Project Phase 2 Report On

Speech To Sign Language Conversion Using NLP

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology

in

Computer Science and Engineering

By

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CERTIFICATE

This is to certify the project report entitled ***Speech To Sign Language Conversion Using NLP*** *is a bonafide record of the work done by* ***Ayaz M Ziyad(U2003053)****, submitted to the Rajagiri School of Engineering & Technology (RSET) (Autonomous) in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology (B. Tech.) in Computer Science and Engineering during the academic year 2023-2024.*

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Abstract

In a world increasingly defined by the power of communication, the ability to convey thoughts, emotions, and ideas lies at the core of our shared human experience. Yet, for the deaf and hard of hearing population in India, this fundamental aspect of life is often fraught with challenges. Communication barriers, born out of a lack OT familiarity with Indian Sign Language (1SL) among the hearing population, can isolate individuals with hearing impairments,limiting their access to information education and social interaction This project embarks on a transformative journey to address these challenges and pave the way for a more inclusive and accessible society. The aim is to develop a Multilingual Speech to Indian Sign Language Generator, a system designed to bridge the communication gap between the hearing and the hearing-impaired. This endeavor seeks to facilitate real-time translation of spoken language into ISL gestures. Our goal is to break down linguistic speech by providing a versatile and incusive system capable of translating spoken language into expressive and culturally relevant sign language in real-time. The methodology for developing the Multilingual Speech to Sign Language Generator (MS2SLG) involves collecting diverse multilingual datasets, utilizing advanced Natural Language Processing (NLP) models for spoken language translation, integrating computer vision for sign language recognition and generation, ensuring cultural sensitivity and customization, creating user-friendly interfaces for real-time interaction. The Multilingual Speech to Sign Language Generator (MS2SLG) serves as an invaluable learning tool, particularly in educational settings catering to Deaf and Hard of Hearing (DHH) students or those learning sign language as a second language. The integration of MS2SLG into news programs represents a groundbreaking step toward making information more accessible to the Deaf and Hard of Hearing (DHH) community during televised or online news broadcasts.

Contents

List of Abbreviations

NLP - Natural Language Processing

STT - Speech-to-TexT

API - Application Programming Interface

ISL - Indian Sign Language

CNN - Convolutional neural networks

DNN - Deep Neural Networks

SVM - support vector machine

LSTM - Long short-term memory

GRU - Gated recurrent unit

SLT - sign language translation

MT - Machine translation

XML - Extensible Markup Language

NMT - Neural machine translation

HDMI - High-Definition Multimedia Interface

HMM - Hidden Markov model

List of Figures

Chapter 1

Introduction

1.1 Preamble

Each nation employs a distinct sign language rooted in its native tongue, presenting a linguistic challenge. Engaging in conversation becomes daunting, particularly with those who are hearing-impaired. Even those possessing adequate hearing often sidestep communication with the deaf. Mastering the ability to communicate with the hearing-impaired not only fosters connection but also facilitates the exchange of ideas. This inclusive dialogue could inspire contributions from the hearing-impaired community, enhancing technological advancements.This is why our group has decided to design a versatile multilingual speech-to-sign language converter to bridge communication gaps between people with hearing impairments and those unfamiliar with sign language.

1.2 Problem Definition

The problem is that those who have difficulty hearing have few options when it comes to communicating. The complexity and regional variances of sign language make it difficult to learn, while hearing aids are expensive and require upkeep.This results in a society with many barriers for certain individuals.

1.3 Objectives

Multilingual Support: Create a system that can understand and generate sign language for multiple spoken languages.

Real-time Conversion: Develop a system capable of converting spoken language into sign language in real-time.

Accuracy and Precision: Ensure high accuracy and precision in sign language generation to convey the nuances of spoken language effectively.

User-Friendly Interface: Design an intuitive and user-friendly interface that allows both hearing-impaired and hearing individuals to use the system easily.

1.4 Purpose and Need

The purpose of the project is creating system that will reduce the gap between the deaf people and the normal people. Ensuring that the communication can be done is seamless manner. The system also support multilingual so that what ever language is given as the output it will convert to sign language.

1.5 Scope

• Speech Recognition Integration: Develop a robust system for accurately interpreting spoken language across multiple languages and dialects.

• Sign Language Generation: Implement an efficient module that converts recognized speech into clear, expressive sign language gestures.

• Multilingual Support: Ensure inclusivity and adaptability to diverse linguistic contexts.

• Real-time Conversion Capability: Achieve instantaneous translation of spoken words into sign language gestures.

• Accuracy and Precision: Ensure high accuracy and precision in the conversion process.

• User Interface Design: Design an intuitive, user-friendly interface accessible to both hearing-impaired and hearing individuals.

• Application in Education: Integrate the system into educational settings for effective learning aid for hearing-impaired students.

• Sector-Specific Applications: Consider real-time sign language conversion for news broadcasts, online videos, etc.

• Testing and Validation: Conduct rigorous testing to validate the accuracy and reliability of the system.

1.6 Industrial Relevance

• Enhances Accessibility Solutions: The project caters to the needs of the hearing-impaired community in sectors like customer service, entertainment, and communication platforms.

• Revolutionizes Communication Enhancement in Education: The project could revolutionize communication between educators and hearing-impaired students, aligning with the trend in educational technology and inclusive learning practices.

• Relevant for Media and Broadcasting: The real-time conversion capability of the system makes content more accessible to a broader audience.

• Applications in Healthcare and Assistive Technologies: The system aids in effective communication between healthcare professionals and hearing-impaired patients.

• Supports Corporate Communication and Training: Facilitates effective communication and training sessions, supporting workplace accessibility and inclusivity efforts.

• Ensures Legal Compliance: The project may help industries comply with regulations and standards for accessibility for individuals with disabilities.

• Contributes to Technological Innovation: The project contributes to advancements in natural language processing, machine learning, and human-computer interaction.

1.7 Organization of the Report

The report on Speech-to-Sign Language translation through Natural Language Processing begins with an Introduction, emphasizing inclusivity by bridging communication gaps for individuals with hearing impairments. The focus is on developing a rule-based machine translation system, showcasing the project's innovative initiative. The Literature Survey critically reviews existing papers, evaluating pros and cons to justify the chosen project paper.

The Existing System section delves into the current methods, spotlighting the Indian Sign Language translation system's statistical-based model. While effective, its vulnerability to overfitting in complex language structures is discussed, emphasizing the need for a more robust rule-based approach. The Proposed System outlines a hybrid model combining rule-based and statistical approaches for accurate sign language video generation.

The Design section details the system's architecture and interaction through a Sequence Diagram. The Modules section breaks down the project into four components, providing in-depth explanations. Assumptions and Challenges acknowledge underlying beliefs and obstacles, including accent variations and linguistic complexities, with strategies for mitigation.

Work Breakdown and Responsibilities showcase the division of tasks, while Hardware and Software Requirements discuss the necessary tools. Project Milestones and Schedule are visualized through a Gantt Chart, outlining the implementation timeline. Risks and challenges are explored in the final section, addressing potential hurdles in project execution. This comprehensive structure ensures a thorough understanding of the project's context, methodologies, and potential obstacles.

1.8 Conclusion

The initiative is driven by the vision of eliminating barriers to communication for individuals with hearing disabilities. By doing so, aspire to foster a society where successful communication is accessible to everyone, irrespective of their hearing abilities. The overarching goal is to create an inclusive environment where individuals with hearing disabilities can actively participate in conversations, share their thoughts, and engage with others on an equal footing.Envisioning a future where communication is not hindered by hearing limitations, the initiative seeks to bridge the existing gap. believing that by addressing communication challenges, contributing the creation of a more open and interconnected society. In this inclusive society, the diverse perspectives and contributions of individuals with hearing disabilities enrich the fabric of collective interaction. By removing communication obstacles, aim's to promote understanding, empathy, and equal opportunities for all. Through collaborative efforts, collectively work towards building a world where communication is a universal right, reinforcing the principles of inclusivity and shared connection.

1.9 Summary

The project emphasizes developing a system that may fill communication gaps for hearing-impaired people and may show real-time transcription of spoken language into sign language. This multilingual system is going to have the capability to work within diverse linguistic contexts. It targets the objectives of having a high degree of accuracy, real-time conversion, and an easy-to-use interface design. Its objective is to overcome the communication gap between the hearing-impaired and the normal hearing people, thus enabling interaction between them. The project's scope comprises integration of speech recognition, sign language generation, and its use in education, media, healthcare, and corporate areas. The industrial relevance of the project is in providing better accessibility solutions, revolutionizing education, aiding media broadcasting, supporting healthcare communication, and ensuring legal compliance. The project contributes to technological innovations and inclusive society, where the right to communicate will be considered a universal right. An outline of the report includes sections on the Introduction, Literature Survey, Existing and Proposed System, Design, Modules, Assumptions, Challenges, Work Breakdown, Hardware/Software Requirements, Milestones, and Risks. At the conclusion, the vision of a barrier-free world is discussed, making the people of all kinds of people inclusive, understanding, and inclusive, irrespective of hearing capabilities. By working together, the project would tend to build a world in which communication enriches collective interaction, reinforcing the basic principles of inclusivity and shared connection.

Chapter 2

Literature Survey

Machine translation from text to sign language plays a crucial role in breaking linguistic barriers and fostering inclusivity for the Deaf community. Sign languages, complete natural languages with distinct grammar and lexicons, utilize manual and non-manual features for expression. The translation process involves multiple modules: pre-processing, rule-based machine translation (RBMT), and sign synthesis. RBMT, relying on linguistic information, analyzes source language sentences morphologically, syntactically, and semantically to generate target language sentences. The subsequent step involves mapping the translated sentences into sign glosses, videos, or animated avatars.

In the realm of deep learning, a novel approach utilizes LSTM-based Seq2Seq architecture with attention mechanisms for text-to-sign language translation. This model outperforms previous methods, demonstrating impressive results in translating from text to sign language glosses. The integration of a state-of-the-art speech recognition system, coupled with natural language translation, ensures accuracy and reliability in converting spoken words to sign language. The last step is to use the 3D avatar to animate the signs, enhancing the Deaf community's ability to communicate.

