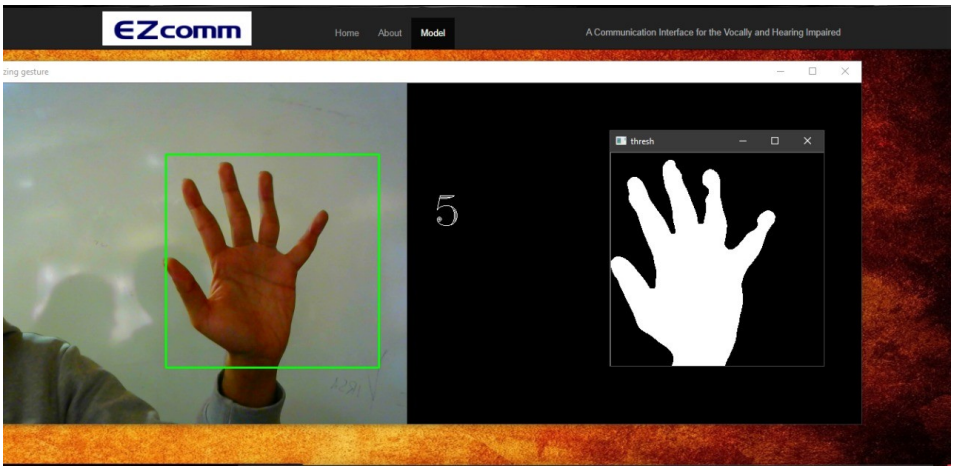

Fig 5.9: Numeral Detection

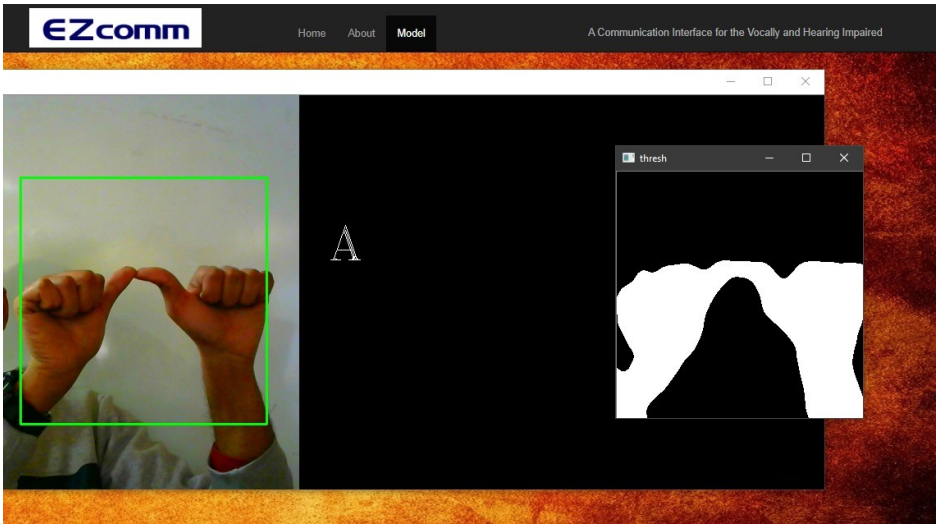

Fig 5.10: Alphabet Detection

5.4 Testing Process

5.4.1 Test Plan

5.4.1.1 Features to be Tested

The following features will be tested thoroughly using the below test strategy to ensure an efficient system.

- To validate that after setting of the hand histogram, the hand detection is done properly by the system.
- To validate that for a gesture represented in an image, the correct symbol/alphabet is detected by the model.
- To check if the system can correctly recognize what a person says and convert it accurately to text.
- To validate that the web application works efficiently without any breaks or problems.

5.4.1.2 Test Strategy

1. Unit Testing: The main objective of unit testing is to verify whether every single unit operates as intended. All the modules of placing the 3D models over the marker image are verified along with displaying of notices and promotional videos over the target image are checked separately and bugs corresponding to each module are fixed.

2. System Testing: System testing is generally conducted after Unit Testing. The objective of System Testing is to evaluate compliance of an integrated application with its requirements. All the modules are combined to form a single application and the bugs corresponding to integration of system are fixed.

Types of System Testing

- Performance Testing: Performing testing is conducted to detect issues related to memory consumption, power utilization, network connectivity, switching between applications.
- Interrupt Testing: The work of the application may be interrupted by various reasons, e.g., an upcoming call, message, other apps notifications, mail, low memory warning etc. The application should be suspended and afterward launched from the place it was stopped without losing data.

- Usability Testing: Usability testing is applied to check whether the application is easy to use and understand from the user's point of view.
- Installation and Launch testing: During installation testing, an engineer checks whether there are any issues during the installation, uninstallation, and updating of the application. Once the application has been installed, an engineer checks launching process. The application must be loaded quickly and correctly. Closing the application should not require much time as well.

