Project Completion Report

Project Details:

File No: 16-1/2015-DD-III

Funding Agency: Ministry of Social Justice& Empowerment, Department of Empowerment of Persons with Disabilities, Govt. of India

Project Title: Development of Public Announcements System at Railway Stations using Indian Sign Language Synthetic Animations for Differently Able Hearing-Impaired People

Research Scheme: Disability Related Technology, Product and Issues

Total Approved Grant: Rs. 24,15,000/-

Project Duration: 24 months

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Total Grant received as First Instalment: Rs. 9, 66,000/-

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Outstanding Grant: Rs. 12,00,276/-

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Index

1. Introduction

The Development of Public Announcements System at Railway Stations using Indian Sign Language Synthetic Animations for Differently Abled Hearing Impaired People is a ground-breaking project that aims to revolutionize accessibility and inclusivity for individuals with hearing impairments. The project recognizes the significant communication challenges that hearing impaired people face while accessing critical information at railway stations and seeks to address them through innovative solutions. Railway stations serve as important transport hubs and connect people from various places. However, individuals with hearing loss face significant barriers when trying to access important notifications due to their reliance on audio-based communication systems. The traditional speaker systems cater primarily to individuals with intact hearing, so those with hearing loss are at a disadvantage. They struggle to receive and understand essential information such as train timetables, platform changes, safety instructions and notices of delays or cancellations. This communication gap not only limits their independence and autonomy, but also creates potential security risks when navigating railway stations.

The existing methods of communicating information to hearing-impaired residents, such as written announcements or assistance from the facility's staff, are not always efficient or accessible. Written announcements may not capture the nuance and immediacy of audio announcements, leading to potential misunderstandings. Relying on station staff for assistance can be time consuming and does not always ensure accurate and timely information. These limitations create a compelling need for a comprehensive and accessible solution that specifically addresses the communication needs of individuals with hearing loss at rail stations. To address these challenges, our project seeks to develop a public notification system using Indian Sign Language (ISL). By harnessing technological advances and sign language generation techniques, this project was aimed to bridge the communication gap and ensure equal access and participation for all individuals, regardless of hearing ability.

The main objective of this project was to provide comprehensive and visually representative announcements in Indian Sign Language (ISL). Using advanced technology and advances in sign language generation, synthetic animations that accurately depict ISL signals were created. These animations serve as a visual representation of the audio announcements, making them accessible and understandable to hearing impaired individuals. This system consists of several interconnected components. First is the collection of a

comprehensive database of the announcements commonly used at railway stations. This dataset serves as the basis for the development of the ISL dictionary, which contains a large selection of ISL symbols along with their corresponding representations using HamNoSys notation, a standard language for writing symbols.

To ensure accurate conversion of spoken announcements into ISL sentences, an input text processing module has been designed and implemented. This module uses Natural Language Processing techniques to analyze collected railway announcements and generate grammatically correct ISL sentences. Then the ISL sentences have been converted into the corresponding notation using the ISL dictionary, allowing for the creation of accurate synthetic animations. With computer-generated artificial human characters, realistic animations that visually represent ISL signals have been created. These synthetic animations were synchronized with the corresponding railway announcements and provided a comprehensive and accessible public announcement system for persons with hearing loss at railway stations. By revolutionizing the accessibility of train station announcements, this project aimed to empower people with hearing loss. Development of public announcement system at railway stations with ready animation in Indian Sign Language will not only enhance their travel experience but also promote inclusivity, independence and sense of belonging in public space. People with hearing loss will be able to move around railway stations with confidence and autonomy, ensuring they have equal opportunities to participate in society.

1.1. Background

The development of a public announcement system at railway stations using synthetic animations in Indian Sign Language for the hearing impaired addresses an urgent problem faced by hearing impaired people while accessing essential information at railway stations. This project recognized the challenges and communication barriers that hinder the inclusion and independence of the hearing impaired population in public spaces. The train stations serve as bustling transportation hubs, allowing the movement of millions of people every day. However, people with hearing impairments often face significant difficulties in accessing important messages and updates due to the primary reliance on hearing-based communication systems. The traditional announcement systems, which mainly appeal to people with intact hearing, constitute a significant barrier for those with a hearing impairment, and prevent them from receiving and understanding critical information such as train schedules, platform

changes, safety instructions and notifications regarding delays or cancellations. This communication gap significantly affects the autonomy and independence of people with hearing impairment when navigating train stations. This not only limits their ability to plan their trips effectively, but also poses safety risks. For example, they may miss important announcements about change of the platform, causing confusion, delays and potential accidents. Moreover, relying on written messages or requesting assistance from station staff may not always be effective or available, further exacerbating the communication challenges faced by the hearing impaired population.

To address these limitations and create an inclusive environment in railway stations, a public announcement system using Indian Sign Language synthetic animations utilizing the technological advancements and synthesis techniques of the Indian Sign Language has been developed. By leveraging these tools, the project aimed to revolutionize accessibility and ensure equal participation for people with hearing impairment. The existing methods of providing information to the hearing impaired population, such as written messages or assistance from the station staff, have inherent limitations. Written messages may not capture the nuance and immediacy of auditory messages, leading to potential misunderstandings or delays in receiving critical information. Relying only on station staff for assistance may not always ensure accurate and timely information, resulting in frustration and lack of independence for people with hearing loss.

In addition, an input text processing module has been designed and implemented to convert the collected train messages into grammatically correct ISL sentences. This module uses advanced Natural Language Processing techniques to extract relevant information and create accurate ISL sentences. The ISL sentences then has been converted into corresponding sign writing notation using an ISL dictionary, allowing accurate and life like synthetic animations to be created. Using computer-generated artificial human characters, the project uses engaging and visually accurate animations representing the ISL signs. These animations are synchronized with the corresponding train announcements and provide a comprehensive and accessible public announcement system for people with hearing impairments at railway stations.

1.2. Purpose of the document

The purpose of this document is to provide a comprehensive and detailed overview of the project "Development of a public announcement system at railway stations using synthetic

animations of Indian Sign Language for people with various hearing impairments" completed by Prof. Vishal Goyal, Principal Investigator, Professor, Department of Computer Sc, Punjabi University Patiala and Dr. Lalit Goyal, Co-PI, Associate Professor, Department of Computer Applications, DAV College, Jalandhar. It will serve as a reference guide for project stakeholders and anyone interested in understanding the project's goals, objectives, and implementation strategies. This document describes the objectives, methodologies and outcomes of the project. It provides a clear understanding of the meaning and potential impact of implementing a public announcement system that specifically addresses the communication needs of people with hearing impairments in train stations. The document also highlights the innovative use of Indian Sign Language (ISL) synthetic animations and technological advances to bridge the communication gap and improve accessibility.

1.3. Scope of the project

The scope of the project includes the following key components:

1. Collection of Announcements: The project involves gathering a comprehensive dataset of announcements typically used at railway stations. These announcements includes train schedules, platform changes, safety instructions, delays, cancellations, and other essential information.
2. ISL Dictionary Creation: The project entails creating an ISL dictionary using HamNoSys Notation, a standardized language for writing signs. The dictionary will encompass a wide range of ISL signs along with their corresponding representations, serving as a reference for accurate translation and synthesis of announcements into ISL.
3. Input Text Processing Module: The project involves designing and implementing an input text processing module that converts the collected railway announcements into grammatically correct ISL sentences. This module will employ natural language processing techniques to analyze the input text and generate accurate and contextually appropriate ISL sentences.
4. Conversion to Sign Writing Notation: The project includes the conversion of ISL sentences into equivalent Sign Writing Notation using the ISL dictionary. This step ensures the generation of precise and standardized representations of the signs, facilitating the synthesis of accurate synthetic animations.

It is important to note that while the project aims to develop a functional Public Announcements System, it does not encompass the physical infrastructure, such as the installation of display screens or audio systems at railway stations. The scope primarily revolves around the development of the software and the underlying technologies required for the synthesis and delivery of ISL-based announcements. Additionally, the project's scope encompasses testing, evaluation, and refinement of the developed system to ensure its usability, effectiveness, and user satisfaction. This includes conducting user feedback sessions, usability studies, and iterative improvements based on user input and requirements. It is crucial to adhere to the defined scope throughout the project's implementation to ensure its successful completion within the allocated resources, timeframe, and desired quality standards. Any changes or expansions to the scope should be carefully assessed, documented, and approved by relevant stakeholders to maintain project focus and alignment with the project's objectives.

2. Project Overview

The project "Development of Public Announcements System at Railway Stations using Indian Sign Language Synthetic Animations for Differently Abled Hearing Impaired People" is an innovative initiative that aims to enhance accessibility and inclusivity for individuals with hearing impairments at railway stations. The project recognizes the communication challenges faced by the hearing-impaired population when accessing critical information and aims to bridge the communication gap through the use of Indian Sign Language (ISL) synthetic animations.

2.1. Objectives of the project

Following are the main objectives of the project that were approved during the sanction of the project for grant. All the below approved objectives has been achieved and incorporated in the developed system.

i. To collect all the announcements used at the railway stations.
ii. To create the ISL dictionary using HamNoSys Notation (Language to write the signs).
iii. To create input text processing module that would convert the railway announcement into the ISL sentence.

iv. To convert the ISL sentence to equivalent Sign Writing Notation (HamNoSys notation) using ISL dictionary.

v. To create synthetic animation (using computer generated artificial human character).

2.2. Stakeholders

Stakeholders are individuals or groups who have a vested interest or involvement in a project. In the case of the project "Development of Public Announcements System at Railway Stations using Indian Sign Language Synthetic Animations for Differently Abled Hearing Impaired People," the stakeholders can be categorized as follows:

1. Individuals with Hearing Impairments: The primary stakeholders of the project are individuals with hearing impairments who rely on accessible communication systems at railway stations. They are the intended beneficiaries of the Public Announcements System, and their needs and preferences are at the forefront of the project's development and implementation.
2. Railway Authorities and Staff: Railway authorities, station managers, and staff members who operate and manage railway stations are important stakeholders. They play a crucial role in implementing and maintaining the Public Announcements System. Their collaboration and support are vital for the successful integration of the system into existing station infrastructure and operations.
3. Project Team and Developers: The project team and developers involved in the design, development, and implementation of the Public Announcements System are key stakeholders. Their expertise, skills, and contributions are instrumental in bringing the project to fruition. They are responsible for ensuring the system meets the needs of individuals with hearing impairments and aligns with the project objectives.
4. Sign Language Experts: Professionals with expertise in Indian Sign Language (ISL) are significant stakeholders in the project. They provide insights, guidance, and support in creating the ISL dictionary, ensuring accurate translation of announcements, and maintaining the linguistic integrity of the sign language used in the synthetic animations.

5. Government and Regulatory Bodies: Government agencies and regulatory bodies responsible for transportation and accessibility policies are stakeholders with an interest in the project's implementation. Their support, guidance, and compliance requirements are essential for the successful integration of the Public Announcements System into the existing railway infrastructure.
6. Funding Agencies: Entities providing financial support for the project, such as government grants, private foundations, or corporate sponsors, are stakeholders. They have a vested interest in the project's success and may require regular updates, progress reports, and accountability regarding the utilization of funds and achievement of project objectives.
7. General Public: The general public, including railway passengers and other members of society, are indirect stakeholders. The project aims to create a more inclusive and accessible environment, benefiting not only individuals with hearing-impairments but also fostering a greater understanding and acceptance of diverse communication needs.

