HamNoSys based Indian Sign Language Generation System

Thesis submitted in partial fulfillment of the requirements for the award of degree of

Master of Engineering

in

Software Engineering

Submitted By

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Certificate

I hereby certify that the matter which is being presented in the thesis entitled as, **"HamNoSys based Indian Sign Language Generation System"**, in partial fulfillment of the requirements for the award of degree of Master of Engineering in ***Software Engineering*** submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of ***Dr. Parteek Kumar*** and refers other researcher's work which is duly listed in the reference section.

The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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Abstract

Sign language (SL) is the most natural way of expression of thoughts and feelings for the deaf community. Indian SL is a gestural language which provides information by using hands and other body parts. In India, there are approximately over 24 million people who are deaf or hard of hearing, out of which only 5% attend schools. The reason for the lack of language and literacy skills among hearing impaired people is that there are very few sources in India that can provide education to them. There is a need of automated systems that can overcome this problem, thus improving the communication skills among deaf communities.

In this thesis, a system for creation of HamNoSys based ISL dictionary has been proposed. The system has a virtual keyboard for entering HamNoSys of a given sign. The sign gloss and the HamNoSys of a given word are stored in ISL dictionary. There are various signs in Indian Sign Language that make use of non-manual sign gestures. A system for selecting non-manual components such as eye-gaze, mouth gestures, face expressions and body postures for a given sign is also developed and embedded in the proposed system. The sign and its HamNoSys that are stored in the dictionary can be retrieved from it by the users. The system has a translator that converts the retrieved HamNoSys to SiGML. The generated SiGML file is then given as an input to the signing avatar which animates the signs. Thus in this way the proposed system can be used for creating Indian sign language dictionary as well as for animating the signs also.

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Chapter 1

Introduction

1.1 Sign Language

Sign language (SL) is the most common approach of expression of thoughts and feelings for the deaf community. SLs are gestural languages which provide information by using hands and other body parts. These languages contain symbolic encoded messages for communication among deaf people without any speech channel. Many hearing impaired people learn sign language as their first language. These people learn the local language of the region in which they are born as a second language. Sign languages are unique in many ways from other languages. They cannot be written like other spoken language, a special mechanism is required for transcribing the signs. Most of the deaf people prefer to communicate by using sign language only as they don't have much knowledge about other spoken languages [1].

1.2 Indian Sign Language (ISL)

Indian Sign language (ISL) uses hand and body movements for communication among deaf and hard-hearing people. In ISL, the signer uses the three dimensional space around him to convey his message by using hands and other body parts. The syntax and grammar of ISL is totally different from that of spoken and written languages used in India. It is used as the main mode of communication among deaf people in India and also in some other South Asian countries. It is used in various parts of Indian subcontinent including some regions of Pakistan across the Indian border, Nepal, Bangladesh and Sri Lanka. In India various varieties of sign language are used in different regions. The various dialects of ISL have same grammar but these may differ in terms of lexical variations [2].

1.3 Development of ISL among Deaf Communities in India

India, with its 1.25 billion people, is the second most populated country in the world. Although no exact figures are available, but there is an estimation of approximately over 24 million people who are deaf or hard of hearing [3]. As the census of India does not list sign languages and most of the studies done till date have mainly focused on urban areas, so, it is very tough to estimate

the accurate number of deaf people in India. But it would be realistic to believe that the actual count of deaf and hard of hearing people is much more that the estimated one. Based on these facts and figures, it is known that out of every five hearing impaired people in the world one lives in India [4].

There are very few sources in India to impart knowledge about sign language among the deaf communities. The use of ISL is limited only to short term courses and programs. The professionals in India believe that a very few schools are available for deaf children that can teach them sign language. These schools also do not have a proper and adequate audio visual support in oral educational. This results in poor communication and language skills among the hearing impaired people in India. In India, approximately 5% of the people who are hard of hearing attend deaf schools [5]. Due to which there is a need to build a system which can automatically generate the sign language content, so that it could be used at various educational institutions for teaching sign language to the deaf people. It could also be used for learning Indian sign language both by hearing and deaf people, thus improving the literacy rate and language skills among deaf communities.

1.4 Types of Signs in ISL

The signs used in India are divided into two types, *i.e.,* Manual and Non-Manual signs. Manual signs are the ones that make use of hands only while non-manual signs use mouth gestures, body postures and face expressions. The signs of the words in ISL may use either manual or non-manual or both components while signing. Manual signs are further classified as one-handed and two-handed signs. The single dominant hand is used for signing one-handed signs. The two-handed signs use both dominant and non-dominant hands while signing [6]. The manual signs also describe the movement of hand which can be cyclic or straight while signing a given word. The non-manual signs include head and body postures, mouth and face expressions that can be used while signing. These also include signs for various eye gaze and eye lid expressions for describing a given sign. The signs may contain both manual and non-manual components while signing a particular word. In ISL, majority of the signs consist of manual components while there are some signs which may contain non-manual components only [7]. For example the word “No” is signed by horizontally shaking the head from left to right and it has no manual component. The various types of signs used in ISL are shown in Figure 1.1.

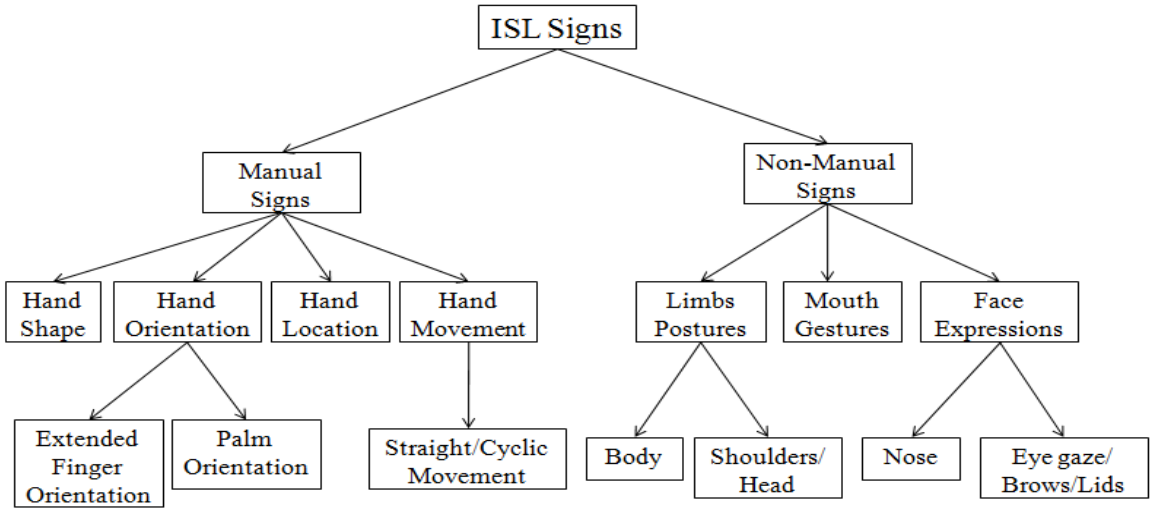


Figure 1.1: Classification of signs used in ISL

1.5 Challenges in Computerization of Sign Language

The sign language depends on multiple components like hand shape, hand movement, hand orientation, cyclic or straight movement of hand or arm, body postures, mouth gestures and face expressions [8]. The sign language can change various components of manual signs such as shape of hand, hand movement, repetition of signs, path and the 3-D space around signer while signing to convey the meanings of words more accurately. Due to which it is difficult to generate signs with as much accuracy and clarity as the natural sign language has. So, there is a need to build a system for automatic generation of sign language. The system should be developed in such a way that if any of the above components is missing, then it should assume it itself to convey the exact meaning of the signs.