5.4.1.3 Test Techniques

Software testing Techniques allow us to design better cases. Testing Techniques help reduce the number of test cases to be executed while increasing test coverage. They help identify test conditions that are otherwise difficult to recognize. There are five primarily used techniques.

- Boundary value analysis is testing at the boundaries between partitions.
- Equivalent Class Partitioning allows you to divide set of test condition into a partition which should be considered the same.
- Decision Table software testing technique is used for functions which respond to a combination of inputs or events.
- In State Transition technique changes in input conditions change the state of the Application Under Test.
- Error guessing is a software testing technique which is based on guessing the error which can prevail in the code.

Equivalence Class Partition testing method can be used as it divides the input domain of a program into classes of data from which test cases are designed. So, the input domain for the application is 3D models, images and videos.

5.4.2 Test Cases

- The response time of app should be fast.
- On clicking the set histogram button, a window should pop up and the web camera should turn on.
- On clicking the sign to text button, the web camera should start recording image frames.

- The hand gesture should be recognized correctly.
- Correct gestures should be displayed while performing text to sign conversion.
- On clicking the speech to sign button, the microphone should become active so as to record what a person says.

5.4.3 Test Results

- The response time of app is fast.
- On clicking the set histogram button, a window pops up and the web camera turns on to set the histogram of hand.
- On clicking the sign to text button, the web camera starts recording image frames and converts hand gestures to text.
- Most of the hand gestures are recognized correctly. Varying light conditions and background affect the results. Also some of the symbols have similar gestures, so the model finds it difficult to distinguish them properly.
- While performing text to sign conversion, correct gestures corresponding to the text are displayed.
- On clicking the speech to sign button, the microphone becomes active and records whatever a person says.

5.5 Results and Discussions

The system was tested corresponding to all the above test cases and the following results were observed.

The web app integrates two modules, both of which are working properly.

- Most of the hand gestures were recognized correctly. Varying light conditions and background affects the results. Also some of the symbols have similar gestures, so the model finds it difficult to distinguish them properly.
- If a person speaks something, it will be converted to the corresponding sign language for the hearing impaired.

Below are attached some working examples of different gestures:

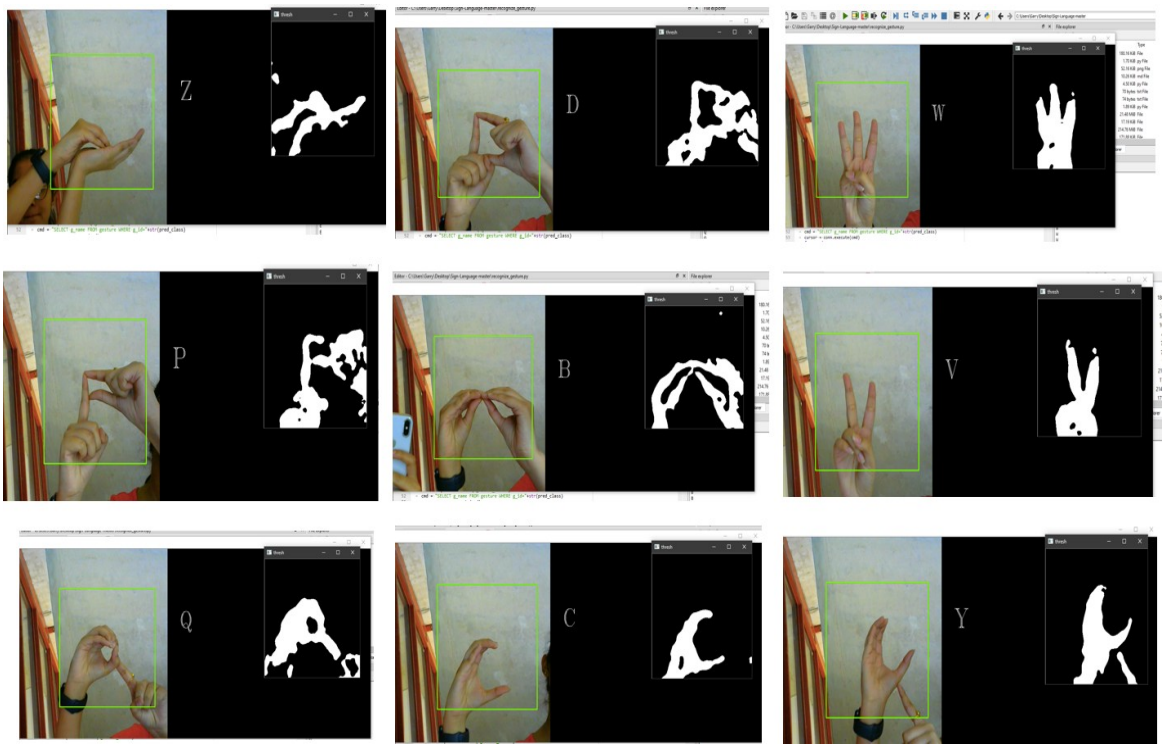

Fig 5.11: Recognition of Gestures in real time

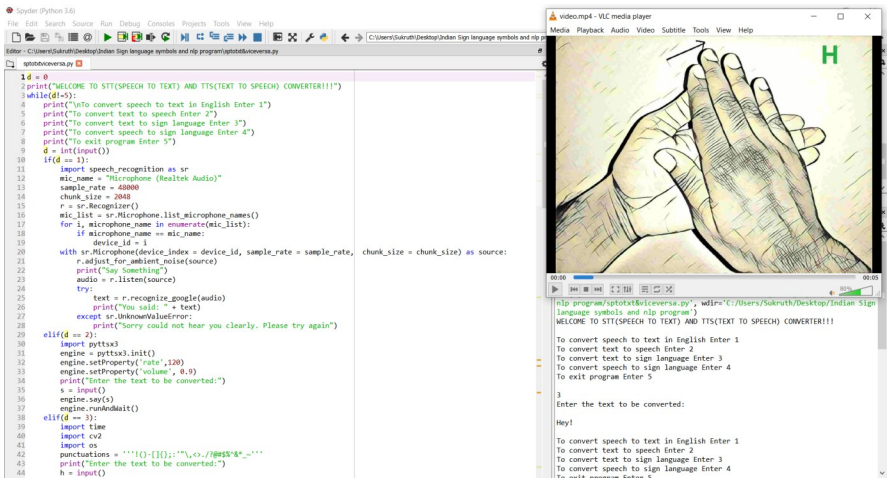

Fig 5.12(a): Text to sign language conversion

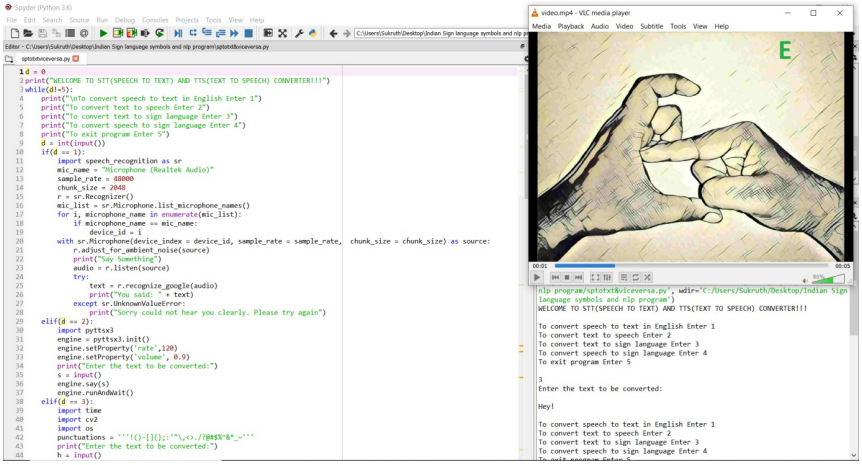

Fig 5.12(b): Text to sign language conversion

5.6 Inferences Drawn

From the test results the following inferences can be drawn:

- Varying lighting conditions and background have great influence on our results and system accuracy.
- Some of the gestures being similar are difficult to recognize.
- Background noise affects speech recognition.

5.7 Validation of Objectives

Our main objective was to create a web application that can convert hand gesture to text and speech/text to the corresponding hand gesture. In the course of this project, all the objectives were achieved.

Table 5: Validation of Objectives

S No.	Objective	Status
1	Implementing the conversion of hand gestures to text using deep learning algorithms.	Successful
2	Design a model to convert speech/text input into Indian Sign Language gestures using NLP.	Successful
3	To develop a web application software for automatic translation of Indian sign language into text and vice-versa to assist communication between speech and/or hearing impaired people with normal people.	Successful
4	Analyzing and verifying the test results.	Successful

CONCLUSIONS AND FUTURE DIRECTIONS

6.1 Conclusion

Hand gestures are a powerful way of human communication, with lots of potential applications in the area of human computer interaction. Vision based hand gesture recognition techniques have many advantages over traditional devices. However, hand gesture recognition is a difficult problem and the current work is only a small contribution towards achieving the results needed in the field of sign language gesture recognition. We wish to extend our work further in recognizing continuous sign language gestures with better accuracy. This method for individual gestures can also be extended for sentence level sign language.