2.3. Project Deliverables

The following are the deliverables of the project:

a. Railway Announcement System: The project delivers a fully functional railway announcement system in the form a website (https://iras.vishalpup.in/) that displays announcements in real time using synthetic animations. This system provides timely and accessible information to individuals with hearing impairments in their own language, Indian Sign Language (ISL). The system is designed to be user-friendly and easily navigable, ensuring a seamless communication experience.
b. ISL Dictionary: An ISL dictionary specifically tailored for the railway announcement system is developed. This dictionary contain approximately 5000 unique root words and 30,000 words that includes inflected words, synonyms etc. Corresponding to these words, signs related to railway announcements, covering a wide range of vocabulary necessary for effective communication in railway stations have been included. The dictionary serves as a reference for accurate translation and synthesis of announcements into ISL.

2.4 Benefits to User Group: The following are the benefits for the users:

Enhanced Accessibility: The railway announcement system will greatly improve accessibility for individuals with hearing impairments. It will provide them with real-time information in their own language, enabling them to stay informed about train schedules, platform changes, safety instructions, delays, and other important announcements. This will enhance their overall travel experience and empower them to navigate railway stations independently.

Consistent Synthetic Animations: The use of synthetic animations ensures that the visual representation of signs remains consistent regardless of the state of mind of the signer. Unlike human videos, which can vary in quality and expression, computer-generated animations provide a uniform and standardized communication experience for individuals with hearing impairments.

Efficient Data Storage and Transfer: Synthetic animations generated by computer algorithms consume less memory compared to human videos. This makes it more efficient to upload and download sign animations over the network, ensuring faster and smoother communication. Additionally, the use of coded signs in HamNoSys notation allows for efficient storage and editing of animations without relying on human videos.

Reduced Dependency on Interpreters: By converting written announcements into ISL sentences and subsequently into synthetic animations, the project reduces the dependency on sign language interpreters for communication. Individuals with hearing impairments can directly access the announcements in ISL, promoting greater independence and self-reliance.

Scalability and Adaptability: The proposed railway announcement system can be extended beyond railway stations to other public settings such as bus stands, airports, or any other location where public announcements are made. The technology and infrastructure developed for this project can be adapted and customized for different contexts, further enhancing accessibility for individuals with hearing impairments in various public gatherings.

In summary, the project's deliverables include a railway announcement system with real-time synthetic animations, an extensive ISL dictionary, and several benefits for the user group, such as improved accessibility, consistent animations, efficient data storage and transfer, reduced dependency on interpreters, and potential scalability to other

public announcement systems. These deliverables aim to empower individuals with hearing impairments, enabling them to access information effectively and participate fully in public spaces.

3. DATA COLLECTION AND DEVELOPMENT OF BILINGUAL ENGLISH-ISL DICTIONARY

3.1. Data Collection

To facilitate this project, a comprehensive compilation of announcements used in railway stations was required. As a result, these announcements were gathered through direct communication and visits to various railway stations. Multiple attempts were made to establish contact with Indian Railways for the collection of railway announcements. The announcements were obtained from a diverse range of 18 railway zones, namely: Central Railway, East Central Railway, East Coast Railway, Eastern Railway, Konkan Railway, North Central Railway, North-Eastern Railway, North Western Railway, Northeast Frontier Railway, Northern Railway, South Central Railway, South Coast Railway, South East Central Railway, South Eastern Railway, South Western Railway, Southern Railway, West Central Railway, and Western Railway. Additionally, field visits were conducted at Jalandhar, Ludhiana, Patiala, Ambala, and Amritsar Railway Stations to collect the necessary announcements. Subsequently, a consolidated and unique list of all the railway announcements was compiled based on the collected data..

3.2. TYPES OF ANNOUNCEMENTS

The announcements in this project are categorized into three types: Static Announcements, Dynamic Announcements, and Special Announcements, as depicted in Figure 1.

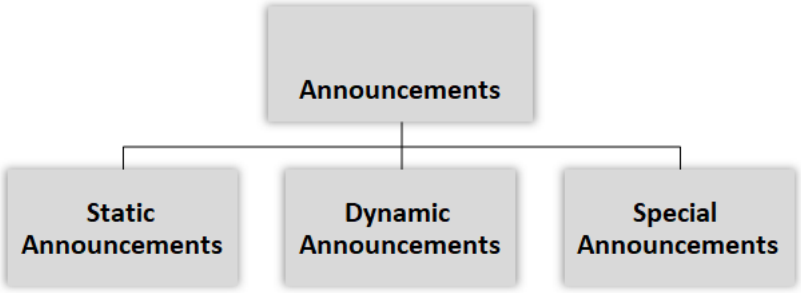


Figure 1. Types of Announcements

Static Announcements: Static announcements are fixed messages that remain unchanged. These announcements do not involve elements such as time, train numbers, train names, platform numbers, etc.

Dynamic Announcements: Dynamic announcements contain specific information such as time (in hours and minutes), train number, train name, source station/city name, destination station/city name, via station/city name, etc. These details may vary depending on the situation.

Special Announcements: Special announcements, also known as instant announcements, are not stored in the database. Instead, they are generated spontaneously during specific events like accidents or natural calamities. In reality, these announcements are promptly delivered by human operators in response to the situation.

3.3. COLLECTION OF RAILWAY ANNOUNCEMENTS

The collection of railway announcements involved ongoing communication with various railway zones of Indian Railways. Lists of railway announcements were periodically obtained from these zones, and a consolidated list was created, comprising all unique announcements. Subsequently, these announcements were categorized into static and dynamic announcements. In total, 159 railway announcements were gathered, with 137 classified as static railway announcements and 22 as dynamic railway announcements, as presented in Table 1.

Table 1. Statistics of Railway Announcements

Sr. No.	Railway Announcements	Number of Announcements
1.	Railway Static Announcements	137
2.	Railway Dynamic Announcements	22
	Total Railway Announcements	159

3.3.1. Static railway announcements

The 137 static railway announcements have been further classified into eight distinct categories, namely Precautionary/Safety, Cleanliness Instructions, Refreshment Instructions, Tickets Instructions, Greetings, Baggage Safety Instructions, General Instructions, and Announcements, as outlined in Table 2. This categorization allows for better organization and analysis of the static railway announcements.

Table 2. Categories of Static Railway Announcements

Sr. No.	Static Railway Announcements	Number of Announcements
1	Precautionary/Safety Announcements	31
2	Cleanliness Instructions Announcements	11
3	Refreshment Instructions Announcements	7
4	Tickets Instructions Announcements	17
5	Greetings Announcements	10
6	Baggage Safety Instructions Announcements	3
7	General Instructions Announcements	19
8	Miscellaneous	39
	Total Static Announcements	137

Some examples of the static railway announcements have been given in Table 3.

Table 3. Examples of Static Railway Announcements

Category	Static Railway Announcements
Precautionary Announcements	Inflammable materials are prohibited.
	Suspicious articles are prohibited on station.
	Do not entrain while train in motion.
Cleanliness Announcements	Passengers please do not spit in train or station premises.
	Please do not use toilet while the train is on station.
	Do not throw a waste material around please use the dustbins provided.
Refreshment Announcements	Buy eatables from station vendors. Please do not accept eatable from strangers.
	Catering facilities are available in the station.
	Veg and Non veg catering facility available
Ticket Instructions Announcements	Apart from being socially evil, ticketless travelling is also punishable offense.
	Please make sure that you have proper ticket with you while travelling.
	Please carry a valid platform ticket of travel ticket while entering the platform.
Greetings Announcements	Wish you a happy journey.
	Thank you for keeping the emergency window shutter closed during travel.
	Thank you for not using the mobile phone near the doors during travel.
General Announcements	Switch off fans and light's while not in use.
	Use foot over bridge to go from one Platform to another.
	Do not encourage the beggars.
	Do not pull chain without proper reason.

3.3.2. Dynamic railway announcements

Likewise, the 22 dynamic railway announcements have been classified into seven distinct categories: Train Arrival, Train Departure, Delayed Trains, Available Trains, Train Rescheduling, Train Cancellation, and Announcements, as indicated in Table 4. This categorization enables a systematic analysis and understanding of the dynamic railway announcements.

Table 4. Examples of Static Railway Announcements

Sr. No.	Dynamic Railway Announcements	Number of Announcements
1	Train Arrival Announcements	7
2	Train Departure Announcements	3
3	Available Trains Announcements	3
4	Delayed Trains Announcements	2
5	Train Rescheduling Announcements	2
6	Train Cancellation Announcements	2
7	Miscellaneous	3
	Total Dynamic Announcements	22

Some examples of the dynamic railway announcements have been given in the Table 5.

Table 5. Examples of Dynamic Railway Announcements

Category	Railway Dynamic Announcements
	Passengers your attention please. Train number.....(Train Name) … From .....to.....Via …... is just arriving on platform number.....
	Train number..... (Train name)… From .....to..... Via…will arrive shortly on platform number ..... Keep away from platform edges.

Train Arrival Announcements	Passengers your attention please. Train number .....(Train name)…... from .....to..... via..... is expected to arrive at ..... hrs on platform number ……
Train Departure Announcements	Passengers your attention please. Train number.....(Train Name)…....from .....to..... will leave from platform number .....
	Passengers your attention please. Train number .....(Train name) ……. from ..... will leave shortly from platform number …….
Available Trains Announcements	Passengers your attention please. Train number .....(Train name)…... From... to….. in now available on platform number …….
	Passengers your attention please. Train number.....(Train name)…... from.....has arrived on Platform number …
Delayed Trains Announcements	Passengers your attention please. Train number .....(Train Name)…..From .....to.....Via… is running late by ..... and is expected to arrive at.....
	Train number..... (Train Name) … From..... to.....Via……. is running late by ..... Inconvenience caused to passengers is regretted.
Train Rescheduling Announcements	Passengers your attention please. Due to operational reasons, Train number..... (Train Name)….. From..... to.....Via…….. scheduled to depart on..... will leave only at.....
	Passengers your attention please. Due to late arrival of pairing train, Train number..... (Train name)….....From.....to.....Via... scheduled to depart on ..... hrs will leave only at.....
Train Cancellation	Passengers your attention please. Train number ……. (Train name) ……. from ……. to ……. schedule to leave at ……. is cancelled. The inconvenience caused is regretted.
	For your kind attention, please train number… (Train name)… is

Announcements	cancelled today. Inconvenience caused is deeply regretted.

Furthermore, for the research study, the names of cities where railway stations are located in India, along with their corresponding station codes, have been compiled. A comprehensive list of 10,656 railway station names and their respective codes has been gathered, as presented in Table 6.

Similarly, the names of trains operating in India, along with their corresponding train codes, have also been collected. A total of 14,100 train names and their respective codes have been compiled, as shown in Table 6. These data sets provide valuable information for the research study and its analysis.