At present there is a little approach to signed content on the Internet for ISL and most of the content is in textual form. The sign language content in the form of text is complex and is not of much use to the deaf people. So, an alternate solution of presenting the signed content as videos was adopted and this solution is somehow satisfactory in terms of usage by deaf people. The video approach is time and space consuming. Each time when there is a slight change in the sign language content, a new video has to be created from beginning which results in increasing costs [9]. The best choice for automatic generation of sign language content is by transcription of signs. The signs are transcribed in HamNoSys (Hamburg Notation System) notation form and its

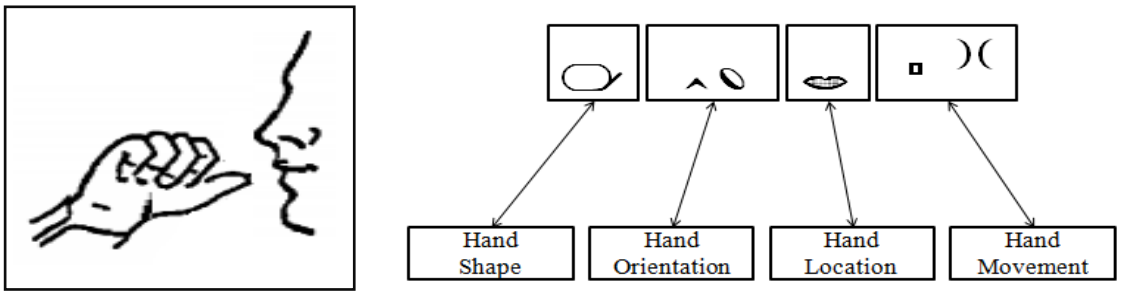
related mark-up language SiGML (Signing Gesture Mark-up Language), which is also suitable for textual manipulation [10].

1.6 HamNoSys

The Hamburg Notation System was introduced in 1985 at the University of Hamburg, Germany. It is used for transcribing signs, like phonetic alphabets used for spoken languages. HamNoSys is capable of describing all signs used in all sign languages. It does not rely on the sign language conventions differing from country to country and thus can be used internationally [11]. HamNoSys transcription consists of HamNoSys symbols as icons which are easy to use and understand [8]. The HamNoSys notation system can be easily used in standard text processing and database applications. It has a well-defined formal syntax so that it can be easily integrated with standard computer tools [12].

1.7 General Structure of HamNoSys

HamNoSys notation of a given sign includes transcription of non-manual features. The HamNoSys structure for a single handed sign describes the non-manual specifications only [13]. But for two-handed signs, a symmetry operator is used that describes the sequence of actions performed by both hands [14]. The sign of ISL word "Water" is shown in Figure 1.2 (a) and its HamNoSys Notation is described in Figure 1.2(b).



(a) (b)

Figure 1.2: a) Sign for "Water" b) HamNoSys Notation for "Water"

There are four elements in the general structure of HamNoSys, *i.e.* Hand-Shape, Hand-Orientation, Location and Movement of hand [8] as shown in Figure 1.2 (b). The first element in the structure of HamNoSys for "Water" describes that the shape of hand is like fist and thumb is outside the fist. The second element describes the orientation of hand, in which extended finger direction is upwards and palm is down and leftwards. The location of hand near teeth is denoted

by the third element in the structure of HamNoSys for "Water". The fourth element describes that the proximity of the hand with respect to the body, the hand is close to the teeth as shown in Figure 1.2(a).

a) Hand Shapes

The Hand Shapes are mainly grouped as Fist, Flat-Hand, Separated Fingers and Thumb combinations [11]. These four basic forms along with thumb variations (thumb extended or across the hand) and bending of fingers allows the user to write HamNoSys for any given Hand Shape [8]. Some of the fundamental Hand Shapes with flat and rounded hands are shown below in Figure 1.3.

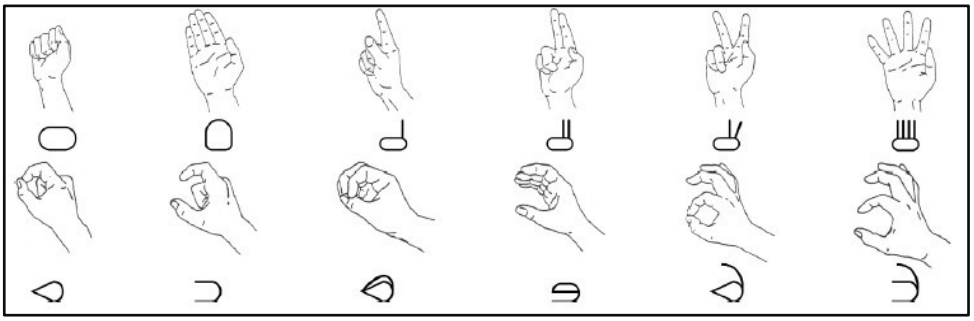
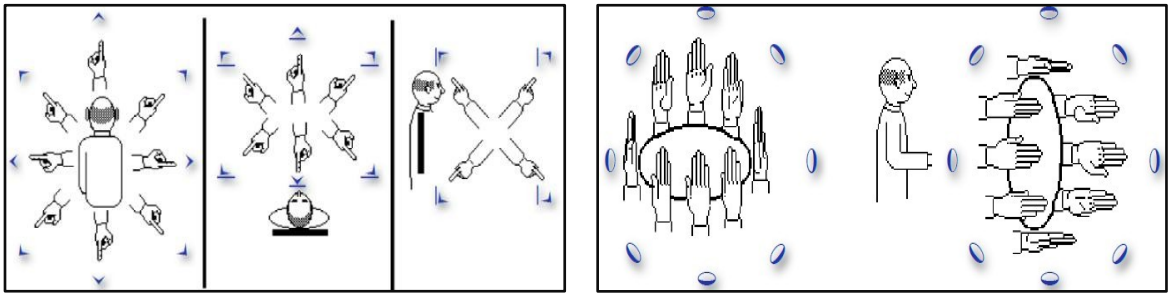


Figure 1.3: Basic Hand Shapes [8]

b) Hand Orientation

The orientation of hand for a given sign is transcribed by combining two components, *i.e.*, extended finger direction and palm orientation. There are three perspectives (signer's view, parallel view, and right side view) which are used to show the direction of extended finger. The palm orientation is also described with the same model for a given extended finger direction [8]. The various types of extended finger and palm orientations are shown in Figure 1.4(a) and Figure 1.4(b) respectively.



(a) (b)

Figure 1.4: a) Extended Finger Direction [11] b) Palm Orientation [11]

c) Hand Location

The location specifications are used to tell the location of the hands of the signer. These are split into two parts. The first part describes the location of hand with respect to the body part. The second part determines the distance of hand from the selected body part [11]. If the location parameter is not specified then a default location is assumed by animation avatar [13]. The various body part locations that can be specified in HamNoSys notation of a sign are shown below in Figure 1.5.