6.2 Environmental, Economic and Societal Benefits

The economic benefits of 'Easy Communication Interface for the Vocally and Hearing Impaired: EZCOMM' can be assessed from the acceptance of the user. The system works for the betterment of communication between the vocally and haired impaired and the people around them. As we know that around nine million people around the world are deaf and dumb therefore our web application can be seen as a benefit to the society because it would help people communicate easily and would also encourage them to share their thoughts freely. For a person who does not have knowledge about the sign language and wants to communicate with a hearing impaired person, our system will communicate whatever the person speaks by converting speech into sign language so that the hearing impaired can understand.

6.3 Reflections

After the complete analysis and validation of the proposed system, some of the following reflections can be stated:

- The ideated concept of 'Easy Communication Interface for the Vocally and Hearing Impaired: EZCOMM' was successfully transformed into a working project.
- The developed web application is working as a reliable product.

- Working on this project helped us in implementing our previously gained knowledge about machine learning and other subjects.
- Building a prototype for the capstone idea widened our horizon of knowledge. We came across various glitches while working on the prototype of our app and we worked on them to improve our project.
- Working on this project promoted team building skills and taught us how to work in a group. It helped us to learn how to cooperate among the team members.

6.4 Future Work

The Hand Gesture recognition is moving at a tremendous speed for the futuristic products and services and major companies are developing technology based on the hand gesture system which includes companies like Microsoft, Samsung, Sony and it includes various devices like Laptop, Hand held devices, etc. The verticals where the Gesture technology is and will be evident are Entertainment, Education, Artificial Intelligence, and Medical and Automation fields. And with a lot of Research and Development going on in this field, the use and adoption will become much more cost effective and cheaper. Smart phones have been experiencing an enormous amount of Gesture Recognition Technology with look and views and working to manage the Smartphone in reading, viewing and that includes what we call touch less gestures. The technology has also been embedded into smart televisions nowadays, which can be easily controlled and managed by Voice and Hand options. In the medical fields Hand Gesture may be experienced in terms of Robotic Nurse and medical assistance. As the Technology is always changing and revolving the future is quiet unpredictable but it is certain that Gesture Recognition is here to stay with more eventful and Life touching experiences.

7.1 Challenges Faced

There were many challenges faced in this project. Initially it was very difficult to find the complete dataset of Indian Sign Language. Due to this, we decided to make the dataset on our own. As our project involves recognizing the gestures in the image, it was deeply affected by the lighting and background conditions. The dataset created involves images with different light effects so as to improve the accuracy. But still the challenge faced was how to get great accuracy because of the varying light conditions at different places. Another challenge faced was during the integration of various modules to build the web application. At first it seemed as if we would not be able to do it, but after great effort and hard work we were able to successfully build the application. Some symbols have almost similar gestures so it is really difficult to distinguish them through hand gestures. Another challenge faced was to detect the dynamic motion of hands which we were not able to implement.

7.2 Relevant Subjects

Table 6: Subject Code and Subject Name

Subject code	Subject Name	Description
UML501	Machine Learning	Introduction to machine learning gave us an insight to python programming. More over machine learning taught us how to train the models and implement such real life techniques in form of machine learning programs. The project makes use of CNN algorithm which is developed based on basic understanding of machine learning concepts.
UCS742	Deep Learning	This subject made us learn how to make decisions with the given data which is both unstructured and unlabeled. It is basically AI that mimics human brain. Deep learning in our project played a major role to determine the correct

		gesture. Convolutional Neural Networks are being widely used in the project for Hand gesture recognition.
UCS615	Image Processing	The project uses a lot of concepts from image processing course. The images of different gestures are processed which help us in recognizing the correct gesture. Our keras based model utilizes concepts like Image sampling, quantization, object recognition for manipulating our images.
UML602	Natural Language Processing	Our project involved tasks such as conversion of speech to text and vice versa. All of this uses NLP.
UCS303	Operating System	It is necessary for us to be familiar with Linux commands as well as the Linux architecture to easily be able to run python code and keras library. The linux commands and the Linux architecture.
UCS406	Data Structures and Algorithms	Our project's efficiency lies in the use of suitable data structures as well as optimal algorithms which are universally used in Image processing applications. Knowledge of Data structures helps us tackle any inefficiency in the system.
UCS503	Software Engineering	Software engineering involves the systematic application of engineering approaches to the development of software. The testing of our project as well as the software requirements specifications involved the knowledge of software engineering.