2.0.1 Machine translation from text to sign language

Sign languages are full-fledged natural languages with their own grammar and lexicon. They are expressed through manual articulations in combination with non-manual components. There are two kinds of features to be considered in signs: manual features and non-manual features. Manual features include the movement of hands, fingers, and arms. Non-manual features hold a fundamental component in all sign languages. They include facial expressions, eye gaze, head, and upper body movement, and position. Non-manual signs, in combination with manual signs, give a complete representation of sign language. Sign languages, like spoken languages, organize elementary units called phonemes into meaningful units called semantic units. These units are represented through hand shape, orientation, location, movement, and non-manual expressions. Unlike spoken languages, sign languages take advantage of the spatial nature of the language through the use of classifiers. Classifiers help in spatially showing type, size, shape, and movement.

2.0.2 Machine translation

Machine translation is a computer science field that investigates the use of software to translate text/voice from one language to another. It can assist in breaking linguistic barriers and providing easy access to information. There are different types of machine translation: Neural Machine Translation (NMT), Corpus-Based machine translation (CBMT), Rule-Based Machine Translation (RBMT).

Process of text to sign language machine translation

The first module pre-processes the input text in which the text is morphologically and syntactically analyzed and broken into words with their types (noun, verb, particle, etc.) with a language model's help.

In the second module, the pre-processed words are converted into sign sequences. For this module, various machine translation strategies are used. The method discussed here is Rule-Based Machine Translation (RBMT).

The last module converts the sign sequences into sign glosses, videos, or animated avatars.

Pre-processing

The input is in the form of text. It needs to be tokenized and rearranged so that the meaning of the sentences remains the same when converted to another language. Before doing this, the sentences get tokenized and split into words, from which stop words like "is", "he", "she", "it" are removed. Using part-of-speech tagging, the more important words are tagged, and then some rules are applied to form the sequence of words. For this, some of the language models like TEAM and ZARDOZ are used.

Rule-based machine translation

Rule-based Machine Translation (RBMT) systems are based upon linguistic information about the source and target language. Rule-based systems take sentences of the source language as input and generate output sentences based on morphological, syntactic, and semantic analysis of both source and target languages. The RBMT system consists of a source language morphological analyzer, a source language parser and translator, a target language morphological generator, and a target language parser for composing the output sentences. The Vauquois Pyramid is used to describe the complexity and sophistication of rule-based approaches.

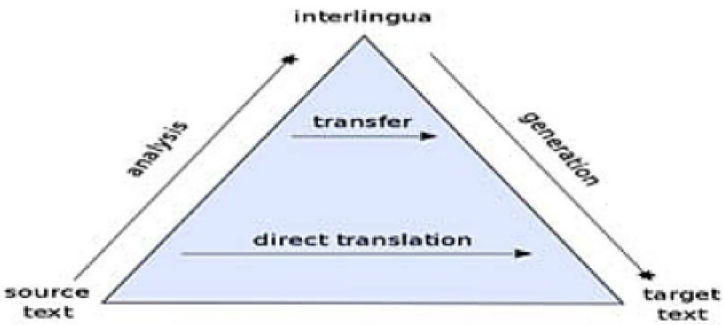


Figure 2.1: Vauquois Pyramid

Sign synthesis

The next step is to map the sentences according to the new formed sequence. For this the new formed sequence of words is split and shows the individual representation of the words one by one.

2.1 Standard Automatic Speech Recognition Model

• As seen in Figure 1, the typical automated speech recognition (ASR) system model entails employing a computer programme algorithm to translate a speech signal into a

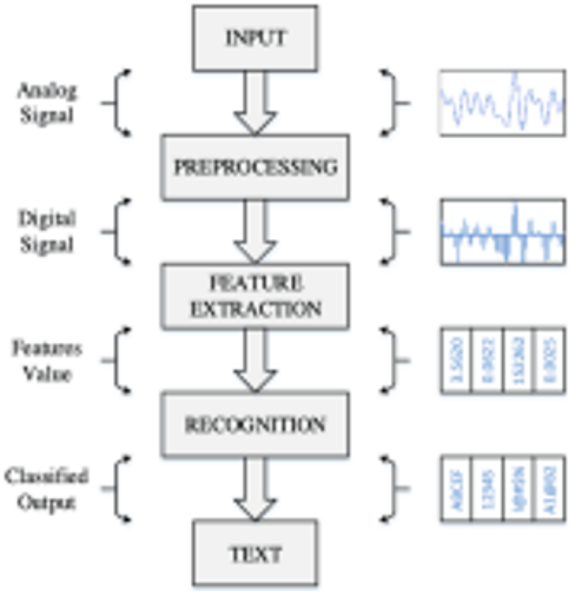


Figure 2.2: Standard Automatic Speech Recognition Model

string of words. Typically, the model consists of the following elements: 1. voice Input: The voice signal is fed into the system as input.

2. Pre-processing: To improve the quality and extract pertinent information, pre-processing techniques are applied to the speech signal.

3. Feature Extraction: In this stage, significant features that are needed for additional analysis are taken out of the pre-processed speech signal.

4. Pattern Recognition: Using spectral parameter-based speech pattern recognition, the system compares detected patterns to pre-existing ones.

5. Classification: To identify the related words or phrases, the patterns that have been identified are categorised.

6.Output: The system produces a sequence of words as the output, representing the recognized speech.

2.2 Sign Language Gloss Translation using Deep Learning Models

2.2.1 Data Preparation

Initiating the process involves curating a comprehensive dataset comprising pairs of input text and their corresponding sign language glosses. Ensuring meticulous alignment and annotation within the dataset lays the foundation for training a robust model capable

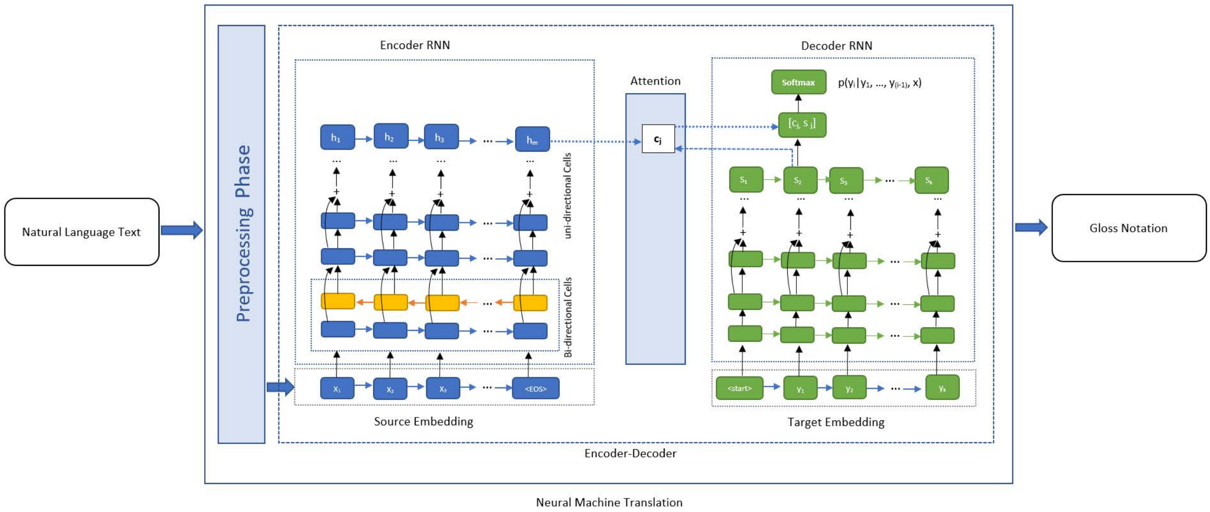


Figure 2.3: seq2seq Encoder Architecture

of accurate conversion.

2.2.2 Tokenization and Embedding

Following data preparation, the input text and sign language glosses undergo tokenization, breaking them into smaller units for sequential processing. Subsequently, these tokens are transformed into continuous vector representations through embedding. This step aims to facilitate the model's ability to comprehend and learn the contextual relationships between words in the sequences.

2.2.3 LSTM-based Seq2Seq Architecture

At the core of the model lies the Long Short-Term Memory (LSTM) based Seq2Seq architecture. The encoder, comprising LSTM layers, sequentially processes the input text, capturing the nuanced contextual information at each time step. An essential enhancement is the integration of an attention mechanism within the encoder. This mechanism empowers the model to selectively focus on specific segments of the input sequence, enabling a more nuanced understanding of complex linguistic structures. [?]

2.2.4 Decoder with Attention

Complementing the encoder, the decoder is also LSTM-based. It takes the encoded information from the final hidden state of the encoder and proceeds to generate the sign language gloss sequence. Crucially, an attention mechanism is embedded in the decoder as well. This dual application of attention mechanisms allows the model to dynamically allocate attention to different parts of the input sequence during the decoding process, contributing to more accurate and contextually aware sign language gloss generation.

2.2.5 Experimental Results

The results of the experiments reveal that the proposed model outperforms previous work on the same corpus. Specifically, the GRU model with Bahdanau attention achieves the best results for translating from text to gloss on the ASLG-PC12 corpus, with a ROUGE score of 94.37% and a BLEU-4 score of 83.98%. Similarly, when translating from gloss to text, the GRU model with Bahdanau attention achieves the best results with a ROUGE score of 87.31% and a BLEU-4 score of 66.59%. On the Phoenix-2014T corpus, the GRU model with Bahdanau and Luong attention achieves the best results for text to gloss and gloss to text translations.

	Rouge	**BLEU1**	**BLEU2**	**BLEU3**	**BLEU4**
GRU L	-	86.70	79.50	73.20	65.90
GRU B	87.31.	88.65	79.68	73.23	66.59

Table 2.1: Test scores of LSTM based seq2seq

2.3 Speech recognition system.

The speech recognizer used in this system is a state-of-the-art speech recognition system developed at GTH-UPM. It is a continuous speech recognition system that recognizes utterances made up of several continuously spoken words. The vocabulary size for this application is 532 Spanish words. The system is designed to be speaker-independent, meaning that it has been trained with a large number of speakers (4000 people), making it robust against a wide range of potential speakers without the need for further training by actual users.