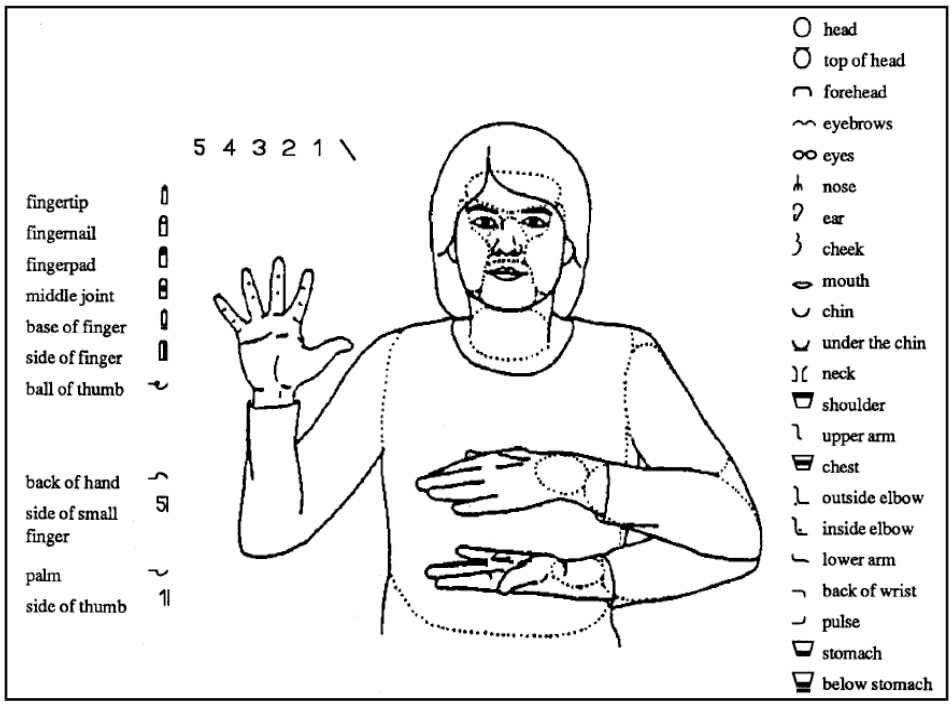
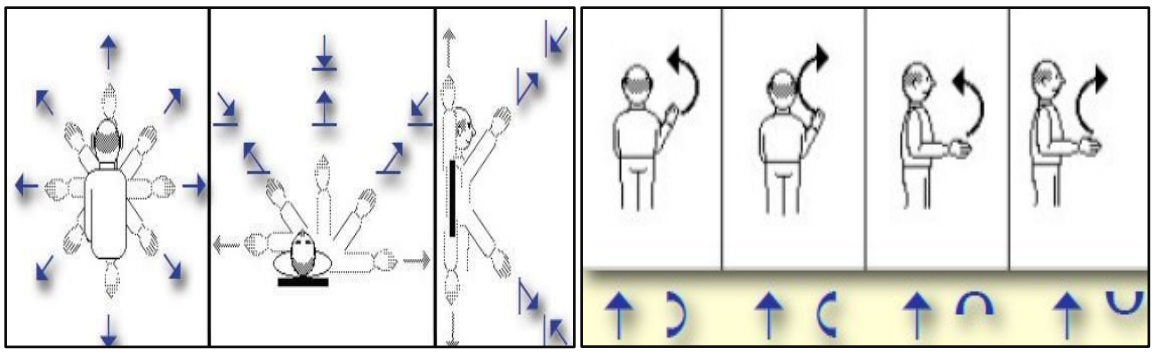


Figure 1.5: Hand Location with respect to body parts [11]

d) Hand Movement

The movement types are distinguished as straight, curved, wavy, zigzag, circular and spiral movements. The straight movements are either parallel to the body or with referent to the body of the signer. The circular movements of the hand can either be clockwise or counter clockwise. The manner of the movements can be any of the three degrees of size, *i.e.*, large (expansive movement), normal size movement and small movement [11]. The straight hand movements are shown in Figure 1.6(a) while the cyclic hand movements are shown in Figure 1.6(b).



(a) (b)

Figure 1.6: a) Straight Hand Movements [8] b) Curved Hand Movements [11]

e) Non-manual Components

The components which make the use of hands for signing are manual whereas those which include signs for shoulder shrugging, head movements, facial expressions or mouth movements are the Non-Manual components [15].

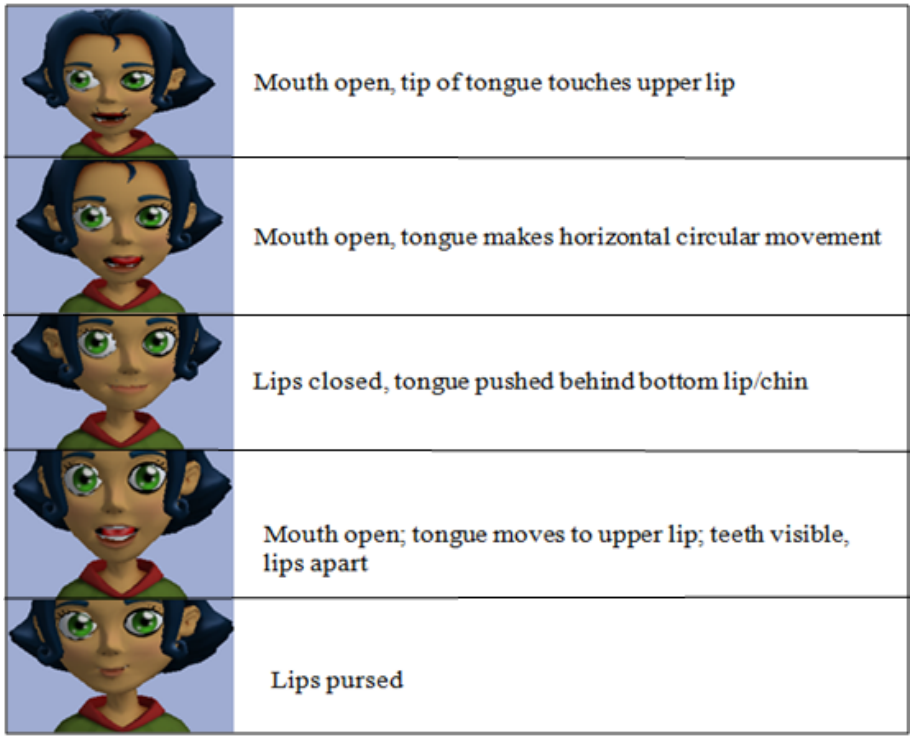
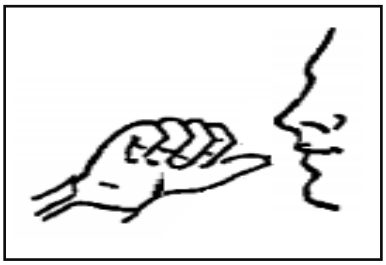


Figure 1.7: Showing various Mouth-Gestures in Non-Manual components

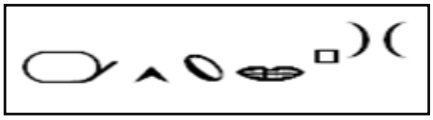
There are various non-manual coding schemes which are defined for facial expressions (eye brows, eye gaze, eye lids and nose), limbs (head, shoulders and body postures) and gestures of mouth, but in ISL mainly the signer uses manual components [9]. The different types of mouth gestures tags in non-manual components that can be used while signing are shown in Figure 1.7.

1.8 SiGML

SiGML is Signing Gesture Mark-up Language. It was developed at University of East Anglia, Norwich, UK. It describes HamNoSys symbols into XML tags form. SiGML representation made from HamNoSys notation of sign language is readable by 3D rendering software [16]. It is more tractable form of HamNoSys that is used to generate sign animation. The SiGML notation can be used to describe signing information given in any sign language [17]. The SiGML file along with its description of HamNoSys notation for word "Water" are shown in Figure 1.8.