7.3 Interdisciplinary Knowledge Sharing

Every project being developed needs multiple fields of knowledge to be incorporated into a single device which leads to interdisciplinary sharing. This project covers different parameters. It combines the concepts of Image Processing along with those of Machine

Learning and Deep Learning to create a model recognizing hand gestures. Developing an interface with the aim to fill the communication gap between vocally and/or hearing impaired and the normal people made us deeply study and understand the most important algorithms and neural networks which form the base of Machine Learning and many applications now-a-days.

7.4 Peer Assessment Matrix

Table 7: Peer Assessment Matrix

Evaluation by: → **Evaluation of:** ↓	Arshit Goel	Arushi Aggarwal	Asees	Sukruth G
Arshit Goel	4	4	4.5	4
Arushi Aggarwal	4	4	4	4.5
Asees	4.5	4	4	4
Sukruth G	4	4.5	4	4

7.5 Role Playing and Work Structure

The following figures depict the work done in present semester amongst the group members. Initially each group member did thorough study on the Deep learning based hand gesture recognition and existing projects. The entire area to be covered under this app was first segmented and database collection was divided amongst the members. The tentative distribution of work is done according to the Design Description given below:

Arshit Goel: Requirement gathering, Built the module for the conversion of Sign Language (gestures) to text using deep learning techniques like CNN and Image Processing to reduce noise.

Arushi Aggarwal: Requirement gathering, Built the module for the conversion of speech/text into corresponding gestures using Natural Language Processing, Dataset generation and project documentation.

Asees: Built the module for the conversion of speech/text into corresponding gestures using Natural Language Processing, Data Acquisition using ML to reduce features and noise using color histogram and hand segmentation, and project documentation.

Sukruth G: Requirement gathering, Data Analysis and Mining, Web Application Development to launch the system.