Table 6. Statistics of Railway Stations and Train Names

Sr. No.	Category	Number
1.	Railway Station Names with Station Codes	10656
2.	Train Names with Train Codes	14100

3.4. Development of Bilingual English-ISL Announcements Database

The collected announcements were meticulously translated into Indian Sign Language (ISL) while adhering to the grammatical rules of ISL. Both static and dynamic announcements were accurately converted into their respective ISL counterparts, resulting in the creation of a bilingual English-ISL corpus. Indian Sign Language teachers and interpreters provided assistance during the translation process. A parallel ISL version of each announcement was generated. In total, 137 static railway announcements and 22 dynamic railway announcements were transformed into ISL. Examples from the developed bilingual English-ISL static announcements database and dynamic announcements database can be found in Table 7 and Table 8, respectively.

Table 7. Examples of Bilingual English-ISL Static Announcements Database

Static Announcement in English	Static Announcement in ISL
Smoking is strictly prohibited.	Smoking prohibited.

Track crossing is punishable.	Track crossing punishable.
Be careful of your pocket.	Your pocket careful.
Do not entrust strangers.	Strangers entrust not
Lady passengers to avoid windows and doors	Lady passengers' windows and door avoid
Take care of your children during travel	Children travel during take care
Do not touch suspicious articles	Suspicious things touch not
Short distance passenger do not enter reservation coach.	Passenger short distance reservation coach. enter not
Cigarette smoking at the platform is punishable.	Platform smoking punishable.
Do not encourage beggars.	Beggars encourage not.
Passengers are requested not to travel between trains and coaches.	Passenger requested coach and train between travel not
Do not pull chain without proper reason.	Chain pull without reason. Not
Use parking on station	Station parking use
Use toilet on station	Station toilet use
Wish you a happy journey	Journey happy

Table 8. Examples of Bilingual English-ISL Dynamic Announcements Database

Dynamic Announcement in English	Dynamic Announcement in ISL
Passengers your attention please. Train number..... (Train Name) ……. From .....to.....Via …….. is just arriving on platform number------- --.	Passengers attention Train number..... (Train Name)……. From ..... to .....via …… platform number…. Arriving
Passengers your attention please. Train number..... (Train Name)….. From .....to.....Via…..... is running late by ..... Inconvenience caused to passengers is regretted.	Passengers attention train number.....(Train Name) …….. from ..... to.....Via …….. delay .....Passengers inconvenience apologize.

The “Mahila” helpline number …… is Available.	Mahila helpline number …… Available.
Police Helpline Number …… is Available.	Police Helpline Number…… Available.
Child Helpline Number …… is Available.	Child Helpline Number.....Available.

4. Development of Bilingual English-ISL Dictionary

The translation process from a source language to a desired target language requires the availability of a bilingual dictionary, which facilitates the translation of English textual data into Indian Sign Language (ISL). However, creating a bilingual dictionary between English and ISL poses unique challenges. Unlike existing bilingual dictionaries for spoken languages, the bilingual English-ISL dictionary is distinct. This is primarily because ISL is a visual-spatial language that can only be expressed through gestures rather than written or spoken words. Consequently, the written form of the counterpart ISL word for each English word is not readily available.

In the bilingual English-ISL dictionary, various approaches are used to represent ISL counterparts for English words. These approaches include pre-recorded human videos, sign images, coded sign language textual forms, or synthetic animations. Each approach has its own advantages and disadvantages. However, synthetic animation is particularly well-suited for translating spoken languages into sign language within a machine translation system. Synthetic animations are more realistic compared to sign images and coded sign text, and they are easily supported by machine translation systems. Hence, synthetic animations have been generated for each English word in this translation system. Written forms or sign glosses have been utilized to create synthetic animations for each English textual word. While it is not possible to represent a three-dimensional sign in written form, researchers have developed notation systems to capture the essence of three-dimensional signs in writing. In this machine translation system, the HamNoSys (Hamburg Notation System) notation system has been employed to construct the bilingual English-ISL dictionary. HamNoSys Notation comprises an alphabet set of approximately 200 symbols that encompass hand shapes, hand locations, hand orientations, palm orientations, hand movements, and all non-manual features of signs. The basic structure of HamNoSys notation is illustrated in Figure 2.

Subsequently, these HamNoSys notations can be converted into SiGML (Signing Gesture Markup Language) code, which is a type of XML tag that can be animated using the JASigning animation app. The process of generating sign animations from English words is outlined in Figure 3.

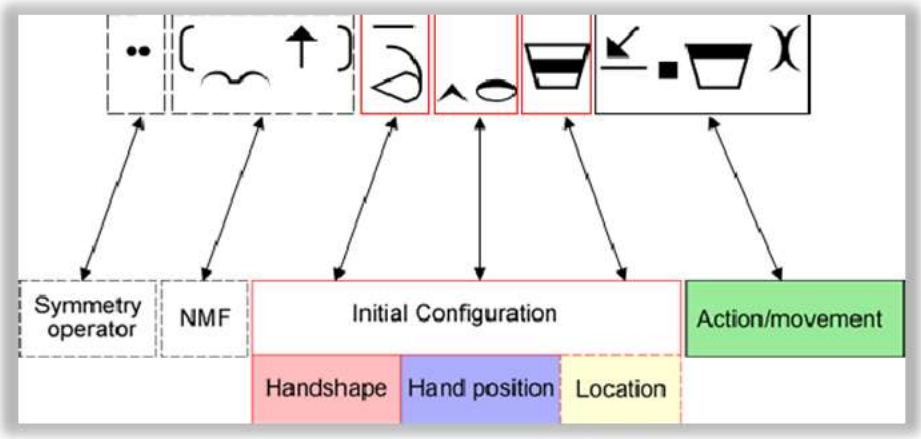


Figure 2. Structure of HamNoSys Notation

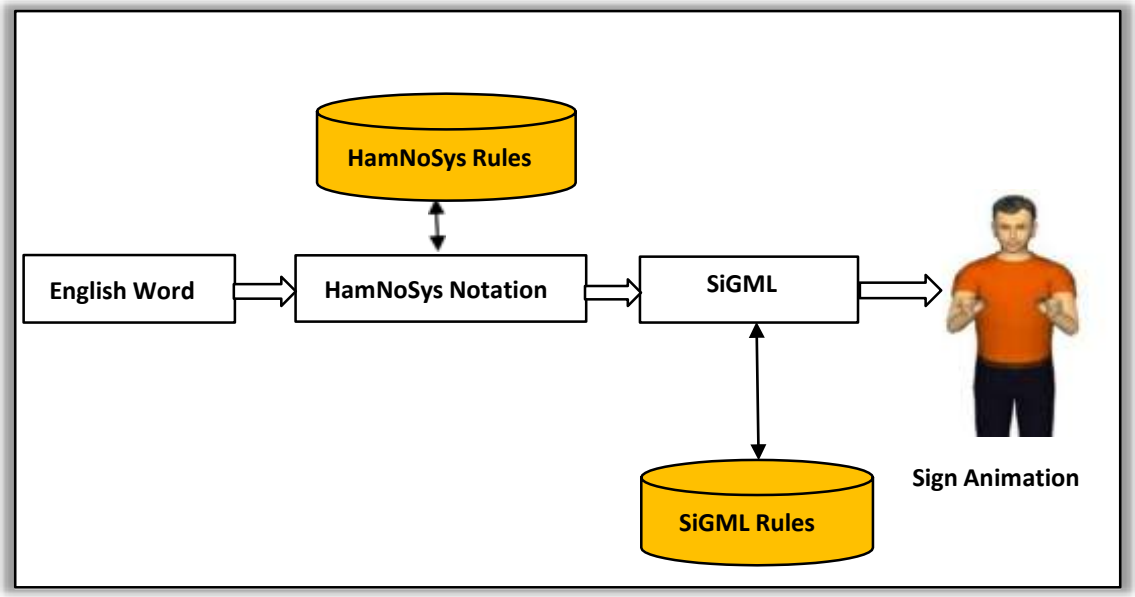


Figure 3. Process of Generating Sign Animations from the English Word

4.1. QUICK OVERVIEW OF eSIGN EDITOR

The eSign Editor is a specialized tool developed to facilitate the generation of signs, including HamNoSys notation. This tool simplifies the process of creating signs by providing

a scrollable dialogue of symbols within the editor. By clicking a button, users can preview the sign as an animation using the SiGML Player within the same tool. The eSign Editor utilizes a graphical user interface (GUI) for composing sign text using HamNoSys notation. The sign text, represented in HamNoSys notation, can be animated using a 3D avatar within the eSign Editor tool. The tool is available for both Windows and Mac OS and offers three language interfaces: English, Dutch, and German. It includes a database that contains the pronunciation of numerous words, aiding in the description of mouth images, gestures, and lip movements. During the creation or modification of sign text, users can easily crosscheck the content by sending the HamNoSys code to the 3D avatar with the press of a button.

In order to play the sign using an avatar, the animation tool requires SiGML tags. These tags are automatically generated and transmitted to the animation tool by pressing a button. Once the coding (HamNoSys) part of a sign is completed, it can be saved within the eSign Editor's database, which contains a lexicon, or it can be saved separately in an independent database for future use.

4.2. BILINGUAL ENGLISH-ISL DICTIONARY STATISTICS

From the collected lists of railway announcements, distinct words were identified and converted into Indian Sign Language (ISL). With the assistance of an ISL interpreter, videos of each individual word were recorded, resulting in a total of 1,504 human videos. Among these videos, 246 unique words were derived from the collected railway announcements.

To expand the database used in the translation system, additional information related to railways was collected online. From this collected information, 7,890 unique words were extracted. Therefore, an extended database comprising 9,340 unique words was prepared, and videos of each individual word were recorded with the help of an ISL interpreter.

After recording the videos, HamNoSys notations were coded for 3,322 words. For the remaining words, 4,052 synonyms were identified and used in place of words for which HamNoSys notations had not been created. Subsequently, HamNoSys notations were coded for 1,019 words from the identified synonyms of the announcements. In total, 4,341 words were coded into HamNoSys notations.

These HamNoSys notations were then converted into SiGML files. Each sign included all manual and non-manual components, such as face expressions, body movements, eye gaze, mouth movements, blinking of eyes, shoulder movements, etc. The developed bilingual English-ISL dictionary comprises 4,341 words. The statistics of these coded words are

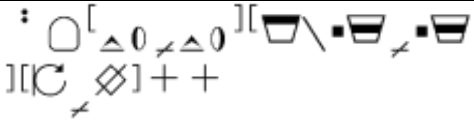
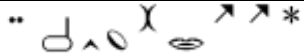
presented in Table 10 and Figure 11.