(a)



(b)

Figure 1.8: a) Sign for "Water" b) HamNoSys Notation for "Water"

```
<sigml>
<hns_sign gloss="water">
<hamnosys_nonmanual>
<hnm_mouthgesture tag=""/>
<hnm_body tag=""/>
<hnm_head tag="PF"/>
<hnm_shoulder tag=""/>
<hnm_eyegaze tag=""/>
<hnm_eyebrows tag=""/>
<hnm_eyelids tag=""/>
<hnm_nose tag=""/>
</hamnosys_nonmanual>
<hamnosys_manual>
<hamfist/>
<hamthumboutmod/>
<hamextfingeru/>
<hampalmdl/>
<hamteeth/>
<hamlrbeside/>
<hamclose/>
</hamnosys_manual>
</hns_sign>
</sigml>
```

(c)

Hand Shape (Fist)

Thumb Shape (Thumb Extended)

Extended Finger Orientation (Upwards)

Palm Orientation (Down Leftwards)

Hand Location (Near Teeth)

Hand Location (Beside Teeth)

Hand Proximity (Close to Teeth)

(d)

Figure 1.8: c) SiGML for word "Water" d) HamNoSys description for word "Water"

1.9 Animation Avatars

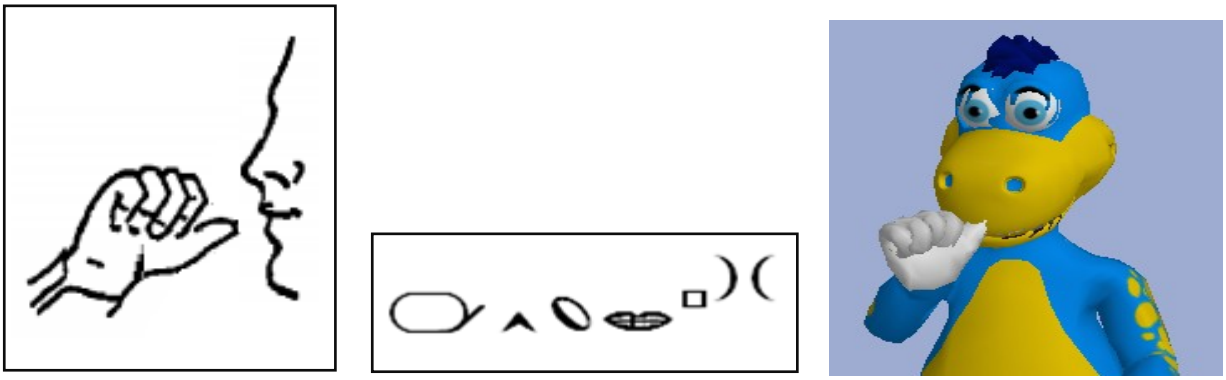
The JA SiGML URL App consists of Avatars that are used to play signs. The JA Signing Avatars were developed in 2002 at University of East Anglia, Norwich, UK. The SiGML file is put in the Player for making the signs corresponding to the inputted text. JA Signing is a

synthetic animation system that is written in Java. It takes avatar-independent Gestural SiGML as an input and produce motion data for an avatar as an output [18]. Animation frame definitions are also given as input to avatar in a sequence, which describes the time stamp of avatar, *i.e.,* at what time avatar will be making what type of pose [19]. The URL for the current release of JA Signing animation avatars is http://vhg.cmp.uea.ac.uk/tech/jas/std. The various JA Signing characters used for sign animation are shown below in Figure 1.9.

Figure 1.9: JA Signing Characters for Sign Animation

1.10 Generating HamNoSys for ISL words

The HamNoSys notation for ISL words is provided below along with the sign shown by JA Signing avatar. The pictorial representation of the words in ISL is also provided. The sign and its HamNoSys for word "Water" are shown in Figure 1.10.



(a) (b) (c)

Figure 1.10: a) Sign Representation of "Water" b) HamNoSys Notation of "Water"
c) Sign animation for "Water" by JA Signing avatar

The sign and its HamNoSys Notation for word "House" are shown in Figure 1.11. The HamNoSys of "House" makes use of both hands while signing, thus symmetry operator is used as both the hands have same shape and orientation.

(a) (b) (c)

Figure 1.11: a) Sign Representation of "House" b) HamNoSys Notation of "House"
c) Sign animation for "House" by JA Signing avatar

1.11 Thesis Outline

This thesis is divided into 6 chapters. Chapter 1 includes introduction about sign language, Indian sign language and its development among deaf communities. The challenges in

automation of sign language and types of signs used in ISL are described. The techniques for transcribing sign language, *i.e.,* HamNoSys and SiGML are also introduced. Chapter 2 describes the existing systems and tools available for sign language generation and automation. Chapter 3 describes problem statement, objectives and methodology used for development of sign language dictionary. Chapter 4 includes detailed description of the proposed system and its implementation. The results for the ISL words tested on the system are discussed in Chapter 5. Chapter 6 covers the future scope and concludes the work done in this thesis.

Chapter Summary

In this chapter, sign language is described along with the growth and development of Indian Sign Language (ISL). In India, there is very little growth of ISL as only 5% of deaf people attend deaf schools. There is a need to build a system that can be used for communication among deaf communities. The various types of manual and non-manual signs are used in ISL. Due to which there are a lot of challenges and problems in creating sign language content by using video approach. So, generation of sign language by transcription of HamNoSys is the best choice for automation of signs.

Chapter 2

Review of Literature

2.1 Existing Systems for automation of Sign Language

There have been a number of considerable research activities in developing systems for generation and automation of sign language. These automated systems take either text or speech as input and generate sign language as output. Some of the available systems for sign language generation and automation are discussed below.

2.1.1 ViSiCAST System

Safar *et al.* (2001) had developed a system for converting English text into British Sign Language (BSL). It consists of a virtual signing technology for easy communication among deaf people. The system is divided into two major parts, first one is conversion of text to a semantic-based string and other one is translation from this string to a graphic output that can be used by signing player. The architecture of the system is given in Figure 2.1.

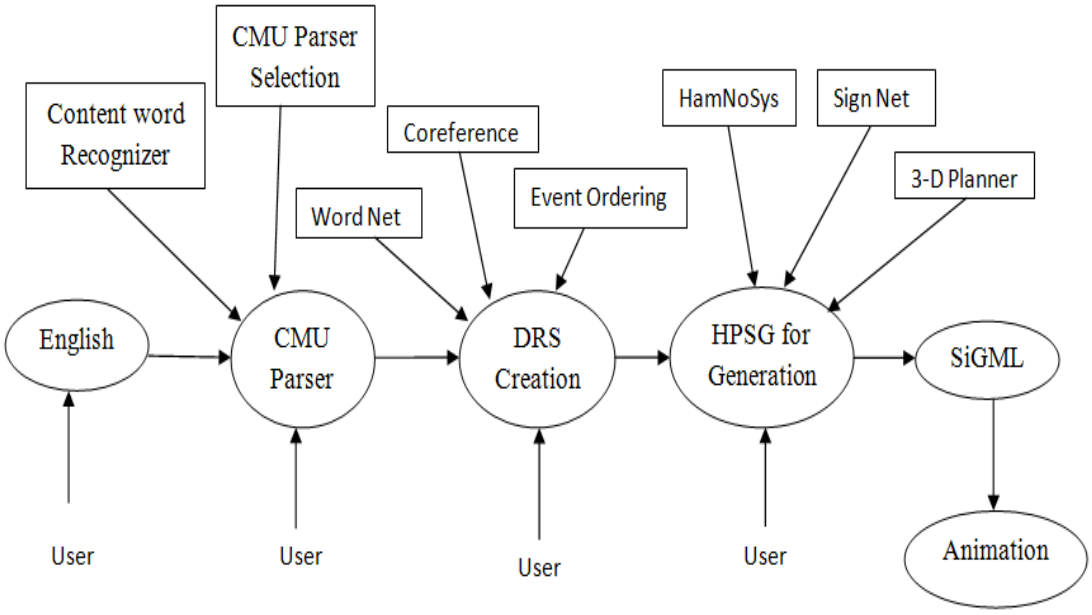


Figure 2.1: Architecture of ViSiCAST translation system from text to BSL [20]

The input is given in English to CMU (Carnegie Mellon University) parser. The parser consists of a content recognizer that recognizes the inputted word. The Discourse Representation

Structure (DRS) uses WordNet for generating the semantic string from the inputted text. The contents are arranged in the linear order of timing. The semantic representation string of the inputted text is prepared. The Head Driven Phrase Structure Grammar uses that string for generating the signing information. Signs are represented in the form of HamNoSys notation that is further converted to SiGML for sign animation of the inputted text [20].