One important characteristic of the speech recognition module is the confidence measure estimation, where every recognized word is tagged with a confidence value between

0.0 (lowest confidence) and 1.0 (highest confidence). This confidence measure is used in the natural language translation module to compute a confidence measure for every sign, which is then used during the sign animation process to inform the user about the reliability of the translated sign.

2.3.1 Natural language translation.

The natural language translation module in the Spanish to sign language translation system is responsible for converting the recognized sequence of words from the speech recognition module into a sequence of signs belonging to the Spanish Sign Language.

Two approaches for natural language translation are described and evaluated: rule-based translation and statistical translation:

1. Rule-based translation:

In the rule-based approach, the translation module is implemented using a bottom-up strategy, where the relationship between signs and words is defined by an expert hand. The translation analysis starts from each word individually and extends to neighborhood context words or already-formed signs to find specific combinations of words and/or signs that generate another sign.

2. Statistical translation:

The statistical translation approach uses parallel corpora for training the statistical model. This approach leverages large datasets to learn the relationships between words and signs, allowing for a data-driven translation process. The best configuration reported a 38.72 percentage Sign Error Rate (SER) and a 0.4941 BiLingual Evaluation Understudy (BLEU).

2.3.2 Sign animation with the eSIGN avatar: VGuido

The sign animation process involves representing the translated signs as a temporal sequence of frames, where each frame defines a static posture of the avatar at the appropriate moment. These postures are defined by specifying the configuration of the avatar's skeleton, along with additional characteristics that define distortions to be applied to the avatar.

The eSIGN 3D avatar, VGuido, is utilized to visually and dynamically represent the signs in Spanish Sign Language (LSE). This visual representation enhances the communication experience for Deaf individuals by providing a lifelike and expressive portrayal of the translated signs.

2.4 Comparison of Existing Technologies

Sl. no	Methodology	Advantage	Disadvantage
1	HMM Model combined with the BPNN algorithm	HMMs have been a traditional choice for speech recognition due to their effectiveness in modeling sequential data	HMMs can struggle to capture long-range dependencies and high-level context in speech, leading to less accurate recognition for complex speech patterns
2	LSTM-RNN Model	LSTMs are excellent at capturing the long-range dependencies in speech, making them well-suited for complex speech recognition tasks	LSTMs often need a large amount of labeled data to achieve high accuracy
3	DNNs and CNNs	CNNs can automatically extract relevant spectral and temporal features from speech spectrograms, making them suitable for speech recognition	CNNs are primarily designed for grid-like data, and they may not capture sequential dependencies as effectively as RNNs or LSTMs, which could be a limitation for complex speech recognition tasks.
4	Support Vector Machine (SVM) and Convolutional Neural Network (CNN)	CNNs can automatically extract relevant spectral and temporal features from speech spectrograms, making them suitable for speech recognition	CNNs are primarily designed for grid-like data, and they may not capture sequential dependencies as effectively as RNNs or LSTMs, which could be a limitation for complex speech recognition tasks.

5	Recurrent neural network Model	Capturing complex pattern	Computationally Intensive: Deeper RNN architectures can be computationally demanding, requiring substantial computational resources and longer training times, making them less practical for real-time or resource-constrained applications.
6	Deep learning models using LSTM and GRU	Less Vulnerable to Vanishing Gradients: LSTMs are generally less vulnerable to the vanishing gradient problem, which can occur during training RNNs	Computationally Intensive: LSTMs are computationally intensive, which can slow down the training process and make them less efficient for real-time applications. Training a large LSTM network can be time-consuming
7	sequence-to-sequence and encoder-decoder Model	Contextual Understanding: The attention mechanism allows the model to focus on relevant parts of the input sequence while generating the output. It provides contextual understanding, which is particularly important in languages with complex grammar and word order, such as sign language	Over-fitting: These kinds of complex models are more likely to over fit, particularly if the training dataset is small.Ample data and regularisation strategies are essential for reducing over-fitting problems.
8	Sign Language Processing like Machine Translation (MT)	An XML-Gloss Annotation System for Sign Language Processing.	An API that helps to generate XML and render the result through a schema style file

9	Neural Machine Translation (NMT) Model	Avatar based approach	Animated avatars are typically used to address the SLP problem.
10	Employed CNN based spatial embedding	Providing smoother gradients	There is no suitable dataset available to support research towards SLT. Due to the cost of annotation, existing linguistic datasets are too small to support deep learning.
11	Neural machine translations and Hybrid Machine Translation System	The process is simple to implement	If the word is not present in the database, the particular word is shown as in sign notation such that every letter sign will be shown
12	automatic interpretation and collaborative approach	Here the text is converted to HamNoSys and later to XML representation for displaying.	The approach is very difficult due to the complex transformation from text to HamNoSys.
13	Model using Python and Raspberry .	It takes input as alphabets and numerals and converts them into equivalent sign code and displays on a screen	There are particular sign notations for words which won't be displayed accordingly
14	Using Natural Language Processing, SiGML	The three-dimensional space around his body to describe an event	Processing is difficult

15	Example-based and rule-based Interlingua approaches	If the sentence exists in the database, we apply the example-based approach. The rule-based Interlingua is used if the sentence does not exist in the database.	Time consumption is very high, chances to show the meaning of a sentence if not properly trained
16	3D Avatar Approach for Continuous Sign Movement Using Speech/Text	Utilizes 3D avatar technology for visual representation of sign language.Enables continuous sign movement for better communication.	May require advanced computational resources for real-time rendering.Potential limitations in accurately capturing all nuances of sign language.
17	Speech to Sign Language Translation System for Spanish	Facilitates translation of spoken Spanish into sign language.Enhances accessibility for Spanish-speaking individuals using sign language.	Challenges in accurately translating complex Spanish sentences into sign language.System may require continuous updates to improve translation accuracy.

Table 2.2: Summary of Studies

2.5 Summary

The provided text discusses machine translation from text to sign language, emphasizing the unique features and grammar of sign languages. The process involves pre-processing the input text, converting it into sign sequences using Rule-Based Machine Translation (RBMT), and then translating those sequences into sign glosses, videos, or animated avatars. The text also introduces the standard Automatic Speech Recognition (ASR) model and delves into the application of deep learning models, specifically a Long Short-Term Memory (LSTM) based Seq2Seq architecture, for sign language gloss translation.

The experimental results indicate the effectiveness of the proposed model in outperforming previous approaches, achieving high ROUGE and BLEU scores. Additionally, the text outlines a speech recognition system that utilizes a state-of-the-art continuous speech recognition model with confidence measure estimation. The natural language translation module explores both rule-based and statistical approaches, with statistical translation demonstrating a 38.72 percentage Sign Error Rate and a 0.4941 BLEU score. The sign animation process involves using the eSIGN 3D avatar, VGuido, to visually represent translated signs in Spanish Sign Language, enhancing communication for Deaf individuals.

Chapter 3

Existing System

3.1 Introduction

In the realm of human-computer interaction, The system employs advanced technologies to seamlessly bridge spoken language and visual communication. Leveraging PyAudio in Python, capturing live speech through the microphone, subsequently utilizing the Google Speech Recognizer API to transform audio into meaningful text. To enhance linguistic precision, The system undertakes pre-processing by intelligently filtering out redundant filler words, optimizing both time and comprehension. Employing the potent Porter Stemming Algorithm further refines the text by extracting root words. The culmination of these processes facilitates the conversion of processed text into dynamic sign language video sequences, fostering an efficient and inclusive communication experience.

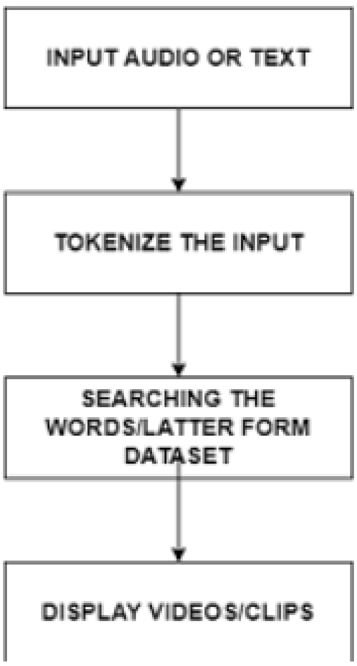


Figure 3.1: Block diagram of speech to sign language

3.1.1 Speech Recognition

The system's microphone provides the live voice as input. PyAudio, a Python library, is used for this. A Python module called PyAudio is used to record audio across several platforms. Google is used to turn the audio that was received into text. Speech Recognition API. The API uses neural network models to assist in the conversion of audio to text. Google Speech Recognizer is used to convert the audio file that was received into text in the input format. Longer audio recordings are split into smaller parts according to the duration of quiet. The Google Speech Recognizer is then used to effectively translate the pieces into text.

3.1.2 Pre-processing of Text

The word appears that the filler words, which are employed to close the sentence's gap, have less meaning. They give the statement less context. The English language has more than thirty filler words that seldom ever make sense in a sentence. Thus, the statement is made more intelligible by the algorithm by eliminating the unnecessary terms. The algorithm will save time by getting rid of these terms.

3.1.3 Porter Stemming Algorithm

Porter Stemming algorithm provides a basic approach to conflation that may work well in practice. Natural Language Processing (NLP) helps the computer to understand the human natural language. Porter Stemming is one of the Natural Language Processing techniques. It is the famous stemming algorithm proposed in 1980. Porter Stemmer algorithm is known for its speed and ease. It is mainly used for data mining and to retrieve information. It produces better results than any other stemming algorithms. It has less error rate.

The system removes the morphological and inflexional endings of the English words. The system uses Porter stemming Algorithm to remove the commonly used suffixes and prefixes of the words and find the root word or original word. For example, the Porter stemming algorithm reduces the words "agrees", "agreeable", "agreement" to the root word "agree". Because of this stemming, we can reduce the time taken for searching the sign language for the given word.