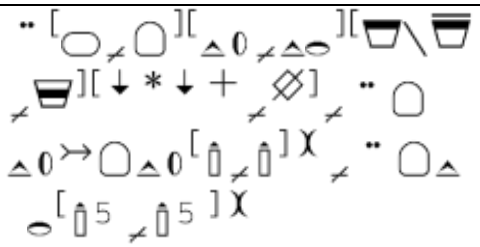
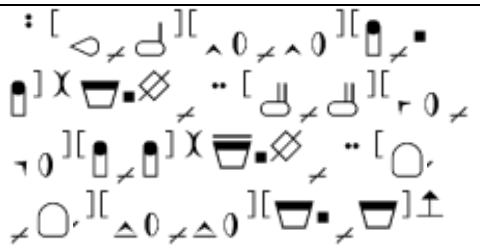
Table 10. Statistics of Bilingual English-ISL Dictionary

Word Category	No. of Words
Adjective	859
Adverb	374
Article	4
Conjunction	4
Interjection	7
Noun	1655
Prefix	20
Preposition	10
Pronoun	76
Verb	1332
Total No. of Words	4341

The snapshots of sign animations with their HamNoSys notations of some English wordshave been given in Table 11.

Table 11. Snapshots of Some English Words with HamNoSys Notations

Words	HamNoSys Notation	Snapshot of Animation
Railway		
Announcements		

Passengers		
Platform		

5. DESIGN AND IMPLEMENTATION OF THE SYSTEM

To ensure the success of the announcement system in translating English announcements/sentences into Indian Sign Language (ISL), it is crucial to have a strong grasp of both the lexical and syntactic aspects of ISL and English language. In order to develop the announcement system in ISL, it is necessary to construct comprehensive grammar rules specific to Indian Sign Language. To accomplish this, thorough study and analysis of Indian Sign Language is undertaken. This involves examining the linguistic structure, syntactic patterns, and grammatical features of ISL. By studying the language in detail, the grammar rules governing ISL can be identified and formulated. The development of ISL grammar rules plays a fundamental role in accurately translating English announcements into ISL, ensuring that the resulting signs adhere to the grammatical principles and syntax of ISL.

5.1. Development of ISL Grammar Rules

When two spoken languages are closely related, such as Hindi and Punjabi, translation between them is relatively simple due to their similar grammar and vocabulary. However,

when the grammar rules of the source and target languages differ significantly, translation becomes much more challenging. This complexity is further amplified when the target language is a sign language, which is visual and spatial in nature, while the source language is a spoken language. To ensure accurate translation between English and Indian Sign Language (ISL), it is necessary to compare and contrast their grammar rules. This allows for a deeper understanding of the linguistic structures and syntactic patterns specific to each language before attempting translation.

In the case of special or instant announcements that are not available in the existing bilingual English-ISL announcements database, the need for ISL grammar rules becomes crucial. To translate these special announcements into ISL, the study of 20 verb patterns and consultation with an ISL teacher were undertaken to devise the necessary grammatical rules. A total of 42 new grammar rules were developed for translating simple sentences into ISL, while 30 existing rules were reformed to improve accuracy. As a result, the announcement system incorporates a total of 72 ISL grammatical rules for translating simple sentences.

Given the potential complexity and compound nature of randomly generated announcements/sentences, additional grammatical rules were implemented to convert complex and compound sentences into simple sentences. Specifically, 49 rules were drafted for converting complex sentences to simple sentences, and 20 rules were drafted for converting compound sentences to simple sentences. Consequently, a total of 141 rules have been implemented in the announcement system to effectively translate announcements into Indian Sign Language, as depicted in Table 12.

Table 12. Statistics of Grammar Rules

Sr. No.	Grammar Rules	No.
1	Simple Sentences to Indian Sign Language	72
2	Compound Sentences to Simple Sentences	20
3	Complex Sentences to Simple Sentences	49
	Total Rules used in System	141

Some examples of developed ISL grammar rules have been given below:

i. English Grammar Rule

Subject + is/are/was/were + Adjective + Adverb+ Object

Example Sentence: Scooter is useless without petrol.

Creation of ISL Grammar Rule

Subject + Adverb + Object + Adjective

Output ISL Sentence: Scooter without petrol useless.

ii. English Grammar Rule

There+ is/are/was/were + Subject + Preposition + Object

Example Sentences: (a) There are plates in the kitchen.

(b) There are books in the library.

Creation of ISL Grammar Rule

There + Object + Subject

Output ISL Sentences: (a) There kitchen plates.

(b) There library books.

In the first rule, linking verbs *is/are/was/were* are removed and *Adjective* is placed at the end of ISL Sentence. In the second rule, linking verbs *is/are/was/were* and *Preposition* are removed and then *Subject* is placed at the end of ISL Sentence.

Some examples of reformed ISL grammar rules are given below:

iii. English Grammar Rule

Subject + Verb + Noun/Pronoun + Adjective

Example Sentences: (a) She washed the plates clean

(b) He turned the lamp low

Reformation of ISL Grammar Rule

Old Rule: *Subject + Noun/Pronoun + Adjective + Verb* New Rule: *Subject + Noun/Pronoun + Verb + Adjective*

Output ISL Sentences: (a) She plates washed clean

(b) He lamp turned low

In the above *old grammar rule* of ISL, *Adjective* was being placed before *Verb* but *Adjective* must be placed at the end of these ISL Sentences according to *new grammar rule*.

iv. English Grammar Rule

Subject + Verb + noun/pronoun + Plain Infinitive

Example Sentence: (a) We saw train coming

(b) I saw him going out

v. Reformation of ISL Grammar Rule

Old Rule: *Subject + Noun/Pronoun + Verb + Plain Infinitive*

New Rule: *Subject + Noun/Pronoun + Plain Infinitive + Verb*

Output ISL Sentences: (a) We train coming saw

(b) I him going out saw

In the above *old grammar rule* of ISL, *Verb* was being placed before *Plain Infinitive* but *Verb* must be placed at the end of these ISL Sentences according to *new grammar rule*.

5.2. Architecture of Announcement System

As previously mentioned, announcements can be categorized into three types: static, dynamic, and special announcements. Static announcements remain unchanged, while dynamic announcements require the inclusion of dynamic information such as time, train

number, train name, source station name, destination station name, and via station name. Special announcements, on the other hand, are randomly generated and occur during specific events such as accidents or natural calamities. The rule-based announcement system developed in Indian Sign Language (ISL) is designed to handle all three types of announcements.

The overall architecture of the ISL announcement system is depicted in Figure 4. It comprises three main modules, which will be discussed in the following sections.

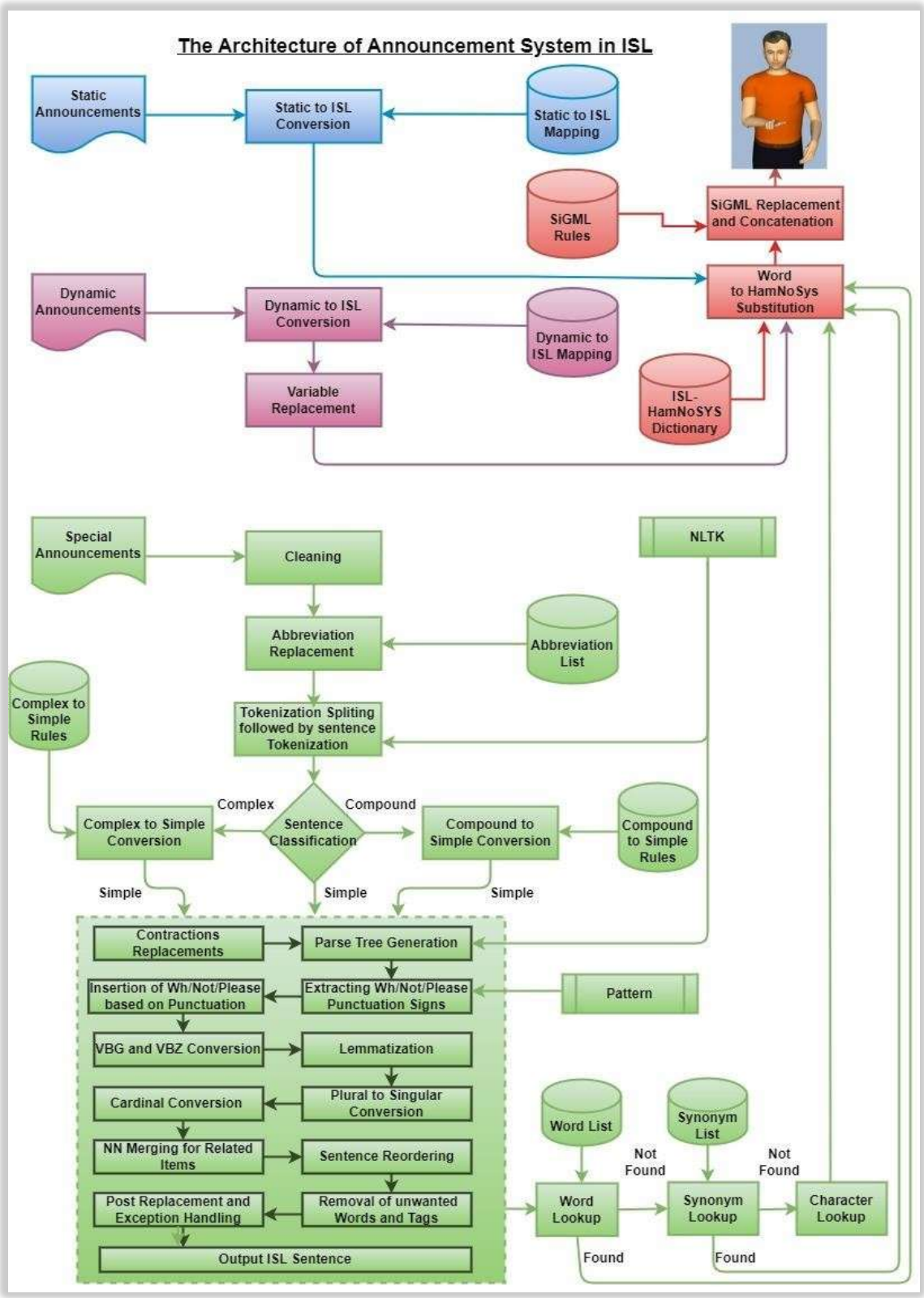


Figure 4. Architecture of the Announcement System in ISL

5.3. STATIC ANNOUNCEMENTS MODULE

This module is responsible for handling and displaying static announcements from railway stations, airports, and bus stands in Indian Sign Language through the use of a three-dimensional avatar. A total of 441 static announcements have been collected, comprising 256 airport announcements, 137 railway announcements, and 48 bus announcements. These static announcements have been translated into their corresponding Indian Sign Language counterparts, and a bilingual English-ISL corpus has been developed following ISL grammar rules with the assistance of an Indian Sign Language teacher. In the system, these announcements are preloaded, and when a specific announcement is selected, the system maps it to its corresponding ISL counterpart from the developed bilingual corpus.

After mapping, the ISL sentence is passed to the Word-HamNoSys Substitution submodule, where each word in the resulting sentence is replaced with its corresponding HamNoSys notation from the Word-HamNoSys dictionary. The SiGML code is then generated from the HamNoSys notation string, and the sentence is ready to be animated. The SiGML code is sent to the SiGML animation tool, which plays the synthetic animation of the announcement.

For Example

Input: Do not entrain when the train is in motion.

System Output: Train motion entrain not.

Input: Please use the dustbins provided.

System Output: dustbins use.

Input: Wish you a happy journey.

System Output: Journey happy.