2.1.2 TESSA

Cox *et al.* (2002) had developed a communication system for hard of hearing people. It is an interactive translation system which is used by the post office officials to carry out the transactions of deaf people. It works by taking the voice of the post office person as an input. That voice is converted into British Sign Language. The resultant signs from that voice are represented by using virtual player avatars. The system converts the input voice to English text. It then matches each character of the text with the dictionary for English to Sign Language. Then it combines all the signs for animation by the avatar. Figure 2.2 shows the general structure of TESSA system.

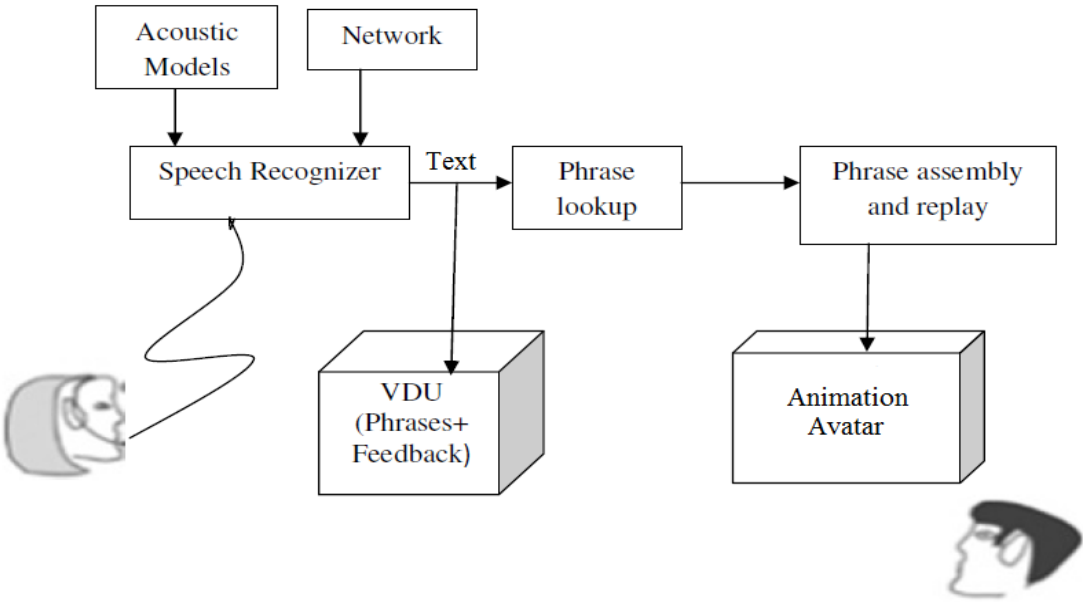


Figure 2.2: Architecture of TESSA system [1]

A headset microphone is used by post office officials. Whenever a sentence is spoken by an officer, the speech recognizer checks it from stored phrases in the grammar. As a result, a list of various facilities such as bill payments, postage and passports is displayed to the officer.

The acoustic models are used for checking the input speech characteristics. The search of the speech recognizer is monitored by using various network models. The system has 370 predefined phrases in the phrase lookup table, which are adequate enough for carrying out all the transactions required in a post office [1].

2.1.3 Zardoz System

Veale *et al.* (1998) had introduced an application known as Zardoz, used for generating signs from given text. It uses a central blackboard structure for regulating the various modules. It is based on the frame-based Knowledge Representation language. The blackboard structure of the system is divided into eight panels as shown in Figure 2.3.

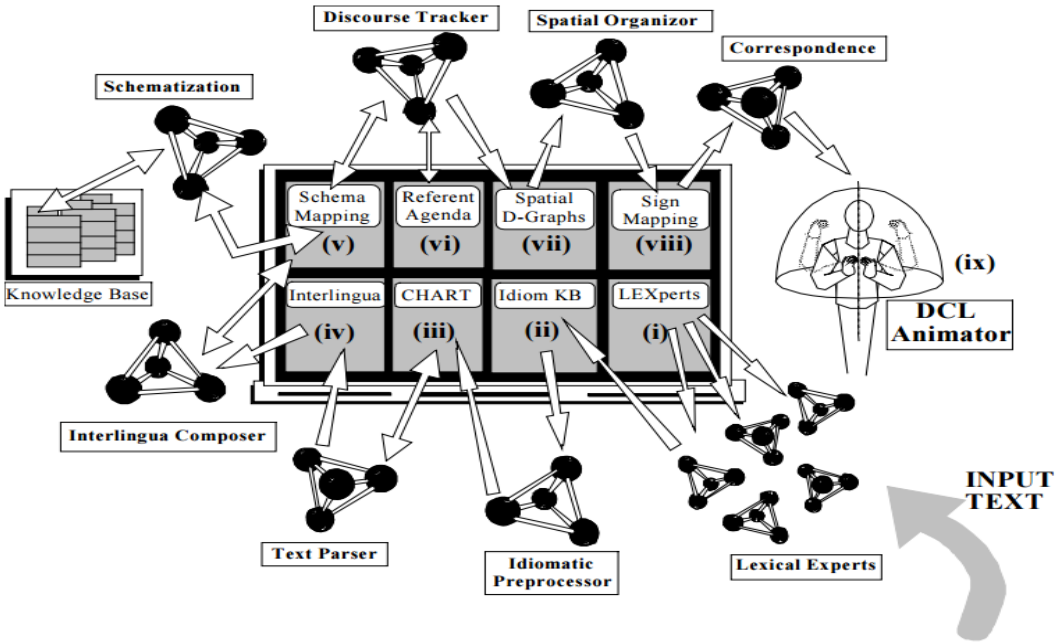


Figure 2.3: Architecture of Zardoz system [21]

The steps for the working of the Zardoz system by using the eight panels for input text stream to its animation are described below.

Step 1: The incoming text stream is processed by lexical experts (Lexperts) to implement morphological rules for converting the input text to know phrases.

Step 2: The identical expressions are used in place of idioms in idiomatic preprocessing.

Step 3: Text parsing is done to generate syntactic / semantic representation of text.

Step 4: The Interlingua composer generates an Interlingua frame format.

Step 5: Schematization process is used to remove metaphoric and metonymic constructs from the text.

Step 6: The Interlingua representation is given to the discourse tracking agency.

Step 7: The sign syntax agency produces Spatial Dependency (SD) graphs.

Step 8: The direct lookup or heuristic measures are used for generating signs corresponding to the tokens of the Interlingua structure.

The Interlingua structure is converted to a stream of sign tokens. These tokens form an input for a Doll Control Language (DCL) program. The sign animation of the input text is done by DCL program for the gesture sequence of the generated tokens [21].

2.1.4 English Text-To-Indian Sign Language Translator

Dasgupta *et al.* (2008) had introduced a system for Text to ISL conversion. The input text is given in English to the translator. It converts the text to ISL format, after carrying out syntactic analysis. The Lexical Functional Grammar (LFG) protocol is used for generating ISL syntax. The prerecorded video streams are used to produce output.