3.1.4 Text to Sign Language

The system iterates through every word in the processed text sentence which is received from the previous step and searches the corresponding sign language video sequences in the local system. If the word is found, the system shows the output as a video sequence. If the word is not found in the local system, then it splits the word into letters, according to letter the sign video clips are play.

3.2 Summary of the chapter

The system seamlessly integrates speech recognition, text pre-processing, and the powerful Porter Stemming Algorithm to enhance efficiency in converting spoken language to meaningful text. By intelligently removing filler words and employing Porter Stemmer, optimize the linguistic structure for quicker processing. The subsequent translation of processed text into sign language further enriches the user experience. This comprehensive approach not only accelerates the conversion process but also ensures accurate representation of the original message in sign language. Through a systematic combination of technologies, The system stands as a robust solution for bridging the communication gap between spoken language and sign language, contributing to a more inclusive and accessible environment.

Chapter 4

Proposed System

4.1 Introduction

The proposed method integrates rule-based and statistical-based approaches to create a comprehensive natural language model for generating sign language videos. The model begins by processing textual input using diverse Natural Language Processing (NLP) technologies. It strategically extracts keywords from the input, employing a hybrid approach that combines rule-based and statistical methods. These keywords are then compared and matched with corresponding sign language videos stored in a database.

In cases where direct matches are not found, the model takes an additional step by tokenizing the keywords into individual words or letters. This tokenization process allows for a more granular analysis, enhancing the model's ability to find relevant sign language expressions. By combining rule-based strategies for explicit linguistic rules and statistical methods for nuanced comprehension, the model achieves a robust and versatile approach to generate accurate and contextually appropriate sign language videos. This hybrid model leverages the strengths of both rule-based and statistical techniques, showcasing a synergistic integration for effective communication through sign language interpretation.

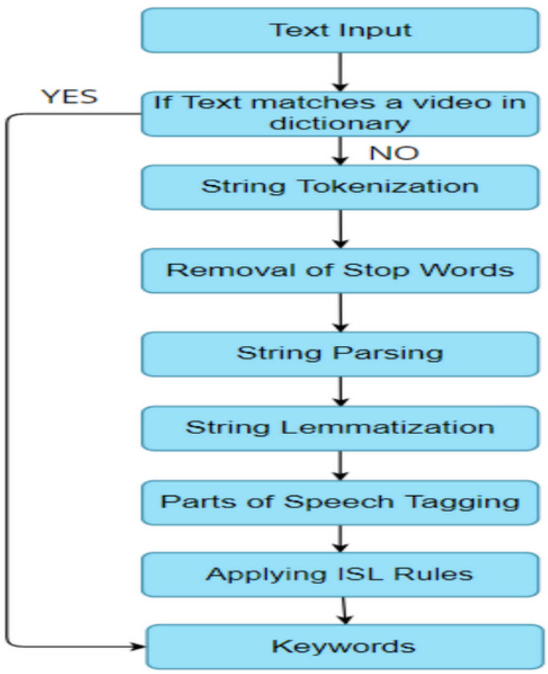


Figure 4.1: Natural Language Model Architecture.

4.1.1 Tokenization

Tokenization is the process of splitting text into a list of words also known as tokens. NLTK has a module named `tokenize()` which is further divided into two types, i.e., word tokenize to split a sentence into a sequence of words and sentence tokenize to split a paragraph into a list of sentences.

4.1.2 The Removal of Stop Words

Stop words are a list of very common but less informative words that can be ignored. Since they are not so important in the sentence, they can be removed from the sentence. This will improve the overall performance of the system.

4.1.3 Parsing

Parsing is the syntax analysis phase in which it checks whether the string obtained after tokenization belongs to proper grammar or not. Parsing helps to adjust the text based on the target language's grammar structure. One of the most used parsers is the Stanford Parser.

4.1.4 Lemmatization

The process of transforming the inflected forms of a word to its root-based dictionary form is known as lemmatization. This root-based dictionary form of a word is referred to as a lemma. The importance of this step lies in ISL, as it requires a root word.

4.1.5 Part-of-Speech Tagging

POS tagging refers to the process of labeling words with different constructs of English grammar, such as adverbs, adjectives, nouns, verbs, prepositions, etc.

4.1.6 Results Analysis

To check the results of lemmatization, we analyze its results through sample sentences. For example, "He was playing and eating at the same time". The results in Table 5 show that lemmatization alone is not sufficient enough to give accurate root words, as it does not take into consideration the context of the sentence. To overcome this problem, part-of-speech tagging comes into the picture.

To check whether part-of-speech tagging can improve the results obtained after lemmatization, we analyze the same sample sentence used above in lemmatization. The results in Table 6 show that after integrating part-of-speech tagging with lemmatization it gives a correct base form of a word, which in turn improves the accuracy of word to base word conversion.

4.2 Summary of the chapter

The proposed natural language model for sign language video generation integrates both rule-based and statistical approaches, offering a comprehensive and versatile solution. Beginning with diverse Natural Language Processing (NLP) technologies, the model strategically extracts keywords using a hybrid method that combines rule-based and statistical techniques. These keywords are then compared with sign language videos in a database. In instances without direct matches, the model further tokenizes keywords into individual words or letters, enabling a more detailed analysis and improving its ability to find relevant sign language expressions. By amalgamating rule-based strategies for explicit linguistic rules and statistical methods for nuanced comprehension, the model achieves robustness and versatility in generating accurate and contextually appropriate sign language videos. This hybrid approach leverages the strengths of both rule-based and statistical techniques, showcasing a synergistic integration that enhances effective communication through sign language interpretation.

Chapter 5

Design

5.1 Architecture Diagram of the System

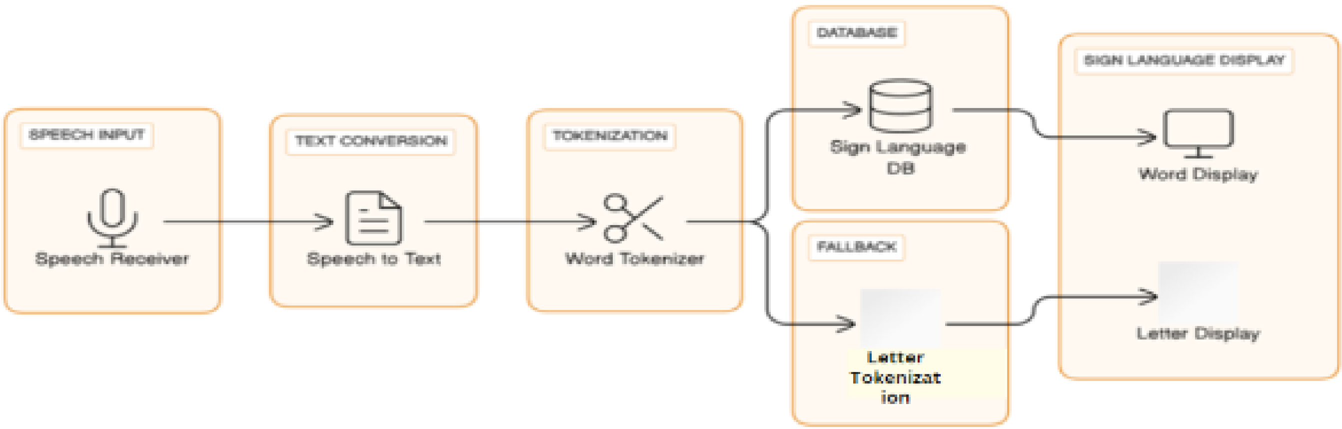
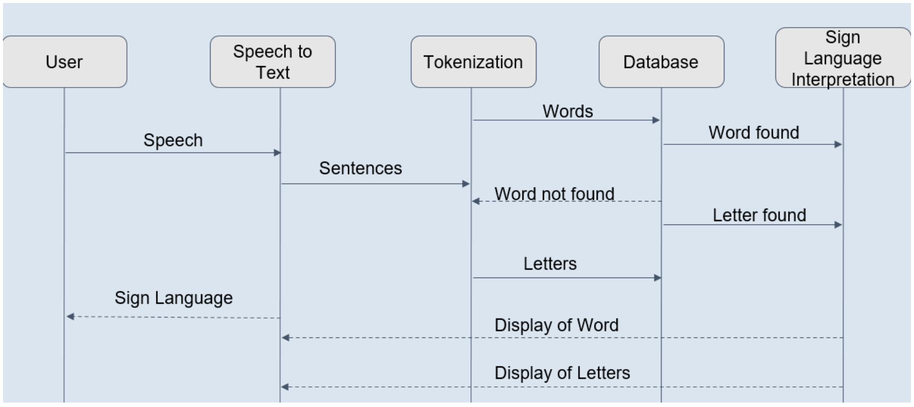


Figure 5.1: Architecture Diagram

5.2 Sequence Diagram

Figure 5.2: Sequence diagram



5.3 Modules

The system is divided into the following modules:

- Audio-to-text Conversion
- Language Conversion
- Tokenization and Keyword Extraction
- Database Matching and Video Display

5.3.1 Audio-to-text Conversion

Speech to text Conversion

STT Conversion is implemented using Speech-to-Text API or library that supports multiple languages, such as "Google Cloud Speech-to-Text","Microsoft Azure Speech".This transcribes the incoming audio to text.

Language Identification:

After obtaining the transcribed text, we analyze it to identify the language spoken. Many STT services provide language identification features that help in this step.