5.4. DYNAMIC ANNOUNCEMENTS MODULE

This module is responsible for handling and displaying dynamic announcements from railway stations in Indian Sign Language using a three-dimensional avatar. A total of 22 dynamic announcements have been collected, which require variable replacements such as time (in hours and minutes), train number, train name, source station name, destination station name, via station name, etc.

These dynamic announcements have been translated into their corresponding Indian Sign Language counterparts, and a bilingual English-ISL corpus has been created following ISL grammar rules with the assistance of an Indian Sign Language teacher. In the system, these announcements are preloaded, and when a specific announcement is selected, the system maps it to its ISL counterpart from the bilingual corpus.

After mapping, the variables within the announcement, such as time, train number, station names, etc., are replaced accordingly. The resulting ISL sentence is then passed to the Word-HamNoSys Substitution submodule, where each word is replaced with its equivalent HamNoSys notation from the Word-HamNoSys dictionary. The SiGML code is generated from the HamNoSys notation string, and the sentence is ready to be animated.

Finally, the SiGML code is sent to the SiGML animation tool, which plays the synthetic animation of the dynamic announcement in Indian Sign Language.

For Example

Input: Passengers your attention please. Train number ..... (Train Name) ……. From .....to.....via …….... is just arriving on platform number ……..

The following variables need to be replaced in above announcement:Train Number: 12925
Train Name: Paschim Express
Source Station Name: Mumbai Central
Destination Station Name: Amritsar
Via: New Delhi
Platform Number: 2
After replacement of above variables, the announcement will look like as given below:

Input after replacements of variables: Passengers your attention please. Train number *12925 Paschim Express* from *Mumbai Central* to *Amritsar* via *New Delhi* is just arrivingon platform number 2.

In the above announcement, the user needs to select train number and then variables like train name, source station name and destination station name will be prefilled automatically except the variables *via* and platform number. Variable *via* can also be selected from dropdown list. User just needs to enter platform number manually and then the system will generate the following ISL output.

System Output: Passengers' attention Train number *12925 Paschim Express* from *Mumbai Central* to *Amritsar* via *New Delhi* platform number *2* Arriving.

For Example

Input: Passengers your attention please. Train number ..... (Train Name) .....from.....

The following variables need to be replaced in above announcement:Train Number: 12925
Train Name: Paschim Express
Source Station Name: Mumbai Central
Destination Station Name: Amritsar
Via: New Delhi
Hours: 5
Time: 16:30
After replacement of above variables, the announcement will look like as given below:

In the above announcement, the user needs to select train number and then variables like train name, source station name and destination station name will be prefilled automatically except the variables *via,* hours and time. Variable *via* can also be selected from dropdown list. User just needs to enter hours and time manually and then system willgenerate the following ISL output.

System Output: Passengers attention train number *12925 Paschim Express* from *Mumbai Central* to *Amritsar* via *New Delhi* delay 5 hours expected arrive 16:30.

5.5. SPECIAL ANNOUNCEMENTS MODULE

In this module, the system handles and displays special announcements that are generated instantly on special occasions, such as accidents or natural calamities, at railway stations. Unlike static and dynamic announcements, special announcements are not available in the developed bilingual English-ISL announcements database. Instead, these announcements are generated on the spot by human operators in response to the situation. To handle these special announcements and convert them into Indian Sign Language, the system utilizes the Sentence Processing Module. This module is further divided into several sub-modules, each designed to address different situations encountered during the conversion of textual data into ISL. Before the special announcements are processed by the Sentence Processing Module, a cleaning process may be applied to the announcements/sentences if necessary. This cleaning process helps ensure that the textual data is in a suitable format for further processing and translation into Indian Sign Language.

5.5.1. Cleaning of input sentence

During the initial phase of processing special announcements or sentences, a cleaning process is implemented to eliminate any non-English words, excluding cardinal numbers, and to rectify any potential spelling errors. This step ensures that only relevant English words remain in the announcement or sentence, preparing it for further analysis and translation into Indian Sign Language.

For Example

Input: Do not carry inflammable articles in trains; it is a public offense.@
Output: Do not carry inflammable articles in trains; it is a public offense.
Note: @ symbol which was wrongly entered is removed after cleaning.

5.5.2. Abbreviation replacement in input sentence

Once the announcement has been cleaned, the next step involves checking for the presence of any abbreviations. If an abbreviation is identified, the system refers to the abbreviation database to find its corresponding short form. The abbreviation is then replaced with its short form in the announcement. To facilitate this process, a comprehensive database containing 3086 abbreviations has been created and integrated into

the announcement system. This ensures that all abbreviations are accurately expanded to their short forms for effective communication in Indian Sign Language.

For Example

Reservation Against Cancellation will be replaced abbreviation as *RAC*. *Air Conditioned* will be replaced abbreviation as *AC*.

State Bank of India will be replaced as SBI Bank

Chair Car will be replaced as *CC*

5.5.3. Sentence tokenization of input sentence

This sub module will split the sentence and then tokenize it with the help of NLTK (Natural Language Toolkit) Module.

For Example

Input: Do not carry inflammable articles in trains; it is a public offense.

Output:

i. Do not carry inflammable articles in trains.

ii. It is a public offense.

In the above announcement, this module tokenizes the sentence and categorizes it as two sentences.

5.5.4. Sentence identification of input sentence

In this sub module with the help of NLTK Module it is identified that whether this sentence is simple, compound, or complex.

i. If the sentence is simple, then it is directly passed to the Sentence Processing Module. *(72 Simple to ISL grammatical rules have been developed)*

ii. If the sentence is compound, then it is passed to Compound to Simple Conversion Module for conversion into simple sentence, and then is passed to Sentence Processing Module. (*20 Compound to Simple Sentence grammatical rules have beendrafted*)

iii. If the sentence is complex, then it is passed to Complex to Simple Conversion Module for conversion into simple sentence, and then is passed to Sentence Processing Module. (*49 Complex to Simple Sentence grammatical rules have been drafted*)

5.5.5. Sentence processing module

The Sentence Processing Module consists of several sub-modules that work together to generate the final ISL sentence output. These sub-modules perform various tasks to ensure accurate and grammatically sound ISL sentences. The activities carried out in this module include replacing contractions, creating a parse tree, extracting and inserting Wh-words, negation markers, politeness markers, and punctuation signs, converting VBG and VBZ forms, lemmatizing words, converting plural to singular nouns, converting cardinal numbers, merging named nouns for related items, reordering sentences, removing unnecessary tags and words, handling special cases, and generating the ISL sentence output. These activities collectively ensure that the input sentence is transformed into a well-formed and understandable ISL sentence, suitable for display using the SiGML animation tool.

i. Contractions replacement sub module

In this module, first of all, all the contractions if any, used in the sentence are replaced with its full phrase.

For Example

We’re going to evacuate the Railway Station soon due to Emergency Alert.

In the above announcement, Contraction *We’re* will be replaced with *We are*.

ii. Parse tree generation module

Obtaining the grammatical structure of the source language is crucial for rule-based translation, as it enables the rearrangement of words in accordance with the grammar rules of the target language. Parsing is a process that helps in understanding the grammatical structure of a sentence. In this research, parsing is performed using third-party software called the Stanford Parser, which utilizes unlexicalized PCFG (Probabilistic Context-Free

Grammar). The parser is trained using hand-parsed sentences, allowing it to learn and apply its knowledge to parse new sentences. The Stanford Parser generates three different outputs, providing valuable information about the syntactic structure and dependencies within the English language sentences.

- Part-of-Speech tagged text
- Context Free Phrase Structure Grammar Representation
- Type Dependency Representation

In this project work, context free phrase structure grammar representation has been used. As rule based approach needs the grammatical structure of the English sentence for the conversion into the target language's grammatical structure sentence. Furthermore, English sentence's part-of-speech plays very important role when it is needed to look up for the interrogative and negative nature of the sentence. To parse the inputted sentence into context free phrase structure grammar form, Penn Tree bank tag set is employed by Stanford Parser.

Penn Tree bank tag set is applied at three levels:

- Clause Level
- Phrase Level
- Word Level

Considering the type of clause, five tags have been utilized at the clause level as shown in Table 13.

Table 13. Clause Level Penn Treebank Tags

Clause Level Tag	Description
S	Simple declarative clause, i.e. one that is not introduced by a (possible empty) subordinating conjunction or a wh word and that does not exhibit subject verb inversion.
SBAR	Clause introduced by a (possibly empty) subordinating conjunction.
SBARQ	Direct question introduced by a wh word or a wh phrase. Indirect questions and relative clauses should be bracketed as SBAR, not SBARQ.
SINV	Inverted declarative sentence, i.e. one in which the subject follows the tensed verb or modal.
SQ	Inverted yes/no question, or main clause of a wh question, following the wh phrase in SBARQ.

Considering upon phrase level, 21 tags have been considered to use upon the type of phrase occurring within the clause as shown in Table 14.

Table 14. Phrase Level Penn Treebank Tags

Phrase Level Tag	Description
ADJP	Adjective Phrase
ADVP	Adverb Phrase
CONJP	Conjunction Phrase
FRAG	Fragment
INTJ	Interjection. Corresponds approximately to the part of speech tag UH.
LST	List marker. Includes surrounding punctuation.
NAC	Not a Constituent; used to show the scope of certain prenominal modifiers within an NP.
NP	Noun Phrase

NX	Used within certain complex NPs to mark the head of the NP. Corresponds very roughly to N-bar level but used quite differently.
PP	Prepositional Phrase
PRN	Parenthetical
PRT	Particle. Category for words that should be tagged RP.
QP	Quantifier Phrase (i.e. complex measure/amount phrase); used within NP.
RRC	Reduced Relative Clause
UCP	Unlike Coordinated Phrase
VP	Verb Phrase
WHADJP	*Wh* adjective Phrase. Adjectival phrase containing a *wh* adverb, as in how hot.
WHAVP	*Wh* adverb Phrase. Introduces a clause with an NP gap. May be null or lexical, containing a *wh* adverb such as how or why.
WHNP	*Wh* noun Phrase. Introduces a clause with an NP gap. May be null or lexical, containing some *wh* word, e.g. who, which seat, none of which, or how many airports.
WHPP	*Wh* prepositional Phrase. Prepositional phrase containing a *wh* noun phrase (such as of which or by whose authority) that either introduces a PP gap or is contained by a WHNP.
X	Unknown, uncertain, or unbracketable. X is often used for bracketing typos and in bracketing the...the constructions.

Considering upon word level, 36 tags have been considered to use depending upon thePOS of the word occurring within the sentence as shown in Table 15.