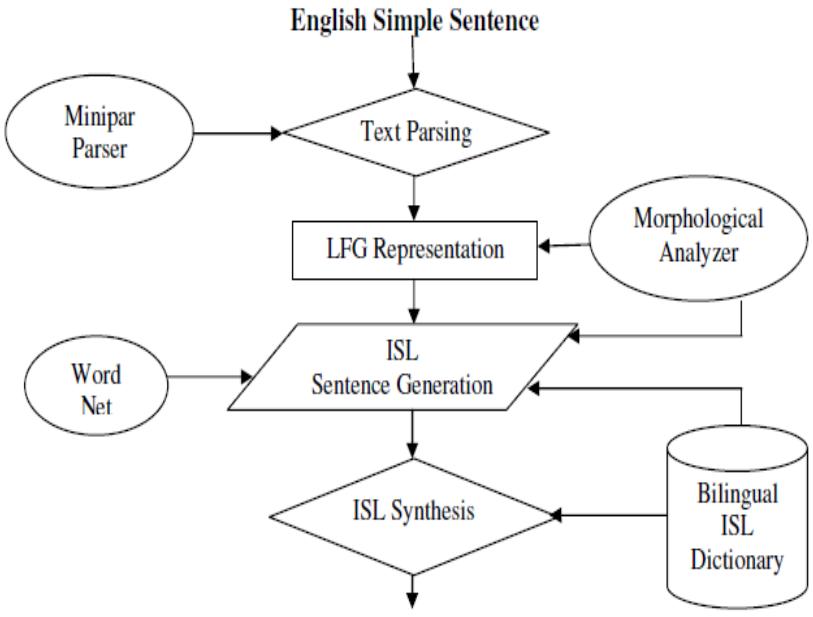


Figure 2.4: Architecture of Text-To-ISL Translator [22]

The architecture of the translator for text to ISL conversion is shown in Figure 2.4.It has four modules, i.e., Text Parser, LFG component, Sentence Generation and Sign Language Synthesis. A simple English sentence, containing only one main verb, is given as an input to the parser. The parsing is done by the Minipar parser. The classification of plural nouns is also included in parsing of the sentence. The plurality of nouns is identified by using an English morphological analyzer. The LFG component finds grammatical associations in the input phrase. It also represents the internal structure of the input text.

In the generation stage, grammar fundamentals are applied to convert English f-structure to ISL f-structure. During the generation phase, two main operations are performed which are lexical association and word order arrangement. For example, the input text "Lunch" in English may be represented by sign of "Afternoon Food" in ISL [22].

2.1.5 Sign Language Recognition by using HMM

Ouhyoung and Liang (1996) developed a system for identification of signs by using Hidden Markov Model (HMM). A statistic based context sensitive model is used for the recognition of both gestures and postures for a given sign. A sign gesture is divided into a string of postures. HMM is used to calculate the probability of each posture string. The probability outputted from Hidden Markov Model for each posture is used for identifying the input text in a linguistic way in real-time. The architecture of the sign language recognition system is shown in Figure 2.5.

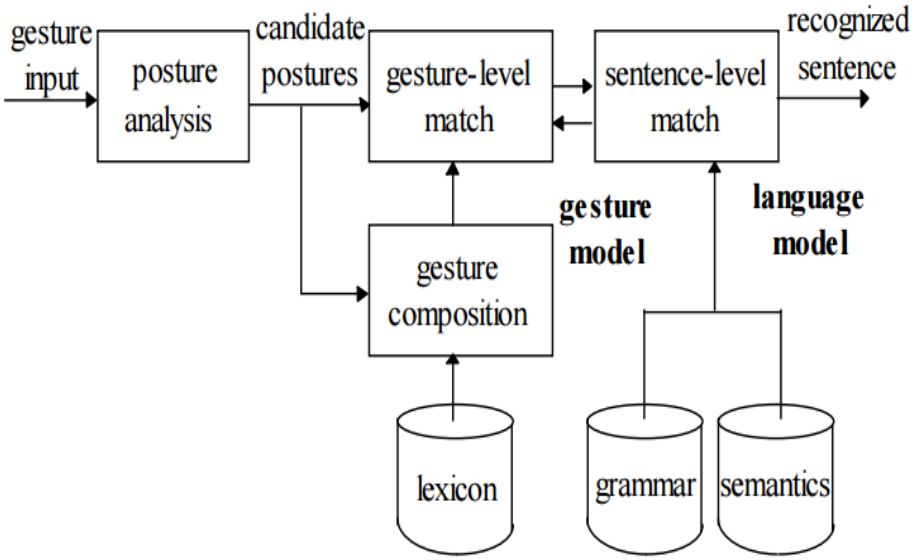


Figure 2.5: Architecture of Sign Language Recognition System [23]

The Posture analysis module receives input in the form of sign gestures. In this module, vector quantization is needed to estimate the probability of each frame of input data. In the hidden Markov Model, each gesture frame is defined as random process for a given sign. The received gesture frames are then fragmented into various postures. In gesture composition module, the various gestures are constructed as per the stored lexicons. The generated probabilities of the posture frames are tested in the gesture level match. The storage grammar is used for generating sentence level probabilities of the gestures. This probability is aggregated with the probability generated from gesture level match. Then the sentence level match produces a sentence having the highest probability for a given sign. The output is generated according to the semantics to recognize the real time gestures for the given sign. The recognized sentence is given as an output by the system for the inputted sign gestures [23].

2.1.6 Dicta-Sign Project

Efthimiou *et al.* (2009) had described Dicta-Sign project for providing technologies for the development of sign language based web applications. The project provides a platform for recognition, modeling and animation of signs. The project is developed for Greek, British, German and French sign language. It is implemented for the improvement of web-based applications which are developed for easy communication among hearing impaired people. The users input the signs by using webcams, which are identified by sign language recognition component. These signs are translated into a linguistic internal representation which is animated by signing avatar. The signs are animated in the language selected by user from all the four given languages. The system also translates the generated sign into the other three sign languages along with the language selected by the user. Dicta-Sign varies from other projects in the way it integrates together various modules for sign recognition, animation and machine translation [24].

The Dicta-Sign project is aimed for the development of corpora for four different sign languages. It is used for implementation of sign language recognition and animation systems. It can also be used for the development of a sign language-to-sign language translator. The visual tracking and feature extraction is done by using various statistical functions and geometrical characterizations of the signer's body parts [25]. These calculations are used for object-oriented morphological filtering, which is used for extracting the position of face and hands of the signer. Hidden Markov model (HMM) adaptation methods are used to ensure that the recognition system works

in a signer-independent way. The system employs a dictation-style interface in which the user is provided with the closest-matching solutions if a sign is not identified exactly. Sign language synthesis and animation is done by using virtual avatar by the composition of sign phonology components. The recognized sign language sequences are written in SiGML form, which is used for execution by an avatar on the computer screen in Greek, British, German and French sign language [26]. The Dicta Sign system is also available online and can be found at the given URL http://vh.cmp.uea.ac.uk/index.php/Dicta-Sign.

2.1.7 Spanish to Spanish Sign Language translation

Segundo *et al.* (2010) had developed a system for translation from Spanish speech to Spanish Sign Language (SSL). It is developed to focus on words uttered by an official when serving people who are applying for Identity Document (ID) and Driver's License (DL). The system is used for translating the officer's instructions into sign language for hearing-impaired people. It has two modules; one is for Spanish speech to SSL translation and other is for Spanish generation from LSE [27].

The LSE translation system has a speech recognizer, a translator and a 3-D virtual avatar module. For identifying the spoken language utterances, a speak recognizer is used. A sequence of words is generated from the recognized speech. The translator is used for converting the generated sequence of words into a set of gestures that belong to the sign language. For playing sign language gestures, animation avatar is used [28]. In this way the words spoken by an officer are converted to signs. The Spanish generator from SSL has a visual interface and language translator. The visual interface is used for providing a pattern of signs in sign-writing. For producing a sequence of words in Spanish, a language translator is used.

The corpus developed for this system has a collection of more than 4,000 sentences, which are commonly pronounced by the officers and users. The sign database of the system uses eSIGN Editor and stores the signs in the form of HamNoSys. There are three techniques that are used by the system for translation from spoken words to sign language. These techniques are example-based technique, rule-based translation and statistical conversion. An example-based technique is used while translating the given words. If the distance of the given sentence and the nearest example in the database is lower than a threshold value, then the translation output is same as the nearest example. The rule-based and statistical techniques are used for translating the word

sequence, if the distance is higher. The output sign is animated by using the eSIGN 3-D animation avatar [27].