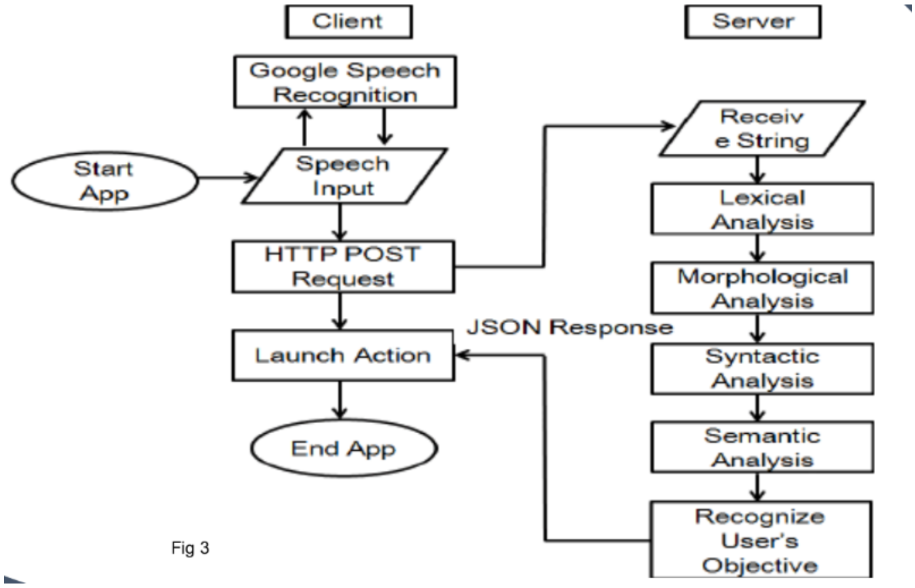


Figure 5.3: Google Cloud STT API

5.3.2 Language Conversion

- The input language sometimes may not be same as the intended language
- Conversion of desired language is important
- Conversion using google API .
- Support 136 language.
- Less time in conversion.
- Uses encoder decoder architecture.
- The encoder which converts the world into Vector.
- The decoder that converts to another language.
- The encoder decoder architecture that uses RNN.
- RNN uses feedback connection to propagate information to the next layer.
- NMT,RNN stacked multilayer of LSTM.

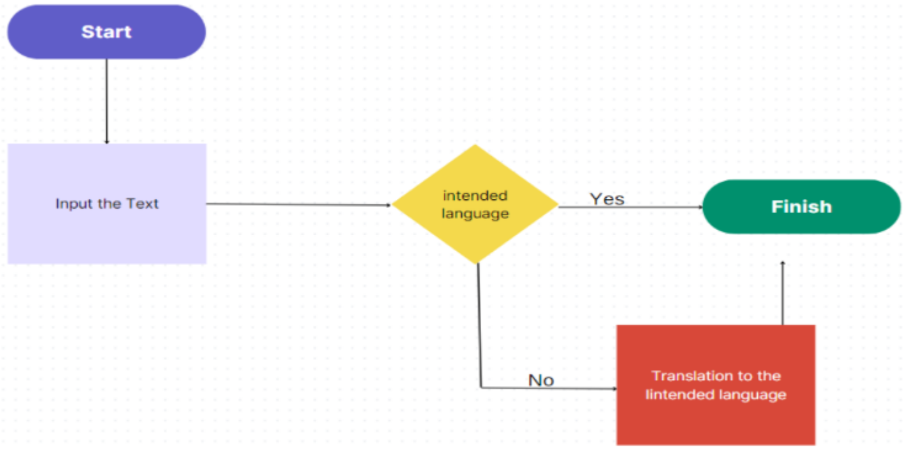


Figure 5.4: Language Conversion

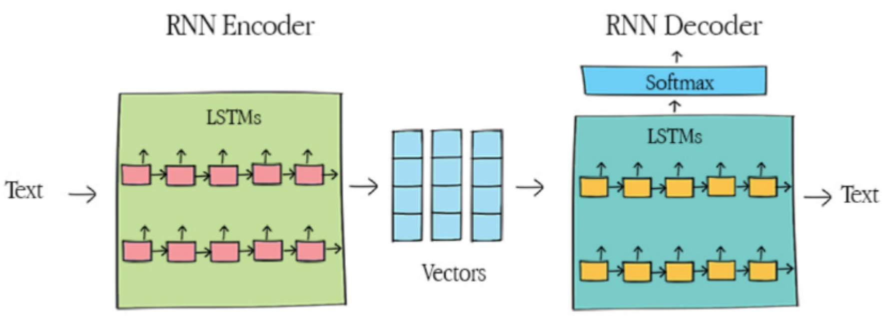


Figure 5.5: Encoder Decoder Architecture

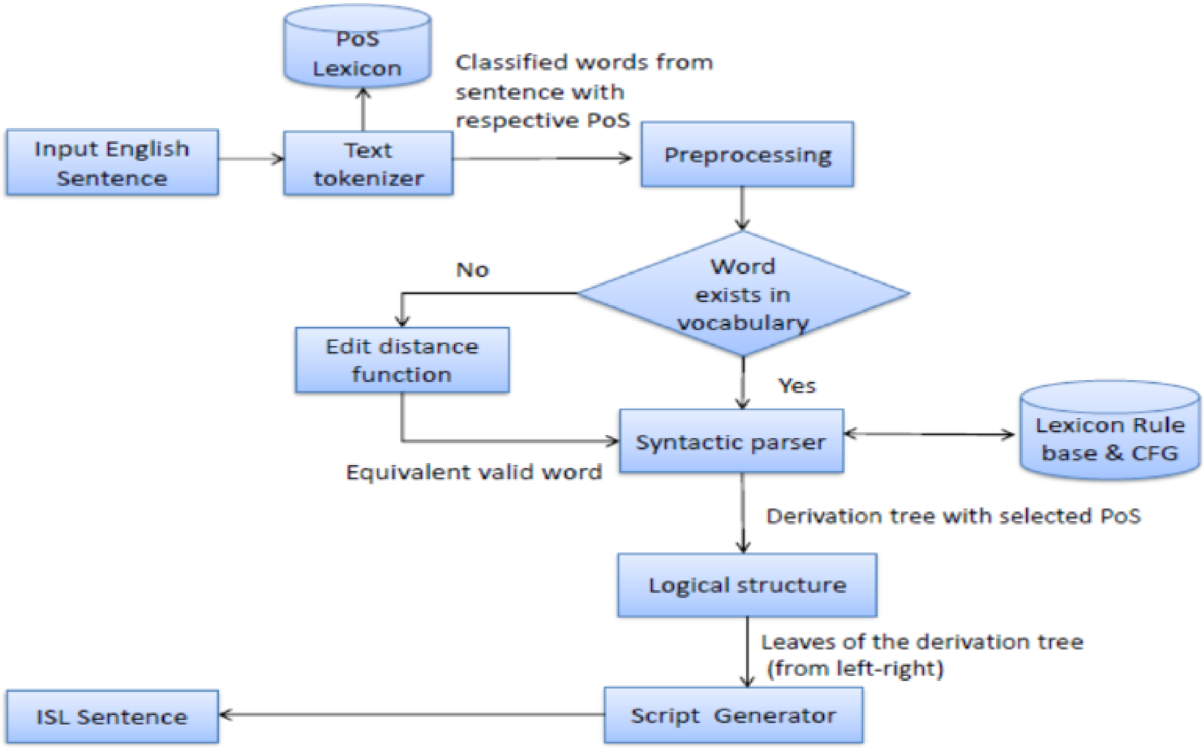


Figure 5.6: Model of ISL sentence generation from english sentence

5.3.3 Tokenization and Keyword Extraction

STEP 1: Preprocessing of Input Text Using Regular Expression NLTK divides the English sentence into separate word–PoS pairs using the text tokenizer.Misspelled words are edited into valid words with the help of "edit distance" function. fig 5.7

The edit distance function takes two strings (source and target) and modifies the

Misspelled/Invalid Word	Equivalent Valid Word
"Hellllo"	"Hello"
"Halo"	"Hello"
"Hapyyyy"	"Happy"
"Happppyyy"	"Happy"
"Noooooooo"	"No"

Figure 5.7: Misspelled words

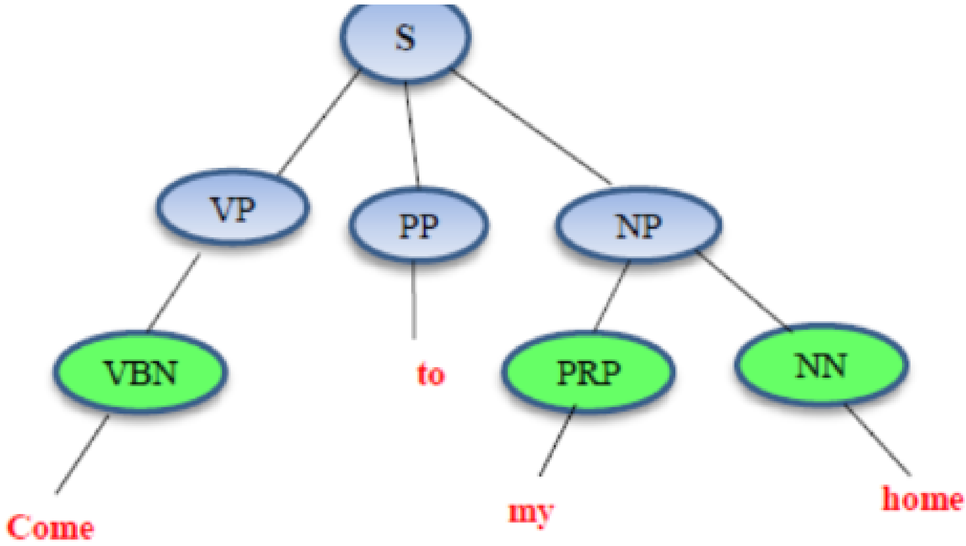


Figure 5.8: Derivation tree

source string such that both source and target strings become equal. The regular expression identifies the meaningful English sentence using the lexicon rule. Eg. of a regular expression: (VP) (PP—PRP—JJ)*(NP)

output: parse tree based on the grammatical tokens (VP, PP, NP, etc.).

STEP 2: Syntactic Parsing and Logical Structure

Construct the derivation tree of the Context-Free Grammar (CFG) If the input sentence is "come to my home." then the derivation tree would look like: fig 5.8

STEP 3: Script Generator and ISL Sentence

Takes a valid English sentence (after semantic parsing) as input. Generates the sequence tree, where each node of the tree is related to different gestures that are associated with the avatar movement. The representation of ISL from the English sentences is done using Lexical Functional Grammar (LFG). ISL follows the word order "Subject–Object–Verb" English language follows the word order "Subject–Verb–Object"

English Sentence	ISL Sentence
I have a pen.	I pen have.
The child is playing.	Child playing.
The woman is blind.	Woman blind.
It is cloudy outside.	Outside cloudy.
I see a dog.	I dog see.