Table 15. Word Level Penn Treebank Tags

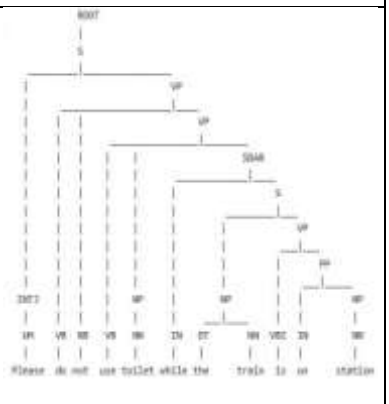
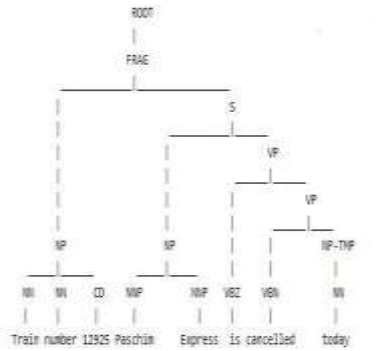
Word Level Tag	Description
CC	Coordinating conjunction
CD	Cardinal number
DT	Determiner
EX	Existential *there*

FW	Foreign word
IN	Preposition or subordinating conjunction
JJ	Adjective
JJR	Adjective, comparative
JJS	Adjective, superlative
LS	List item marker
MD	Modal
NN	Noun, singular or mass
NNS	Noun, plural
NNP	Proper noun, singular
NNPS	Proper noun, plural
PDT	Pre-determiner (precede article or possessive pronoun)
POS	Possessive ending
PRP	Personal pronoun
PRP$	Possessive pronoun
RB	Adverb
RBR	Adverb, comparative
RBS	Adverb, superlative
RP	Particle(word having no meaning in sentence)
SYM	Symbol
TO	*To*
UH	Interjection (always followed by !)
VB	Verb, base form
VBD	Verb, past tense
VBG	Verb, gerund or present participle
VBN	Verb, past participle
VBP	Verb, non-3rd person singular present
VBZ	Verb, 3rd person singular present
WDT	*Wh*-determiner
WP	*Wh*-pronoun
WP$	Possessive *Wh*-pronoun

WRB	*Wh*-adverb

The Context Free Phrase Structure Grammar Representation is generated by the Stanford Parser as a tree structure. Although there is also a tree traversal form, the tree representation is simpler to understand and is more practical for word or phrase reordering. Few instances of announcements that have been parsed are shown in Table 16.

Table 16. Examples of Parsed Tree Structure of English Announcements

Sentence	Inline Parsed Structure	Parsed Tree Structure
Please do not use toilet while the train is on station	(ROOT (S (INTJ (UH Please)) (VP (VB do) (RB not) (VP (VB use) (NP (NN toilet)) (SBAR (IN while) (S (NP (DT the) (NN train)) (VP (VBZ is) (PP (IN on) (NP (NN station))))))))))	
Train number 12925 Paschim Express is cancelled today.	(ROOT (FRAG (NP (NN Train) (NN number) (CD 12925)) (S (NP (NNP Paschim) (NNP Express)) (VP (VBZ is) (VP (VBN cancelled) (NP-TMP (NN today)))))))	

5.5.6. Wh/Not/Please and Punctuations Signs Extraction & Insertion Sub Module

After the parsing of the sentences, all the Wh/Not/Please and punctuations signs are extracted with help of Pattern Module and are inserted at its appropriate place in the sentence.

For Example

Input: when train departs?

System Output: train departs when

In the above sentence, *When* is placed at the end of sentence according to ISL grammar rules.

For Example

Input: Please buy a journey ticket.

System Output: Journey ticket buy please.

In the above sentence, *Please* is placed at its appropriate place according to ISL grammar rules.

5.5.7. VBG and VBZ Conversion Sub Module

The sentences in Indian Sign Language contain only the root words. All the present continuous and past verbs used in the inputted sentence are converted into present form with the help of VBG and VBZ Conversion Module.

For Example

We are going to evacuate the Railway Station.

In the above sentence, *Going (VBG)* will be replaced by *Go (Root Form)*.

5.5.8. Lemmatizer Sub Module

As only root words are used in Indian Sign Language sentences, so all of the words mustnot be inflexions of other words, gerunds, or suffixes. When a word in an ISL phrase is found as not the root word, the stemmer and lemmatization rules are used to transform the word into the root word. The ISL sentence's words are stemmed using the Porter Stemmer[95]. Now, the resultant ISL sentence only contains the root words only after converting the word inflections to their corresponding root forms.

For Example

Input: Passengers are advised not to carry inflammables in train.

In the above sentence, *advised (VBN)* will be replaced by *advise (Root Form).*

5.5.9. Plural to Singular Conversion Sub Module

In Indian Sign Language, plural forms are not used in the sentences so all the plural forms present in the sentence are converted into singular form with help of this module.

For Example
Input: We have closed two platforms due to repair
In the above sentence, *platforms* will be replaced with *platform*.

5.5.10. Cardinal Number Conversion Sub Module

Afterwards, all the cardinal numbers present in the sentence are converted into words.

Named Nouns (NN) Merging for Related Items Sub Module

This module will merge all the Named Nouns (NN) present in the announcement of related items.
For Example

Input: Take care of your children during your journey.

In the above sentence, Take care (NN) will be merged as Take_care.

5.5.11. Sentence Reordering Sub Module

The Sentence Reordering sub module reorders the words of the English sentence according to the rules of ISL grammar as provided in section 7.1 of this chapter. Sentence reordering is necessary because ISL follows the SOV order along with a few other variations for interrogative and negative phrases, but English follows the SVO order.
For Example

Example Sentence: Train *(Subject)* will depart *(Verb)* from platform *(Object)* 2.

Output ISL Sentence: Train *(Subject)* platform *(Object)* depart *(Verb)* 2.

In the above sentence, SVO order of English sentence is converted to SOV order of ISL sentence grammar.

5.5.12. Unwanted Tags and Words Removal Sub Module

Indian Sign Language sentences do not contain words like linking verbs, suffixes, articles etc. After applying the ISL grammar rules, the ISL sentence is generated. The resultant ISL sentence contains all the words of the original sentence but the order of the words may have changed as per the ISL grammar rules. The resultant ISL sentence contains thelinking verbs, suffixes, articles, conjunctions, determiners, adverbs etc. Many of the words are not required to be the part of sign language such as articles, conjunctions, prepositions, modals, possessive endings, interjections, and some of the adverbs. These unwanted words need to be removed from the sentence. These unwanted words are identified and removed from the ISL sentence. Out of the 36 POS tags, the various parts of speech that do not form the part of ISL sentence are TO, POS (possessive ending), MD (Modals), FW(Foreign word), CC (coordinating conjunction), DT (some of the determiners like a, an, the), JJR (adjectives comparative), JJS (adjectives superlative), NNS (nouns plural), NNPS (nouns proper plural), RP (particles), SYM (symbols), Interjections, non-root verbs. These above mentioned unwanted words are eliminated from the ISL sentence.

5.5.13. Post Replacement and Exception Handling Sub Module

After the necessary replacements, if any exceptions occur during the sentence processing, they are handled by the Post Replacement and Exception Handling Module. At this stage, the resulting sentence is in the form of an Indian Sign Language (ISL) sentence. Each word in the sentence is then replaced with its corresponding HamNoSys notation, which represents the sign for that word. However, since the ISL dictionary may be limited, any unknown words in the sentence are replaced with their synonym counterparts. If a word is not found in the Indian Sign Language lexicon, it is spelled out using finger spelling, where each character is represented sequentially. Once the HamNoSys notation string is obtained, it is

transformed into SiGML code, which is the markup language used for sign animations. The sentence is now ready to be animated, and the SiGML code is sent to the SiGML animation tool, which plays the synthetic animation of the sentence in Indian Sign Language.

5.6. SIGN ANIMATION USING AVATAR

To facilitate the animation of announcements and sentences, an animation tool called SiGML Player has been utilized. The SiGML Player requires SiGML (Signing Gesture Markup Language) tags as input to generate the animation. The output of this tool is a computer-generated character performing the sign language animation. During the development of the English-ISL dictionary, the SiGML Player was employed to verify the animation of English words. As this research work involves a web-based animation tool, it is crucial to ensure that the animation is accessible through web browsers. To accomplish this, an equivalent animation tool called JASigning is used, which allows the animation to be displayed in a browser. To generate the SiGML tags necessary for animation, each word in the ISL sentence is converted to its corresponding HamNoSys code. In cases where a word is not found in the bilingual English-ISL dictionary, each character (alphabet) of the word is replaced with the equivalent HamNoSys code for that particular alphabet. Once the HamNoSys codes for the entire ISL sentence are obtained, HamNoSys-SiGML conversion rules are applied to convert the HamNoSys codes into SiGML tags. Once all the SiGML tags for the complete sentence are obtained, they are passed to the animation tool, which then plays the animation using a three-dimensional animated character.

5.7. TOOLS USED IN THE RESEARCH

5.7.1. Natural language toolkit

NLTK, short for Natural Language Toolkit, is a highly influential library and framework for performing symbolic and statistical Natural Language Processing (NLP) tasks specifically for the English language. It is implemented in the Python programming language and provides a wide range of tools and resources to enable machines to understand and respond to human language effectively. NLTK was developed by Steven Bird and Edward Loper at the University of Pennsylvania. NLTK offers various functionalities for NLP tasks, including classification, tokenization, stemming, tagging, parsing, and semantic reasoning. These capabilities empower developers and researchers to process and analyze text data, extract meaningful information, and perform advanced language-related tasks. NLTK also

includes numerous graphical examples and sample data, which serve as valuable resources for learning and experimentation in the field of NLP.

5.7.2. Text parser

In linguistics, parsing refers to the process of analyzing a sentence and breaking it down into its constituent parts to understand its structure and meaning. This involves examining the individual words in the sentence and determining their parts of speech, such as nouns, verbs, adjectives, and so on. A parser is a software program that performs this analysis and identifies the grammatical structure of sentences and the relationships between words. One commonly used parser is the Stanford Parser, which is a probabilistic context-free grammar natural language parser. It is available for download and is distributed under the GNU General Public License. The Stanford Parser is capable of generating output in various formats, including Stanford Dependencies, Universal Dependencies (v1), and Phrase Structure Trees. This allows users to obtain parsed sentences represented as part-of-speech (POS) tags or as a hierarchical structure known as a Penn Treebank-style tree.

By employing a parser like the Stanford Parser, researchers and developers can gain insights into the syntactic structure of sentences and utilize this information for various natural language processing tasks, such as information extraction, machine translation, and sentiment analysis.

5.7.3. eSign editor

The bilingual-ISL dictionary is created using a third-party software called the eSign editor. This software was specifically developed to facilitate the construction of signs using the HamNoSys notation. It provides a user-friendly interface where signs can be created using a scrollable dialogue of symbols. Additionally, the eSign editor integrates with the SiGML Player, allowing users to preview animated signs with a simple button press.

The eSign editor, also known as Essential Sign Language Information on Government Networks, is equipped with a graphical user interface (GUI) that enables the composition of sign text using the HamNoSys notation. This tool has multi-language support, including English, Dutch, and German, and it can be used on both Windows and Mac OS platforms.

With the eSign editor, users can generate HamNoSys notation that represents both the manual and non-manual components of signs corresponding to English words. The editor includes a database of word pronunciations, facilitating the description of mouth movements

and lip gestures through photos. To ensure accuracy, users can easily verify the sign content by transmitting the HamNoSys code to a 3D avatar for visualization.

In summary, the eSign editor provides a convenient and efficient solution for creating and editing sign text in HamNoSys notation. It combines ease of use, language support, and integration with a 3D avatar to streamline the process of constructing the bilingual-ISL dictionary.