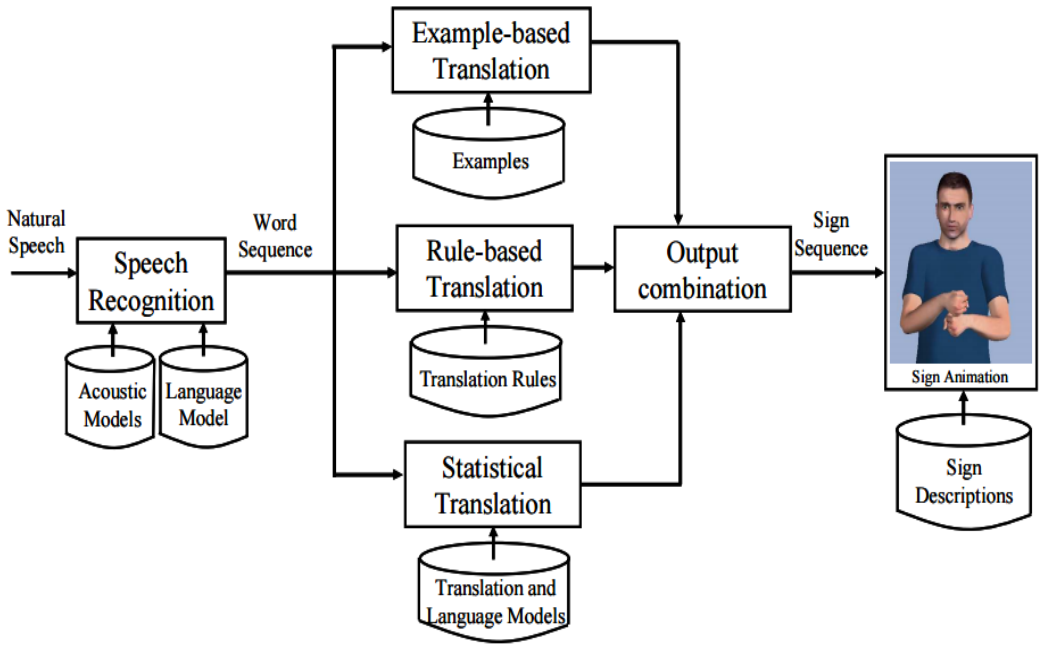


Figure 2.6: Architecture of Spanish Sign Language Translation System [27]

2.2 Comparison of Various Sign Language Automation Systems

The various existing systems for automatic generation and animation of sign language content are compared on the basis of their main features, year of development and the sign language for which they are developed. The comparison of various systems is shown in Table 2.1.

Table 2.1: Comparison of various Sign Language Automation Systems

Sr. No.	Name of System	Year	Sign Language	Main Features
1.	Sign Language Recognition by using Hidden Markov Model (HMM)	1996	Taiwanese Sign Language (TSL)	The system recognizes sign language gestures and postures by using HMM. The probabilities generated from the gesture and sentence level match are used to produce output for the real time gestures of the inputted sign.

Sr. No.	Name of System	Year	Sign Language	Main Features
2.	Zardoz System	1998	American Sign Language (ASL)	The system uses blackboard structure to generate signs from given text. It has eight panels that convert the input string into stream of tokens, which are animated by using Doll Control Language (DCL) program.
3.	ViSiCAST System	2001	British Sign Language (BSL)	The system parses the input sentence and generates a semantic string which is used for animating signs for the inputted text.
4.	TESSA	2002	British Sign Language (BSL)	The system is used by post office officials for interacting with deaf people. The system takes voice as an input and animates the signs.
5.	English Text-To-Indian Sign Language Translator	2008	Indian Sign Language (ISL)	The system takes English sentence as input and uses Minipar parser, Morphological analyzer and Word Net to convert the sentence in the ISL format. The prerecorded video streams are used to produce output.
6.	Dicta-Sign Project	2009	Greek, British, German and French Sign Language	The users input the signs by using webcams, which are recognized by using sign language recognition component. These signs are then animated in the sign language selected by the user.
7.	Spanish to Spanish Sign Language translation	2010	Spanish Sign Language (SSL)	The system takes speech as an input and uses speech recognizer to generate a sequence of words which are converted into a set of sign language gestures by using a translator. The sign gestures are then animated by a virtual avatar.

2.3 Existing Tools for Sign Language generation and automation

Sign Language is different from other spoken and written languages, so there is need of creation of dictionaries for storing signs and relating the spoken language words with the stored signs. Sign language differs in various countries and regions due to which there are a number of different sign language dictionaries. It is difficult to manually create and manage the sign language dictionaries, due to which there is a need of automation tools for sign language. Some of the tools available for creating, storing and automating the sign language content are discussed below.

2.3.1 ESIGN Editor

ESIGN editor is a tool designed for creating signs easily by the users. The signs that are created can be represented for signing by an animated ESIGN agent. The URL for the current release of ESIGN Editor is http://vh.cmp.uea.ac.uk/index.php/SiGML_Tools#eSIGN_Editor. The ESIGN Editor interface is shown in Figure 2.7.

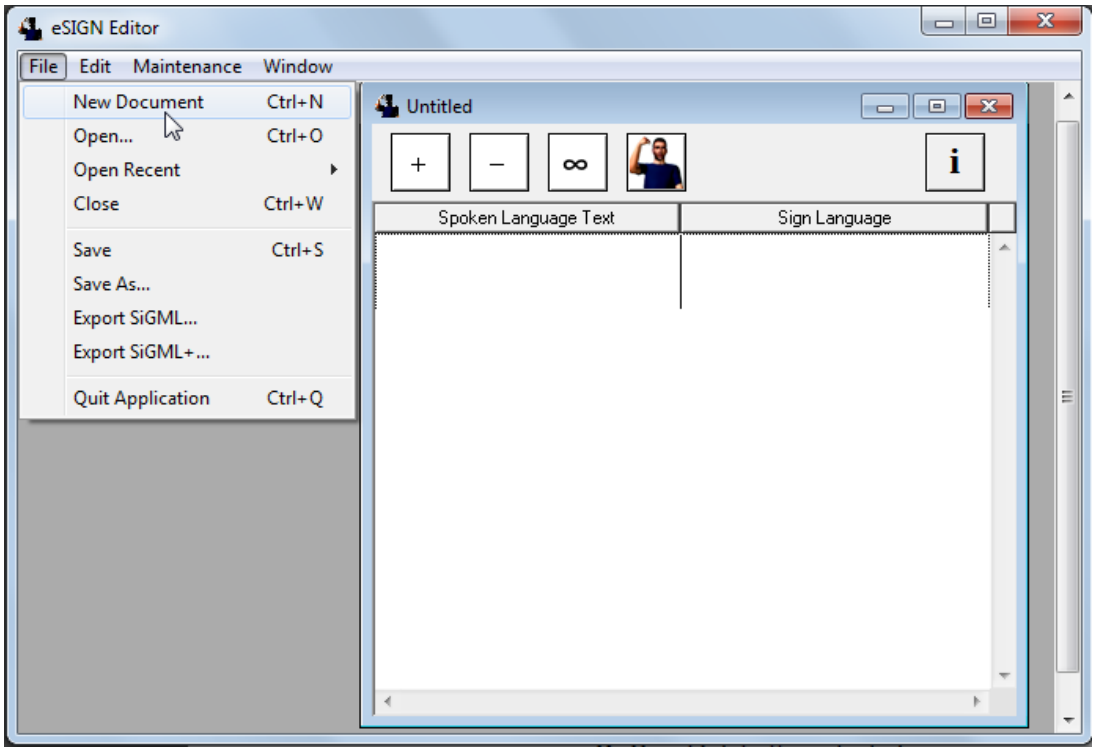


Figure 2.7: ESIGN Editor Interface

The ESIGN editor interface shows the editor window divided in two columns, one to represent an expression in natural language and other for its translation in sign language. The left column is for providing a phrase for the sign while the right is for its description in sign language. The document window is divided into rows where each row contains the description for a sign or a phrase [12]. The ESIGN editor contains a database of signs in which the signs are stored with the sign gloss and their respective HamNoSys notation as shown in Figure 2.8.