Figure 5.9: ISL sentence generation

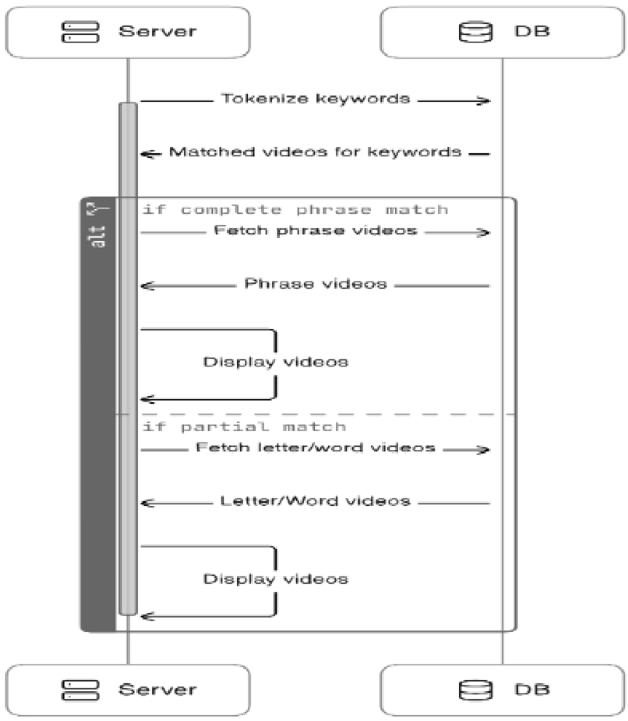


Figure 5.10: Server-Database interaction for sign language video matching

5.3.4 Database Matching and Video Display

The system excels in correlating keywords with sign language videos stored in the database. It effectively tokenizes keywords into individual letters or words, even if the complete phrase is not present in the database. In cases where the entire phrase is unavailable in the database, the system intelligently displays sign language videos for discrete letters or words. fig 5.10

5.4 Summary of the Chapter

The system architecture comprises several modules, starting with "Audio-to-text Conversion," employing Speech-to-Text APIs like "Google Cloud Speech-to-Text". Language identification is then performed on the transcribed text. "Language Conversion" follows, addressing input language variations through Google API, supporting 136 languages and utilizing an encoder-decoder architecture with RNN for efficient conversion.

The "Tokenization and Keyword Extraction" module involves preprocessing input text using Regular Expression and NLTK, refining misspelled words and identifying meaningful sentences. Syntactic parsing and logical structure construction occur using Context-Free Grammar, leading to script generation and Indian Sign Language (ISL) sentence representation through Lexical Functional Grammar. The ISL sentence generation adheres to the word order "Subject–Object–Verb."

Lastly, in "Database Matching and Video Display," the system excels at correlating keywords with sign language videos in the database. It intelligently tokenizes keywords and displays relevant sign language videos, even for partial matches. The overall system integrates audio-to-text conversion, language identification, language conversion, tokenization, keyword extraction, syntactic parsing, script generation, and database matching, offering a comprehensive solution for generating accurate and contextually appropriate sign language videos.

Chapter 6

Assumptions and Challenges

- The system assumes that the input text is in a language that the model is trained in.
- Assumes that the sign language videos are available in the database for the recognized keywords.
- The system assumes a stable internet connection for accessing the database and retrieving the videos.

Chapter 7

Work Breakdown and Responsibilities

Member	Responsibility
Alwin Shibu	Tokenization, Language Translation
Antony Bryan	Database Lookup, Sign Language Representation
Ayaz M Ziyad	Front End, Keyword Extraction
Christopher Jacob	Database Management, Audio to Text Conversion

Figure 7.1: Workbreakdown

Chapter 8

Hardware and Software Requirements

8.1 Hardware Requirements

- A good quality microphone
- Minimum of 4 GB of RAM
- Processor: Intel Core i5 or equivalent,Clock Speed: 2.5 GHz or higher

8.2 Software Requirements

- Operating system such as ”Windows” or ”Linux”
- Programming language (Python)
- Natural Language Processing libraries (NLTK)

Chapter 9

Project Milestones and Schedule

9.1 Gantt Chart

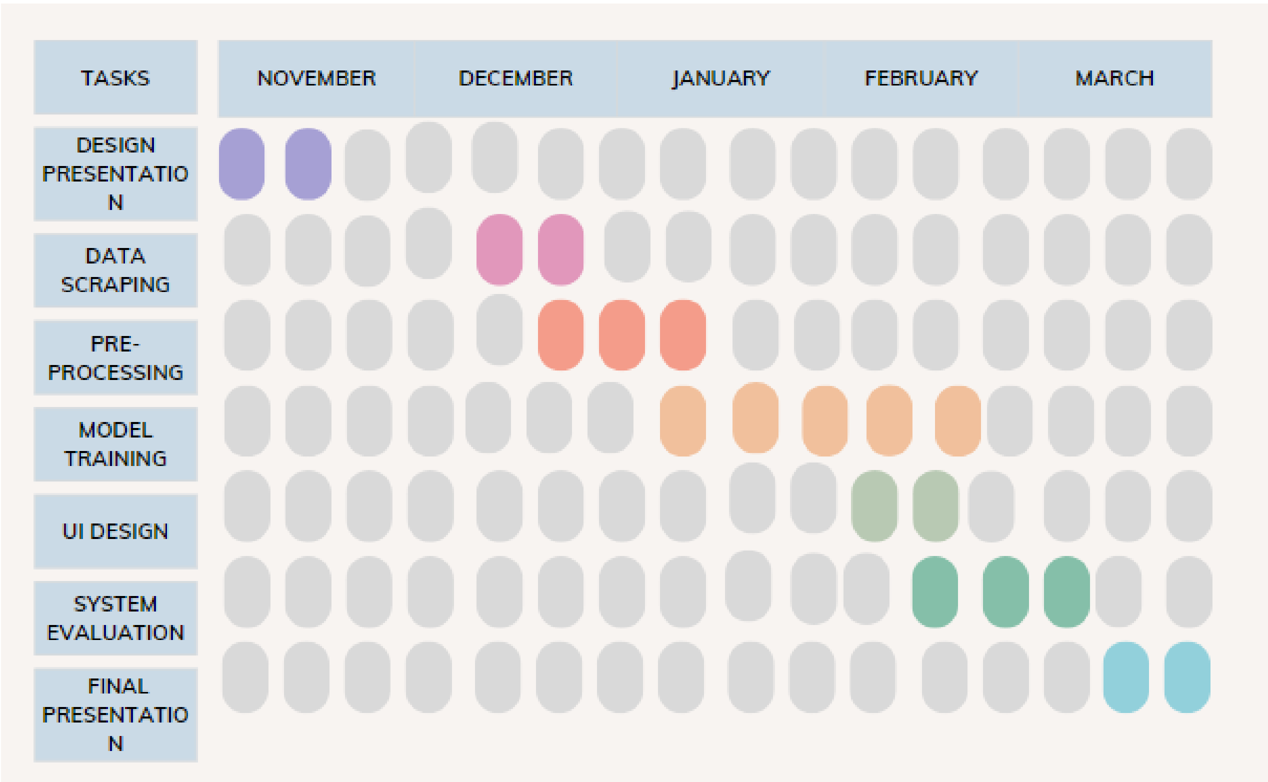


Figure 9.1: Gantt Chart

Chapter 10

Risks and challenges

- Limited availability of sign language videos for certain keywords or phrases.
- Accuracy and reliability of the natural language model in recognizing and extracting keywords.
- Potential technical challenges in integrating the system with the database and video playback functionality.
- Adapting the system to handle different languages and dialects of sign language.