5.7.4. JA SiGML URL app

The Java Avatar SiGML URL App is utilized for playing signs using avatars. The components of JASigning are digitally signed by UEA Consulting Ltd. The current version of JASigning is compatible with Windows (XP and later) and Mac (X10.5 and later) operating systems, supporting both 32-bit and 64-bit systems. JASigning is designed to work with popular browsers such as Safari, Firefox, Opera, Chrome, and Internet Explorer. However, it is not compatible with other browsers or Windows-compatible browsers that are not specified.

Please note that JASigning software is copyrighted by UEA, and it is available for download solely for evaluation purposes. It includes a wide range of animated virtual characters, or avatars, including names such as Max, Anna, Camen, Robotboy, Marc, Luna, Dinoex, Francoise, Darshan, Dino, and Siggi.

To generate signs that correspond to the inputted text, the SiGML file is entered into the player. The avatar within the player interprets the input as a sequence of animation frame definitions, allowing for the creation of 3D animations based on the SiGML tags. The animation module is an essential component for generating the visual representation of the signs using the avatars.

6. EVALUATION AND RESULTS

Evaluating a research study is crucial to assess its feasibility and potential scope in the field. When it comes to evaluating Machine Translation (MT), there are inherent challenges, particularly when multiple accurate translations of a source sentence are possible. Evaluating MT becomes even more complex when it involves translating between a spoken and a non-spoken language. The task becomes more challenging when translating from a spoken language to a sign language due to the lack of standardization in sign languages.

The evaluation process becomes more arduous when dealing with translation between spoken and non-spoken languages. Since sign language lacks standardization, evaluating MT becomes even more challenging when translating into sign language from a spoken language.

In the developed system, the capability to translate all static, dynamic, and special announcements into Indian Sign Language synthetic animations has been achieved. To evaluate the quality of the public announcement system, a set of test sentences was necessary. These sentences were selected from deaf schools and websites dedicated to research in the field of Indian Sign Language. Additionally, commonly used sentences at airports, railway stations, and bus stands were collected for evaluation purposes.

6.1. Evaluation of Announcement System

To evaluate the quality of the announcement system developed in this research, a comprehensive set of test sentences was compiled. The collection includes a total of 548 announcements used at railway stations, airports, and bus stands, along with 288 additional sentences related to these public places sourced from various online websites. Additionally, 700 sentences were taken from English books, and 344 sentences were obtained from a website focused on Indian Sign Language. A diverse range of sentences was gathered, including 1880 simple sentences, 1124 compound sentences, and 1508 complex sentences sourced from various eBooks and online sources. In total, 4512 sentences were used to evaluate the performance of the announcement system.

The evaluation of the announcement system in Indian Sign Language (ISL) employed both qualitative and quantitative techniques. However, it's important to note that the developed bilingual English-ISL dictionary is limited to 4341 words, including their synonyms. If an English sentence contains a word for which the corresponding SiGML animation is not available, the system resorts to finger-spelling the word in ISL.

By conducting the evaluation using a large and diverse set of sentences, the announcement system's performance can be assessed in terms of both its qualitative aspects, such as the accuracy and naturalness of the sign language translations, as well as quantitative measures that indicate the system's overall effectiveness and coverage.

Table 17. Number of Test Sentences

Sr. No.	Type	No. of Sentences
1	Simple Sentences	1880
2	Complex Sentences	1508
3	Compound Sentences	1124
Total		4512

6.1.1. QUALITATIVE EVALUATION

To evaluate the developed system, a visit was made to the Patiala School for the Deaf and Blind located in Saifdipur, Patiala. During the visit, the developed announcement system was demonstrated to deaf students, ISL interpreters, and teachers at the school. The results of the demonstration showed that the developed system achieved a remarkable 100 percent accuracy in translating and conveying static and dynamic announcements to ISL synthetic animations. Deaf students, sign language users, and interpreters expressed satisfaction with the level of understanding they gained from the translated static and dynamic announcements.

In the case of special announcements, the system demonstrated an accuracy rate of approximately 100 percent when simple sentences were inputted. However, for compound and complex sentences in special announcements, the system exhibited a slightly lower accuracy rate of 90 percent.

These evaluation results indicate that the developed system is highly effective in accurately translating and conveying static and dynamic announcements, as well as achieving a high level of accuracy for simple sentences in special announcements. The system's performance with compound and complex sentences in special announcements may benefit from further refinement and improvement.

6.1.2. Intelligibility test

The intelligibility of the translated sentences in the developed system was evaluated using a four-point scale. This test was conducted by individuals who are familiar with Indian Sign Language (ISL). The purpose of the test was to assess the understandability of the translated

sentences without prior knowledge of the original input sentences. The evaluators compared the translated sentences to the correct reference translations and rated their level of understanding on the four-point scale.

By employing this intelligibility test, the system's ability to convey the intended meaning and ensure proper understanding of the translated sentences was evaluated. The test results provide valuable insights into the clarity and effectiveness of the system's translations, as perceived by individuals knowledgeable in ISL.

Table 18. Four Point Scale for Intelligibility Test

Score	Significance
3	The Sentence is highly intelligible.
2	The Sentence is intelligible but has some inaccuracies.
1	The Sentence contains grammatical errors and can be understood only after some study.
0	The Sentence is unintelligible (not understandable).

From test data of 4512 sentences, out of which 3577 (79.27 percent) sentences have been found to be understandable (whether correct or incorrect), 468 (10.37 percent) sentences are intelligible with minor inaccuracies. 236 (5.23 percent) sentences are not properly understandable whereas 231 (5.11 percent) sentences are unable to understand.

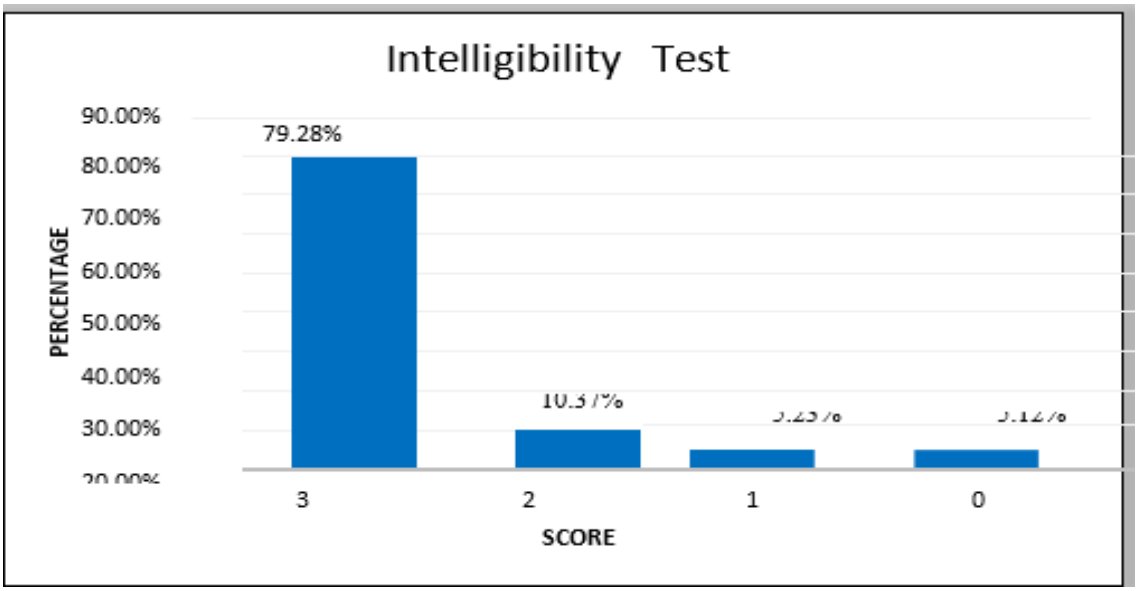


Figure 5. Percentage of Scores of Intelligibility Test

6.1.3. Fidelity test

The Fidelity test is known as the accuracy test which is used to check as to how much information is retained in translating a sentence compared with the original sentence. A four-point scale was used to test the fidelity of the test data sentences.

Table 18. Four Point Scale for Fidelity Test

Score	Significance
3	Totally Accurate
2	Moderately Accurate
1	Hardly faithful
0	Totally Inaccurate

Out of 4512 sentences of testing data, 3422 (75.84 percent) sentences have been found to be correct, out of which 377 (8.35 percent) sentences are moderately correct and these sentences are considered as accurate. About 223 (4.94 percent) sentences are not considered as correct because these sentences are not considered as hardly faithful. A total of 490 (10.85 percent) sentences are not translated or considered as inaccurate sentences.

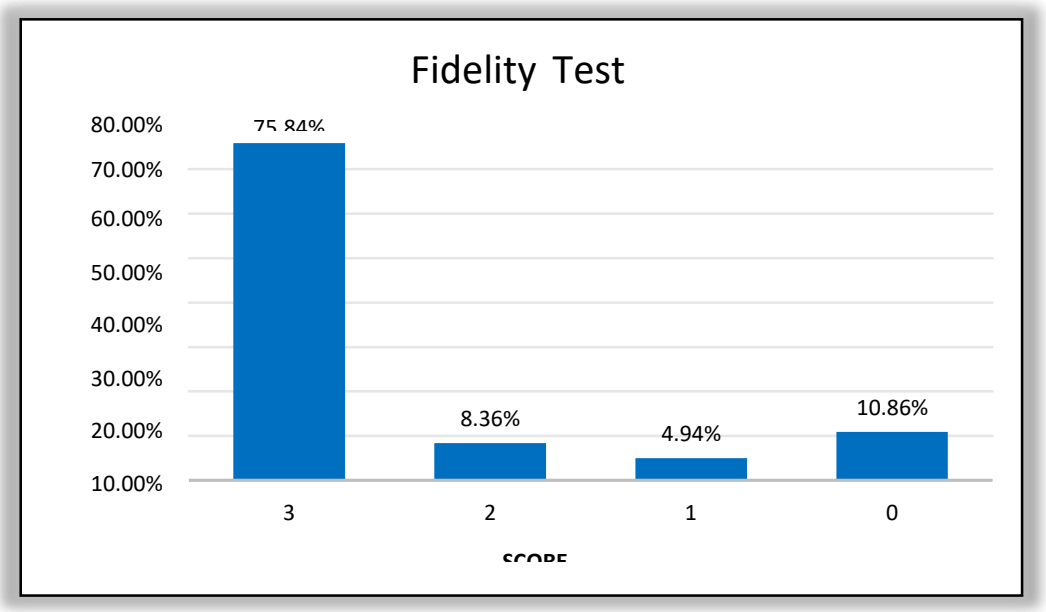


Figure 6. Percentage of Scores of Fidelity Test

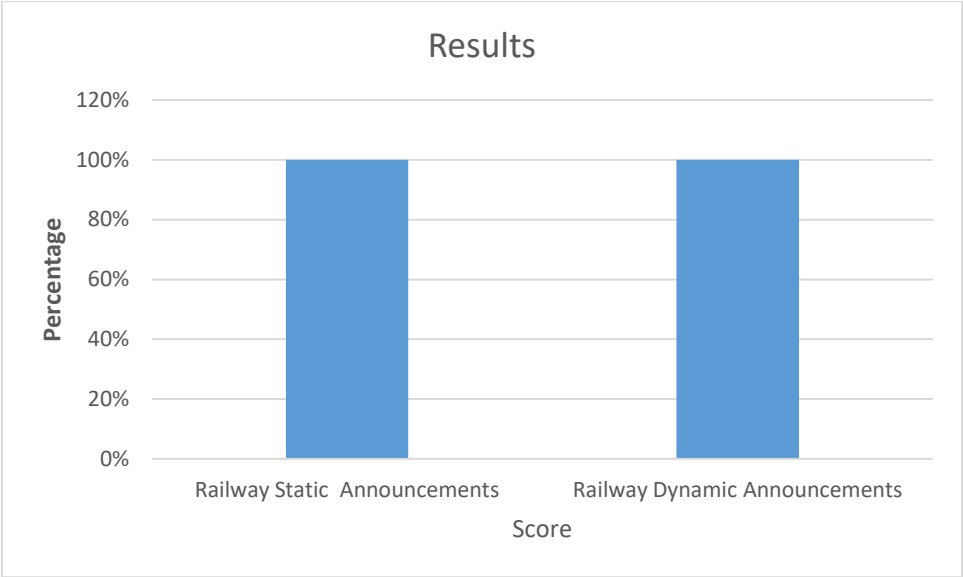


Figure 7 Percentage score of Railway Announcements (Static and Dynamic)