Table 8: Gantt Chart of Arshit Goel

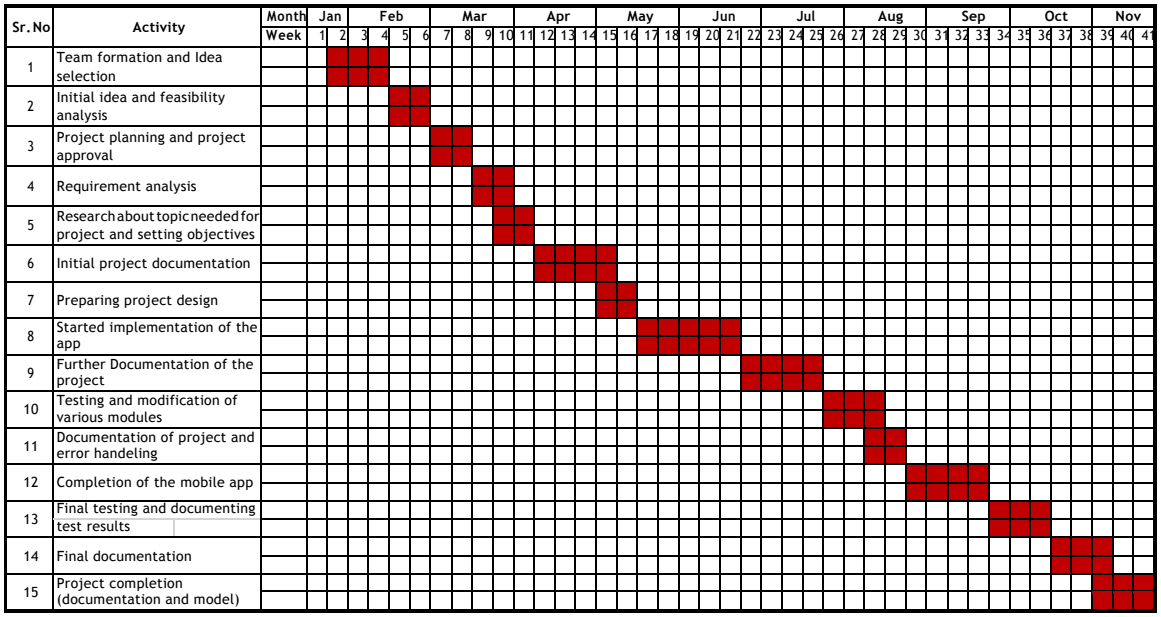

Table 9: Gantt Chart of Arushi Aggarwal

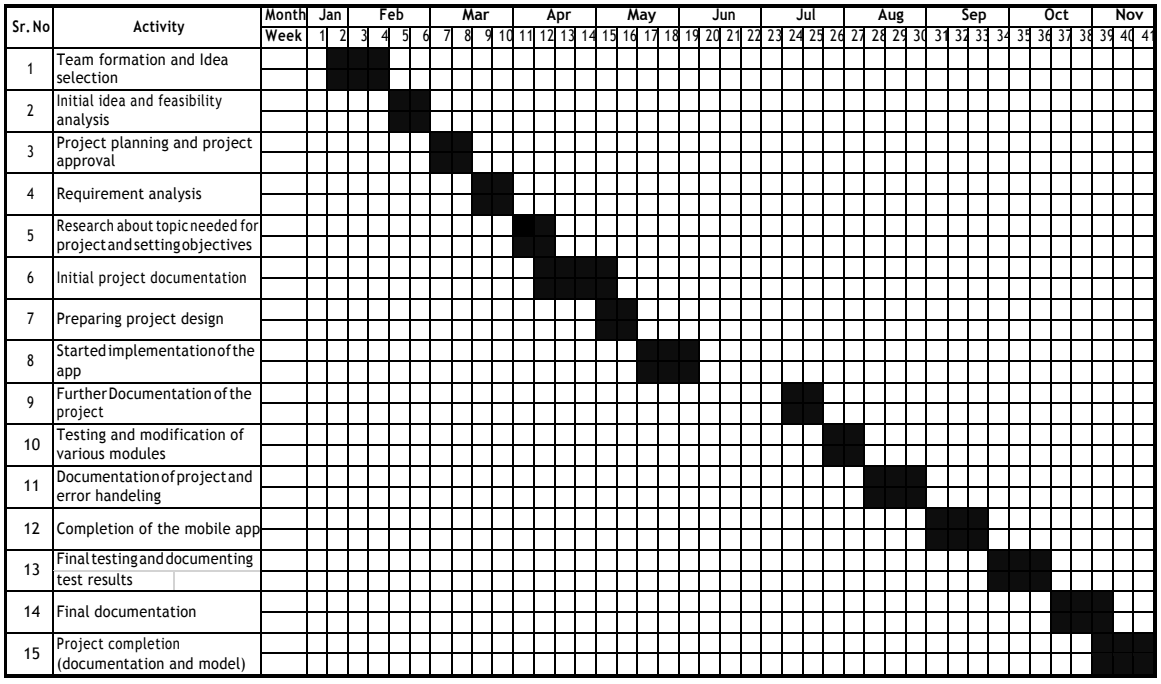

Table 10: Gantt Chart of Asees

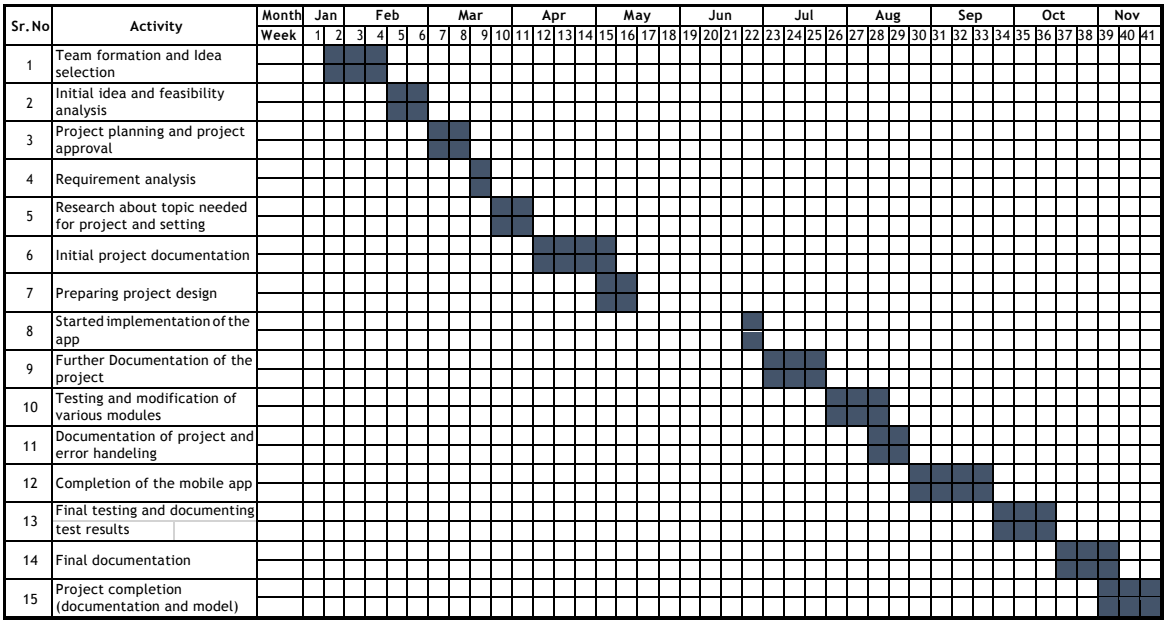

Table 11: Gantt Chart of Sukruth G

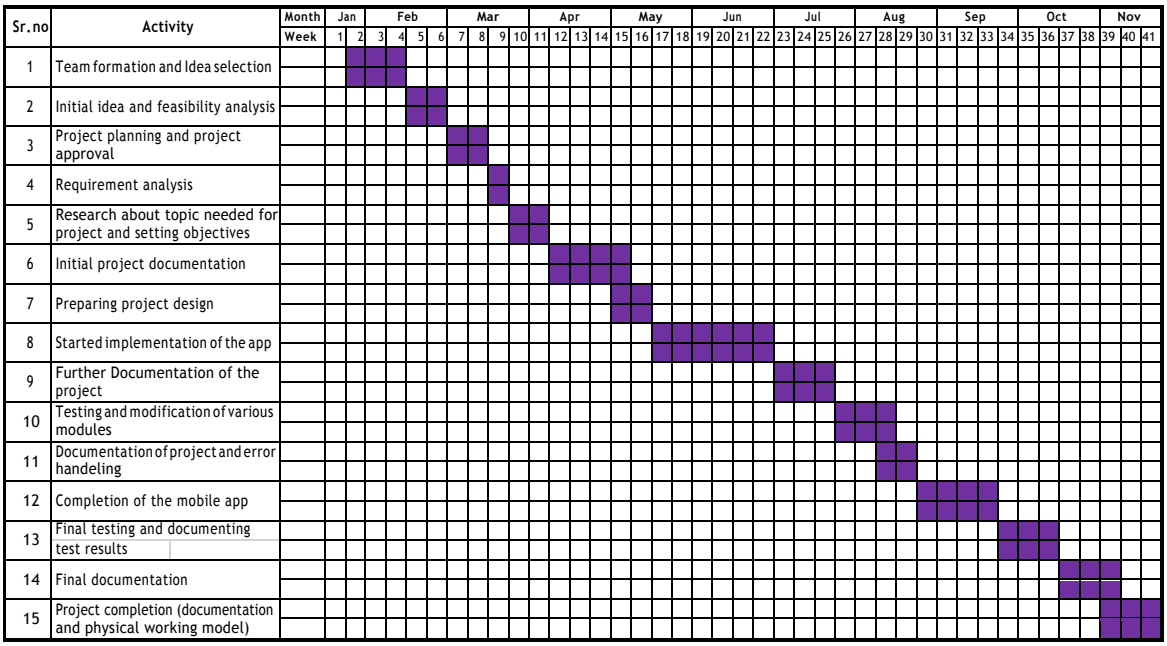

Table 12: Work plan of the Project

S.no	ACTIVITY	JAN	FEB	MAR	APR	MAY	AUG	SEP	OCT	NOV	DEC
1.	Team Formation and identification of problem										
2.	Feasibility analysis and project approval										
3.	Requirement analysis and project documentation										
4.	Study of various software's required										
5.	Implementation of basic app										
6.	Implementation of our objectives										
7.	Testing and modification										
8.	Finalizing of the modules										
9.	Final project documentation										
10.	Final Presentation and evaluation of project										

7.6 Student Outcomes Description and Performance Indicators (A-K Mapping)

Table 13: Performance Indicators

SO	Description	Outcome
B1	Identify the constraints, assumptions and models for the problems.	Yes A lot of research was done by each team member to overcome constraints like orientation of hand, image noise, dynamic motion of hands etc. and huge efforts were put to limit them by applying different models and techniques.
B2	Use appropriate methods, tools and techniques for data collection.	Yes We were not able to find the dataset of ISL to suit our model. So we generated 2000 images of each symbol (A-Z and 0-9) using webcam on our own.

B3	Analyse and interpret results with respect to assumptions, constraints and theory.	Analyzed the web application considering the various constraints like lighting conditions and also the test results related to the assumptions made.
C1	Design software system to address desired needs in different problem domains.	Yes We developed a web application to implement our model.
C2	Can understand scope and constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	Yes Our app aims at reducing the communication gap between the vocally impaired and other people. It would be really helpful for the deaf and dumb.
D1	Fulfil assigned responsibility in multidisciplinary teams.	Yes All the team members were responsible enough to complete the task allotted to them within the required time and take initiative to explore more about the project.
D2	Can play different roles as a team player.	Yes Effort by each team member helped us to successfully complete our capstone. As a team we had to learn a lot of new things like web development, generating our own dataset, how to do effective documentation.
E2	Develop appropriate models to formulate solutions.	Yes We did try a lot of techniques to reach the best effective solution for our project. We used color histogram for detection of hand