Chapter 11

Results

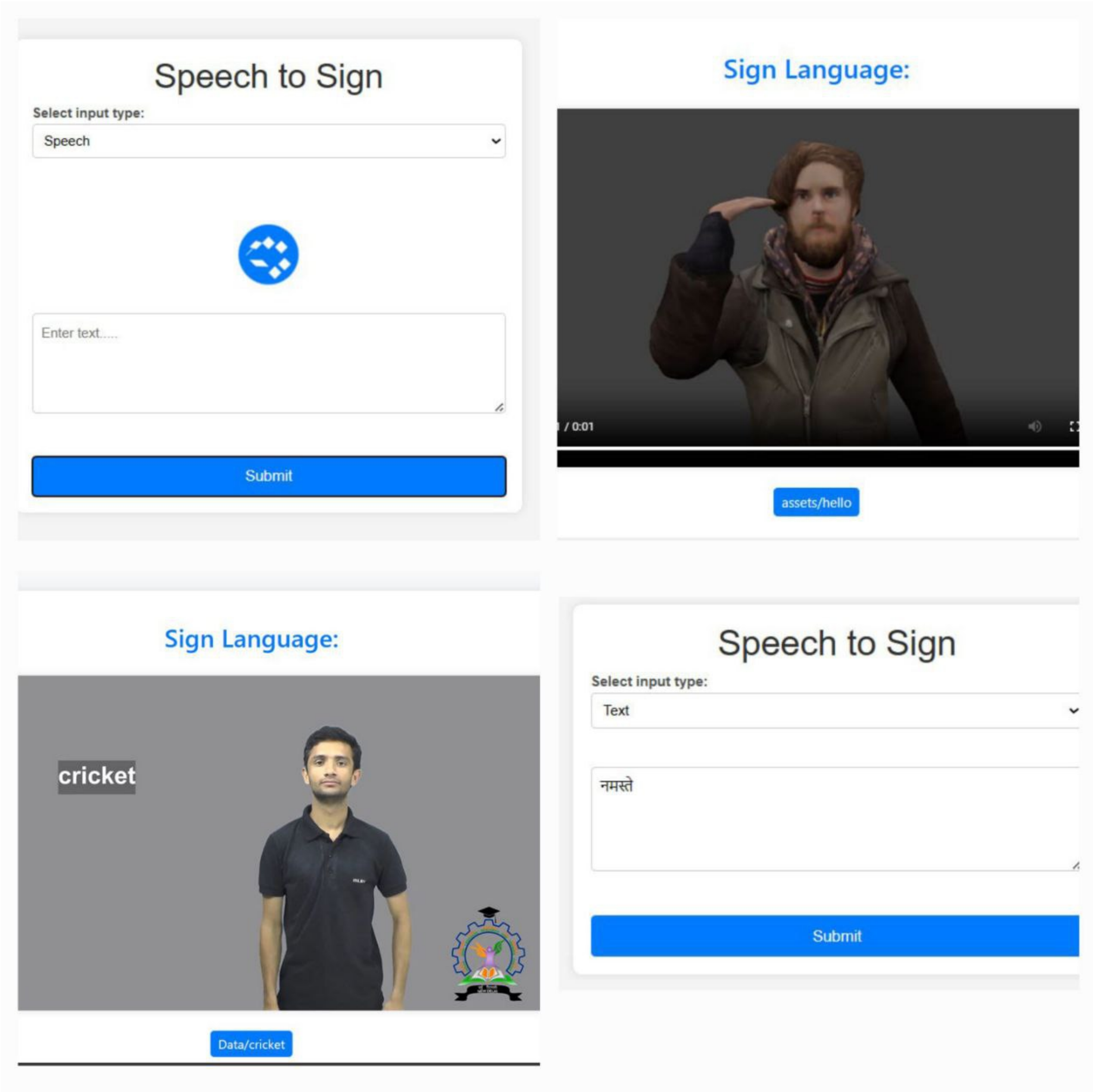


Figure 11.1: Results

Chapter 12

Conclusion

The initiative is driven by the vision of eliminating barriers to communication for individuals with hearing disabilities. By doing so, aspire to foster a society where successful communication is accessible to everyone, irrespective of their hearing abilities. The overarching goal is to create an inclusive environment where individuals with hearing disabilities can actively participate in conversations, share their thoughts, and engage with others on an equal footing.

Envisioning a future where communication is not hindered by hearing limitations, the initiative seeks to bridge the existing gap. believing that by addressing communication challenges, contributing the creation of a more open and interconnected society. In this inclusive society, the diverse perspectives and contributions of individuals with hearing disabilities enrich the fabric of collective interaction. By removing communication obstacles, aim's to promote understanding, empathy, and equal opportunities for all. Through collaborative efforts, collectively work towards building a world where communication is a universal right, reinforcing the principles of inclusivity and shared connection.

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Appendix A: Presentation

Speech to Sign language Converter

Ayaz M Ziyad Alwin Shibu Antony Bryan Christopher Jacob

Guide : Ms Jisha Mary Jose

12 April 2024

Contents

Problem Definition

Problem Definition

- 5 percentage of the world's population has hearing difficulties, which can make communicating with them challenging.
- Design a versatile multilingual speech-to-sign language converter to bridge communication gaps between people with hearing impairments and those unfamiliar with sign language.
- The system should proficiently and adaptively transform spoken language in multiple languages into precise sign language interpretations.

Project Objectives

Project Objectives

- **Multilingual Support:** Create a system that can understand and generate sign language for multiple spoken languages.
- **Real-time Conversion:** Develop a system capable of converting spoken language into sign language in real-time.
- **Accuracy and Precision:** Ensure high accuracy and precision in sign language generation to convey the nuances of spoken language effectively.
- **User-Friendly Interface:** Design an intuitive and user-friendly interface that allows both hearing-impaired and hearing individuals to use the system easily.

Novelty of Idea and Scope of Implementation

Novelty of Idea and Scope of Implementation

- **User-Friendly Approach**: Emphasizing a user-friendly design ensures accessibility for both the hearing-impaired and hearing individuals, making the system more widely applicable.
- **Integration of Natural Language Processing**: The incorporation of natural language processing technologies showcases a cutting-edge approach, enhancing the accuracy and efficiency of the translation system.
- **Adherence to Indian Sign Language Grammar Rules:** The system's integration into various settings like hospitals, buses, railway stations, post offices, and video conferencing applications expands its practicality in real-world scenarios.

Project Gantt Chart

Project Gantt Chart

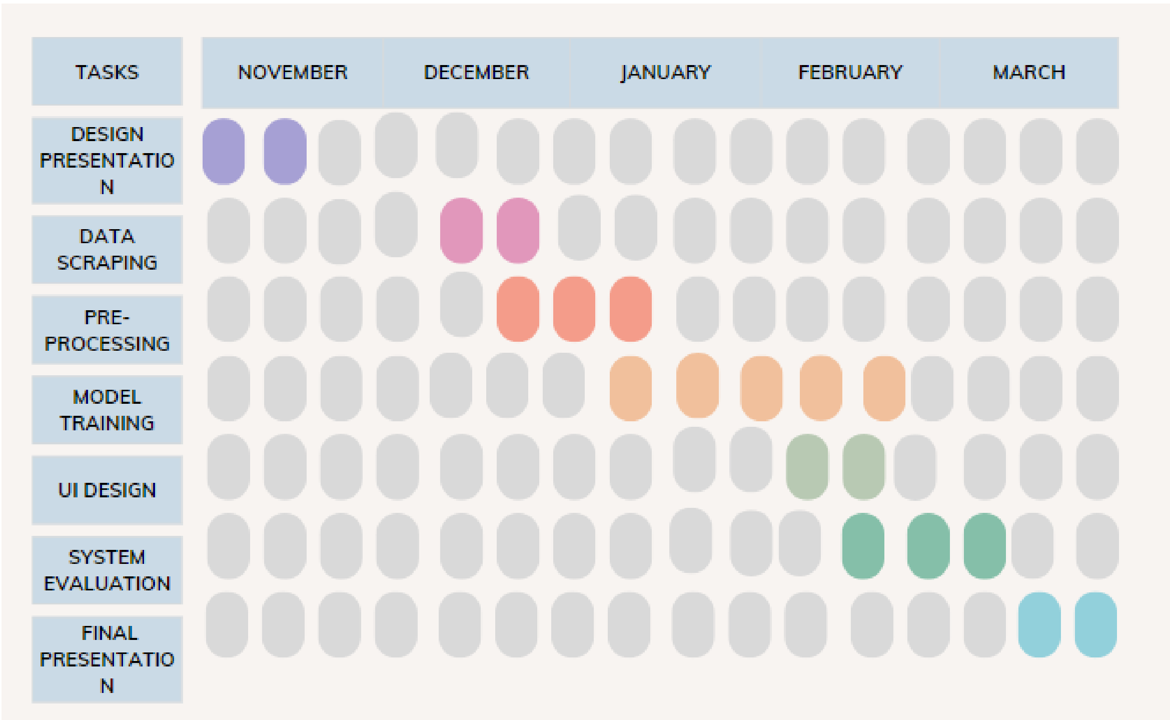

Figure: Project Gantt Chart

Work Done During 30 Percentage Evaluation

Work Done During 30 Percentage Evaluation

- **Speech To Text**: Using googletrans library the speech is converted to text.
- **Translation**: In the case of regional languages the translation was done using pre-trained model.

Work Done During 60 Percentage Evaluation

Work Done During 60 Percentage Evaluation

- **Tokenization**:Tokenization is the process of splitting text into a list of words.This can be done in two ways i.e, word tokenize to split a sentence into a sequence.
- **The removal of stop words**:Stop words are a list of very common but less informative words such as example-an, the, is, are,a etc
- **Parsing**:Parsing is the syntax analysis phase in which it checks whether the string obtained after tokenization belongs to proper grammar or not.

Results

Results

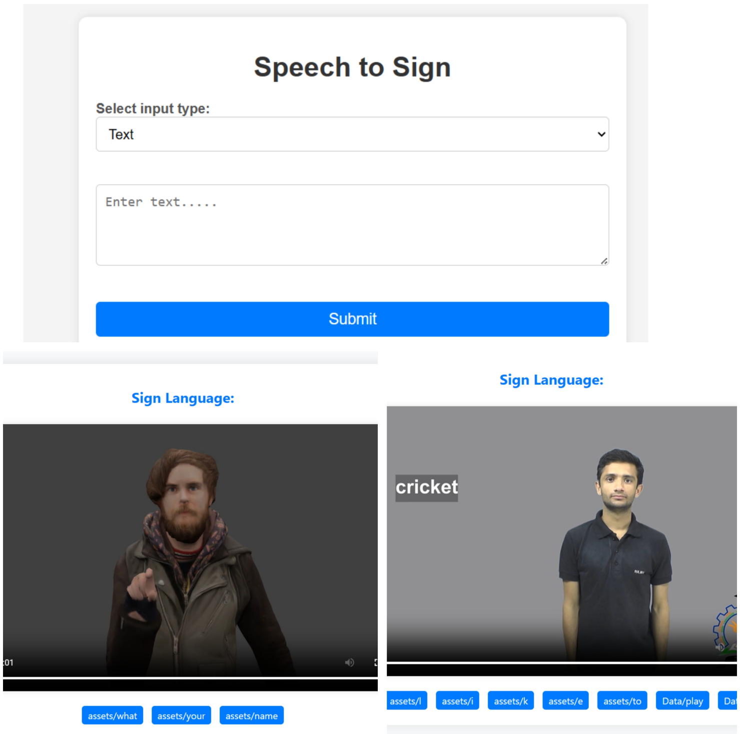

Figure: Screenshots Of The Results

Future Scope

Future Scope

In the future, the scope of speech to sign language translation technology holds immense potential for further advancement. Some of the key areas are :

- ISL Dictionary Expansion: Prioritize enriching the ISL dictionary for comprehensive vocabulary, enhancing translation accuracy and coverage.
- Portable Translation Devices: Develop versatile, user-friendly apps or compact devices for seamless on-the-go translation.
- User-Friendly Interfaces: Enhance tool usability with intuitive interfaces, catering to diverse technical proficiency's.
- Continuous Improvement: Commit to iterative updates driven by user feedback and tech advancements for superior performance.