6.2. QUANTITATIVE EVALUATION

6.2.1. Analysis of sentence error rate

The Sentence Error Rate (SER) is the proportion of unmatched machine translation

outputsentences and total number of the reference sentences.

SER=Number of unmatched sentences/Total number of reference sentences

SER= 713/4512

Out of 4512 sentences, 713 sentences are considered as incorrect, so SER is 0.158.

The developed system has failed to give accurate results on some of the following complex sentences.

For example

English Sentence: Prime Minister will also launch E- Gram Swaraj portal and mobile application.

System Output: Prime Minister E-Gram Swaraj portal application also launch mobile

Correct Output: Prime Minister E-Gram Swaraj portal mobile application launch.

English Sentence: Some additional services related to senior citizens and other category exempted from restrictions.

System Output: Some senior citizens additional service related, some additional services category senior citizens related category exempted other restrictions other.

Correct Output: Senior citizen and other category related some additional service restriction exempted.

English Sentence: Panchayat raj institutions have been an important pillar in India's efforts in rural development and self-governments today's interaction is also significant in the light of the nation fighting to cope with Covid 19 pandemics.

System Output: Panchayat raj important pillar institutions India 's development efforts rural Self - governments today 's interaction light nation fighting also significant pandemics cope Covid 19 .

Correct Output: Panchayat raj institutions ruler development self-government India effort important pillar Covid 19 pandemic fight cope nation light today interactionsignificant.

The most effective approach for evaluating Machine Translation (MT), particularly when translating to sign language, is through human evaluation. This is crucial due to the lack of standardized grammar in Indian Sign Language and the existence of regional language variations. However, conducting evaluations solely with human interpreters is impractical due to time, cost, and resource constraints. To address these limitations and optimize efficiency, various automated MT evaluation methods have been developed.

In the case of the developed announcement system, both qualitative and quantitative metrics were employed for evaluation. During demonstrations to deaf students, interpreters, and teachers, the system achieved 100 percent accuracy for static and dynamic announcements, resulting in a satisfactory level of understanding when translated into ISL synthetic animations. Similarly, the system achieved 100 percent accuracy for special announcements when simple sentences were used as input. However, for complex sentences, the system achieved approximately 90 percent accuracy in translating special announcements.

The accuracy of animating the resulting ISL sentence relies on the bilingual English-ISL dictionary. If a word is not available in the dictionary, it is finger spelled, represented by a sequence of alphabets. While finger spelled words are considered correct, they must be present in the bilingual English-ISL dictionary. To further enhance accuracy, context should be incorporated into the announcement system. Some incorrect translations can be attributed to grammatical errors in the English sentences. For instance, the sentence "when the train will come?" is grammatically incorrect, resulting in an incorrect translation. However, if the sentence is corrected to "when will the train come?", it is accurately translated as "train come when". Additionally, certain special announcements of complex nature were not translated correctly.

In conclusion, the evaluation of the developed announcement system highlighted its high accuracy for static and dynamic announcements, as well as for special announcements using simple sentences. However, there is room for improvement in handling complex sentences and incorporating context to enhance accuracy in translation.

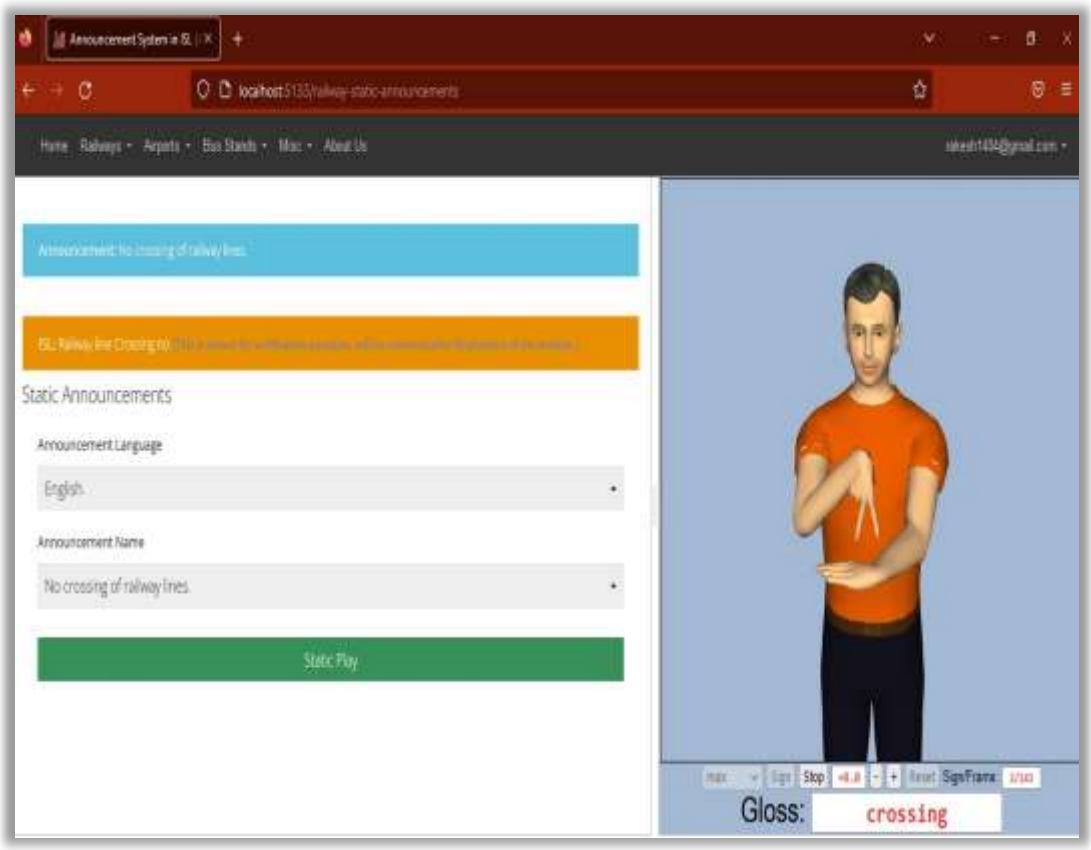


Figure 8. Snapshot of Announcement System in ISL for Railway Stations

Figure 9. Snapshot of Announcement System during Evaluation Process

Figure 10. Snapshot of Deaf Students during Evaluation of System

Figure 11. Snapshot of Deaf Students during Evaluation of System

Figure 12. Snapshot of Deaf Students during Evaluation of System

7. CONCLUSION LIMITATIONS AND FUTURE DIRECTIONS

Machine Translation (MT) between the spoken languages of India has been an emerging area, with extensive project work being conducted. However, there has been limited focus on machine translation between spoken and non-spoken languages in India. Specifically, there has been minimal project work on machine translation between English and Indian Sign Language (ISL). In this project, an announcement system using Indian Sign Language synthetic animations for hearing-impaired individuals at public places has been developed. The system is capable of translating all the announcements used at railway stations into ISL synthetic animations. Synthetic animation is utilized instead of human real videos due to its scalability in providing continuous translation for all words in any given sentence. Synthetic animations offer several advantages over real video signs, including the ability to combine different signs, reduced memory space requirements, affordability, customization to meet sign language standards, and the option to choose from various available characters. The effectiveness of the announcement system in ISL relies heavily on synthetic animation. Furthermore, the system successfully translates complex and compound announcements into ISL synthetic animations.

7.1. Project Outcomes

• This project presents the first-ever announcement system in ISL capable of translating all types of static, dynamic, and special announcements at railway stations into ISL synthetic animations. The developed system is available as website. The website address is http://iras.vishalpup.in

• The developed announcement system successfully translates complex and compound announcements/sentences into ISL synthetic animations.

• A Bilingual English-ISL announcement corpus consisting of 548 announcements has been created.

• The announcement system can translate static announcements into 16 Indian languages, including Hindi, Odia, Malayalam, Assamese, Bengali, Tamil, Telugu, Manipuri, Kannada, Gujarati, Punjabi, Sanskrit, Dogri, Konkani, Urdu, and ISL.

• The developed system is not limited to specific domains and can be used for general-purpose applications.

• A Bilingual English-ISL dictionary containing 4341 words has been developed. Each word includes the corresponding POS tag, considering that an English word can function as a different part of speech in different contexts, and the sign for the same word may vary based on its POS tag. The dictionary also includes non-manual components where applicable, such as lip movements corresponding to the pronunciation of each word. This inclusion benefits hearing-impaired individuals who use oralism and those who use sign language along with oralism.

• A synonym list has been created for each ISL word, consisting of approximately 4052 words.

• The development of the Bilingual English-ISL dictionary took into account the inclusion of non-manual components as much as possible.

• The grammar of Indian Sign Language, which follows SOV order unlike English's SVO order, has been addressed through the formulation of 72 grammar rules for converting English sentences to ISL. Additionally, 20 rules for converting compound sentences to simple sentences and 49 rules for converting complex sentences to simple sentences have been developed and implemented in the announcement system.

• A browser-based dictionary interface has been created to facilitate the learning of Indian Sign Language.

• A browser-based automatic translation system for static, dynamic, and special announcements at railway stations, airports, and bus stands has been developed.

• Modifications have been made to the avatars' costumes based on feedback from deaf students and ISL teachers.

7.2. Future Enhancements

Although the Announcement System in ISL yields satisfactory results, there are certain limitations to consider:

- The ISL dictionary can be further expanded to ensure coverage of all English words with their corresponding signs
- Refinement of rules for complex sentences is required.

- Machine Learning based module must be developed which is capable of automatic generation of SIGML corresponding to human videos. This is required for adding more vocabulary into the system. Our team has already worked on this module to some extent and got success too.

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