		gestures from the video frames and CNN to train our model.
E3	Use analytical and computational methods to obtain solutions.	Yes Analyzed the various features that could be to our model as well our web application.
F1	Showcase professional responsibility while interacting with peers and professional communities.	Yes During the entire course of capstone, we had regular assessments which included giving presentations in front of a panel. In addition, we had meetings with our mentor to discuss our progress. Everyone was very responsible to take it seriously and came to the interactions.
F2	Able to evaluate the ethical dimensions of a problem.	All the ethical aspects of the technology were brought under consideration during the course of project.
G1	Produce a variety of documents such as laboratory or project reports using appropriate formats.	Yes Our project is based on algorithms which have been in existence for many years. This makes it a system that can be further utilized in more complex applications. Moreover, the technologies used are well documented and proven.
G2	Deliver well-organized and effective oral presentation.	Yes During evaluations, we had to give presentations to a panel of teachers discussing the objectives fulfilled and the progress. It helped develop our

		communication skills as each team member was asked questions by the panel.
H1	Aware of environmental and societal impact of engineering solutions.	Yes The objective of our project is to build a communication interface for the vocally and/or hearing impaired. This would help in reducing the communication gap between the deaf and dumb and the normal people.
H2	Examine economic trade-offs in computing systems.	Yes The system while efficient in achieving its objective of hand gesture recognition, requires expense based on basic hardware installation like a laptop.
I1	Able to explore and utilize resources to enhance self-learning.	Yes Various libraries like tensorflow, keras, opencv were used in this project which were not taught as a part of the course.
I2	Recognize the importance of life-long learning.	Team work, accomplishing work in limited time, presentation skills, technical skills, dealing with various errors with patience will help us in future.
J1	Comprehend the importance of contemporary issues.	Yes As we know about nine million people in this world are deaf and dumb. Our project involves solving the issue of communication between such people.
K1	Write code in different programming languages.	Yes Our project uses python for creating the model for hand

		gesture recognition and speech to sign conversion. The web application development required coding in HTML.
K2	Apply different data structures and algorithmic techniques.	Yes To train our model CNN algorithm was used. CNN is a specific type of artificial neural network that uses perceptron which is a ML unit algorithm, for supervised learning and to analyze data.
K3	Use software tools necessary for computer engineering domain	Yes Various software tools including spyder and notepad were used for designing the model and the web application in our project. The basic learning regarding various software tools required for computer engineering domain was also gained.

7.7 Brief Analytical Assessment

Q1. What sources of information did your team explore to arrive at the list of possible Project Problems?

Ans: To arrive at the list of possible project problems, the team members looked for various ongoing projects online. We searched for various projects in different fields on which less research had been done. Various videos were seen to learn about the working and implementation of various projects which could be chosen as our capstone project. Different kinds of reports and research papers were also explored to finally reach to a set of possible topics as our capstone projects.

Q2. What analytical, computational and/or experimental methods did your project team use to obtain solutions to the problems in the project?

Ans: We analyzed the feasibility of the features that could be added to the project and

decided the objectives that could be achieved. We implemented the project in our hostel and also in the library. We brainstormed every test case possible for testing our app. The team deeply thought about the various use cases for the project.

Q3. Did the project demand demonstration of knowledge of fundamentals, scientific and/or engineering principles? If yes, how did you apply?

Ans: Yes, software engineering principles of designing the app, collecting the data and preparing the design document were helpful in completion of the project. Engineering principles like maintainability, ethics, integrity and testability were taken care off during the course of project.

Q4. How did your team share responsibility and communicate the information of schedule with others in team to coordinate design and manufacturing dependencies?

Ans: All the team members were co-operative and gave everyone a chance to present their own ideas. After the approval of our project we broke down the project in various parts and decided how to move further with it. Every team member was allotted a task to do and we had weekly meetings to discuss about the progress of each member in the task allotted to them. We also formed a WhatsApp group of our team members and all the doubts and queries regarding the project were addressed there and also the information regarding the work schedule was shared in the group.

Q5. What resources did you use to learn new materials not taught in class for the course of the project?

Ans: A lot of research went into learning about various topics that had to be used to complete our model. Each team member watched videos to gain knowledge about topics like OpenCV, implementing gesture recognition using tensorflow and keras libraries, web app development using HTML, CSS, Flask etc. This proved to be a major challenge as they were not a part of our curriculum.

Q6. Does the project make you appreciate the need to solve problems in real life using engineering and could the project development make you proficient with software development tools and environments?

Ans: Yes, the project surely makes us appreciate the need to solve problems in real life using engineering. It feels great that using our knowledge and with the help of extra information from the internet made us capable enough to design a system for the deaf and

dumb people to communicate easily with other people. It motivates us to further solve various problems that people are facing.

To a great extent we were able to learn and gain knowledge about software development tools and environment. There is always more to learn, so we hope to become more proficient with all that we have learned till now.

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