Task Distribution

Task Distribution

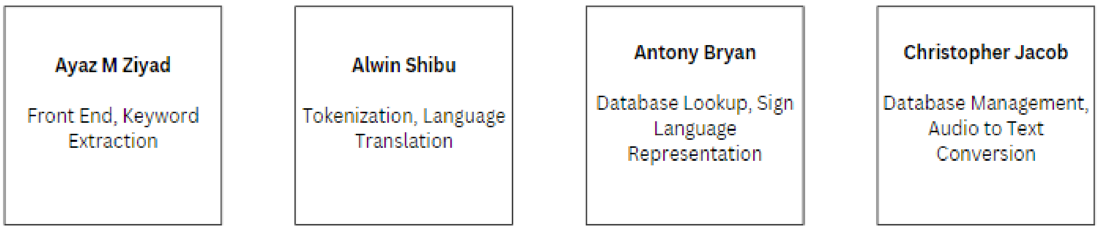

Figure: Task Distribution

Conclusion

Conclusion

- Our initiative aims to remove obstacles to communicate for those who have hearing disabilities.
- We anticipate a society where everyone can communicate successfully, regardless of their hearing abilities.
- Together, we can close the gap and build a society that is more open and interconnected for everyone.

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Thank you!

Appendix B: Vision, Mission, Programme Outcomes and Course Outcomes

Vision, Mission, Programme Outcomes and Course Outcomes

Institute Vision

To evolve into a premier technological institution, moulding eminent professionals with creative minds, innovative ideas and sound practical skill, and to shape a future where technology works for the enrichment of mankind.

Institute Mission

To impart state-of-the-art knowledge to individuals in various technological disciplines and to inculcate in them a high degree of social consciousness and human values, thereby enabling them to face the challenges of life with courage and conviction.

Department Vision

To become a centre of excellence in Computer Science and Engineering, moulding professionals catering to the research and professional needs of national and international organizations.

Department Mission

To inspire and nurture students, with up-to-date knowledge in Computer Science and Engineering, ethics, team spirit, leadership abilities, innovation and creativity to come out with solutions meeting societal needs.

Programme Outcomes (PO)

Engineering Graduates will be able to:

1. Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and Team work: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

10. Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Programme Specific Outcomes (PSO)

A graduate of the Computer Science and Engineering Program will demonstrate:

PSO1: Computer Science Specific Skills
The ability to identify, analyze and design solutions for complex engineering problems in multidisciplinary areas by understanding the core principles and concepts of computer science and thereby engage in national grand challenges.

PSO2: Programming and Software Development Skills
The ability to acquire programming efficiency by designing algorithms and applying standard practices in software project development to deliver quality software products meeting the demands of the industry.

PSO3: Professional Skills
The ability to apply the fundamentals of computer science in competitive research and to develop innovative products to meet the societal needs thereby evolving as an eminent researcher and entrepreneur.

Course Outcomes (CO)

Course Outcome 1: Model and solve real world problems by applying knowledge across domains (Cognitive knowledge level: Apply).

Course Outcome 2: Develop products, processes or technologies for sustainable and socially relevant applications (Cognitive knowledge level: Apply).

Course Outcome 3: Function effectively as an individual and as a leader in diverse. teams and to comprehend and execute designated tasks (Cognitive knowledge level: Apply).

Course Outcome 4: Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms (Cognitive knowledge level: Apply).

Course Outcome 5: Identify technology/research gaps and propose innovative/creative solutions (Cognitive knowledge level: Analyze).

Course Outcome 6: Organize and communicate technical and scientific findings effectively in written and oral forms (Cognitive knowledge level: Apply).

Appendix C: CO-PO-PSO Mapping

CO-PO AND CO-PSO MAPPING

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO 1	2	2	2	1	2	2	2	1	1	1	1	2	3		
CO 2	2	2	2		1	3	3	1	1		1	1		2	
CO 3									3	2	2	1			3
CO 4					2			3	2	2	3	2			3
CO 5	2	3	3	1	2							1	3		
CO 6					2			2	2	3	1	1			3

3/2/1: high/medium/low

JUSTIFICATIONS FOR CO-PO MAPPING

MAPPING	LOW/MEDIUM/ HIGH	JUSTIFICATION
100003/ CS722U.1- PO1	M	Knowledge in the area of technology for project development using various tools results in better modeling.
100003/ CS722U.1- PO2	M	Knowledge acquired in the selected area of project development can be used to identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions.

100003/ CS722U.1-PO3	M	Can use the acquired knowledge in designing solutions to complex problems.
100003/ CS722U.1-PO4	M	Can use the acquired knowledge in designing solutions to complex problems.
100003/ CS722U.1-PO5	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
100003/ CS722U.1-PO6	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
100003/ CS722U.1-PO7	M	Project development based on societal and environmental context solution identification is the need for sustainable development.
100003/ CS722U.1-PO8	L	Project development should be based on professional ethics and responsibilities.
100003/ CS722U.1-PO9	L	Project development using a systematic approach based on well defined principles will result in teamwork.
100003/ CS722U.1-PO10	M	Project brings technological changes in society.

100003/ CS722U.1-PO11	H	Acquiring knowledge for project development gathers skills in design, analysis, development and implementation of algorithms.
100003/ CS722U.1-PO12	H	Knowledge for project development contributes engineering skills in computing & information gatherings.
100003/ CS722U.2-PO1	H	Knowledge acquired for project development will also include systematic planning, developing, testing and implementation in computer science solutions in various domains.
100003/ CS722U.2-PO2	H	Project design and development using a systematic approach brings knowledge in mathematics and engineering fundamentals.
100003/ CS722U.2-PO3	H	Identifying, formulating and analyzing the project results in a systematic approach.
100003/ CS722U.2-PO5	H	Systematic approach is the tip for solving complex problems in various domains.
100003/ CS722U.2-PO6	H	Systematic approach in the technical and design aspects provide valid conclusions.
100003/ CS722U.2-PO7	H	Systematic approach in the technical and design aspects demonstrate the knowledge of sustainable development.

100003/ CS722U.2-PO8	M	Identification and justification of technical aspects of project development demonstrates the need for sustainable development.
100003/ CS722U.2-PO9	H	Apply professional ethics and responsibilities in engineering practice of development.
100003/ CS722U.2-PO11	H	Systematic approach also includes effective reporting and documentation which gives clear instructions.
100003/ CS722U.2-PO12	M	Project development using a systematic approach based on well defined principles will result in better teamwork.
100003/ CS722U.3-PO9	H	Project development as a team brings the ability to engage in independent and lifelong learning.
100003/ CS722U.3-PO10	H	Identification, formulation and justification in technical aspects will be based on acquiring skills in design and development of algorithms.
100003/ CS722U.3-PO11	H	Identification, formulation and justification in technical aspects provides the betterment of life in various domains.
100003/ CS722U.3-PO12	H	Students are able to interpret, improve and redefine technical aspects with mathematics, science and engineering fundamentals for the solutions of complex problems.

100003/ CS722U.4-PO5	H	Students are able to interpret, improve and redefine technical aspects with identification formulation and analysis of complex problems.
100003/ CS722U.4-PO8	H	Students are able to interpret, improve and redefine technical aspects to meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
100003/ CS722U.4-PO9	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
100003/ CS722U.4-PO10	H	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools for better products.
100003/ CS722U.4-PO11	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
100003/ CS722U.4-PO12	H	Students are able to interpret, improve and redefine technical aspects for demonstrating the knowledge of, and need for sustainable development.
100003/ CS722U.5-PO1	H	Students are able to interpret, improve and redefine technical aspects, apply ethical principles and commit to

		professional ethics and responsibilities and norms of the engineering practice.
100003/ CS722U.5- PO2	M	Students are able to interpret, improve and redefine technical aspects, communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
100003/ CS722U.5- PO3	H	Students are able to interpret, improve and redefine technical aspects to demonstrate knowledge and understanding of the engineering and management principle in multidisciplinary environments.
100003/ CS722U.5- PO4	H	Students are able to interpret, improve and redefine technical aspects, recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
100003/ CS722U.5- PO5	M	Students are able to interpret, improve and redefine technical aspects in acquiring skills to design, analyze and develop algorithms and implement those using high-level programming languages.
100003/ CS722U.5- PO12	M	Students are able to interpret, improve and redefine technical aspects and contribute their engineering skills in computing and information engineering domains like network design and administration, database design and

		knowledge engineering.
100003/ CS722U.6-PO5	M	Students are able to interpret, improve and redefine technical aspects and develop strong skills in systematic planning, developing, testing, implementing and providing IT solutions for different domains which helps in the betterment of life.
100003/ CS722U.6-PO8	H	Students will be able to associate with a team as an effective team player for the development of technical projects by applying the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
100003/ CS722U.6-PO9	H	Students will be able to associate with a team as an effective team player to Identify, formulate, review research literature, and analyze complex engineering problems
100003/ CS722U.6-PO10	M	Students will be able to associate with a team as an effective team player for designing solutions to complex engineering problems and design system components.
100003/ CS722U.6-PO11	M	Students will be able to associate with a team as an effective team player, use research-based knowledge and research methods including design of experiments, analysis and interpretation of data.
100003/ CS722U.6-PO12	H	Students will be able to associate with a team as an effective team player, applying ethical principles and

		commit to professional ethics and responsibilities and norms of the engineering practice.
100003/ CS722U.1-PSO1	H	Students are able to develop Computer Science Specific Skills by modeling and solving problems.
100003/ CS722U.2-PSO2	M	Developing products, processes or technologies for sustainable and socially relevant applications can promote Programming and Software Development Skills.
100003/ CS722U.3-PSO3	H	Working in a team can result in the effective development of Professional Skills.
100003/ CS722U.4-PSO3	H	Planning and scheduling can result in the effective development of Professional Skills.
100003/ CS722U.5-PSO1	H	Students are able to develop Computer Science Specific Skills by creating innovative solutions to problems.
100003/ CS722U.6-PSO3	H	Organizing and communicating technical and scientific findings can help in the effective development of Professional Skills.