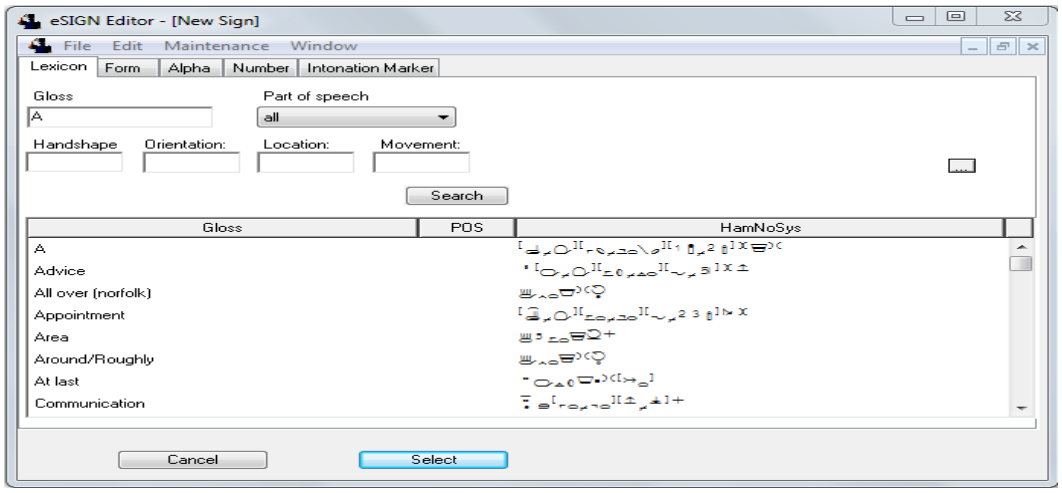


Figure 2.8: List of words in ESIGN Editor

The words in the editor can be searched by providing the sign gloss and HamNoSys can be retrieved from the editor. The ESIGN editor also provides the non-manual features for a given sign. After selecting the word from the database, the users can choose mouth gestures, hand shapes, limbs postures and face expressions for a given sign [12]. The document window for the non-manual gestures for selected signs is shown in Figure 2.9.

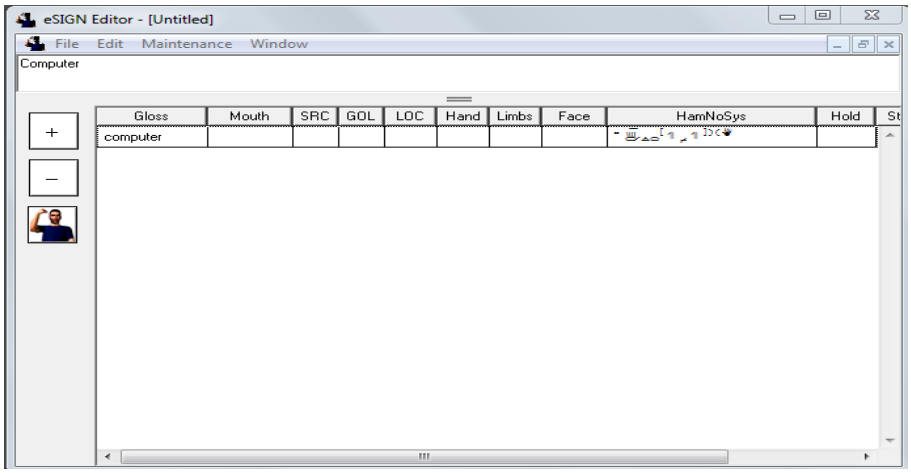


Figure 2.9: ESIGN Editor showing Document window

2.3.2 HamNoSys Editor

HamNoSys2HPSG v. 2.1 is an editor for generating HamNoSys of the given signs. The interface of HamNoSys editor is shown in Figure 2.10. In the Interface of HamNoSys editor, arrow pointing upwards is used for typing the HamNoSys characters for a given sign. When the user clicks on the arrow pointing upwards, a HamNoSys input system is shown to the users. It contains various tabs for hand-shape (Hsh), hand-orientation (Ori), hand-location (Loc), straight (Mov1) and curved (Mov2) movement of hand and symbols used for two-handed (2hd) operations. The HamNoSys symbols are shown as button caption and the HamNoSys string appears in the text field when the button is clicked [11]. The URL for the current release of HamNoSys Editor is http://vh.cmp.uea.ac.uk/index.php/SiGML_Tools#Ham2HPSG_Tool.

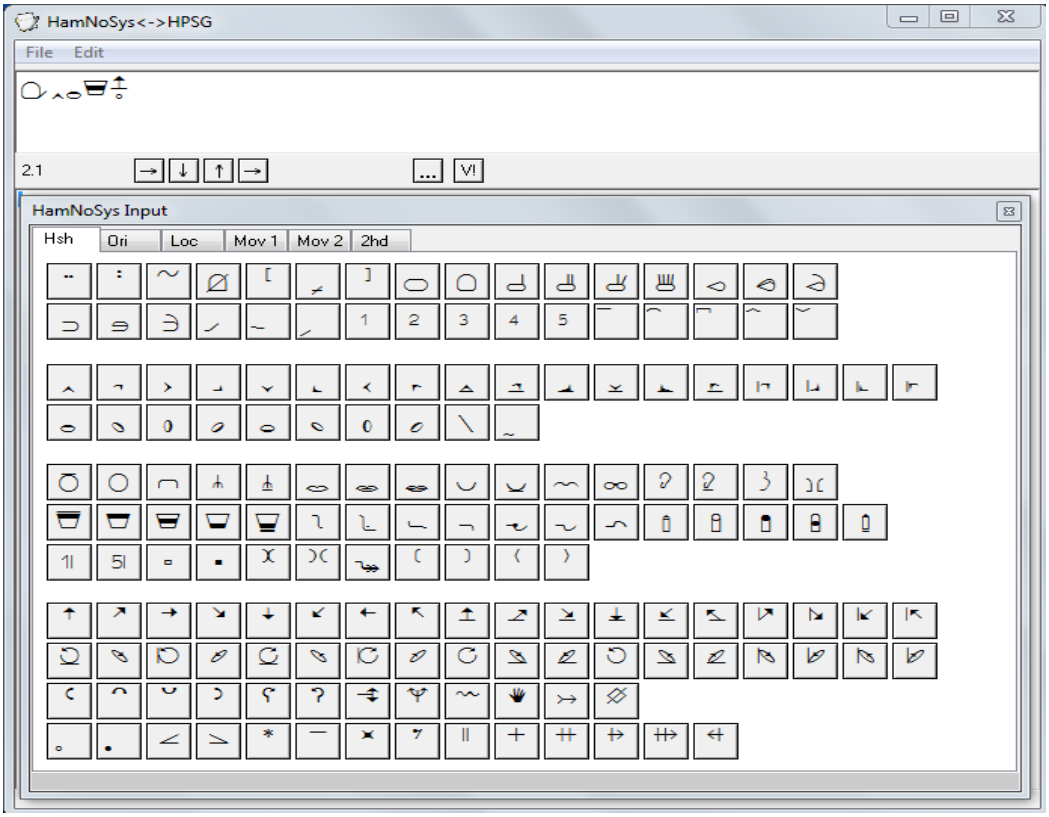


Figure 2.10: HamNoSys Input System

By clicking on the arrow pointing downwards, the user will get the textual representation of the entered HamNoSys notation as shown in Figure 2.11. Alternatively, the user can also manipulate a textual representation and then click the upwards arrow button to get its respective HamNoSys string.

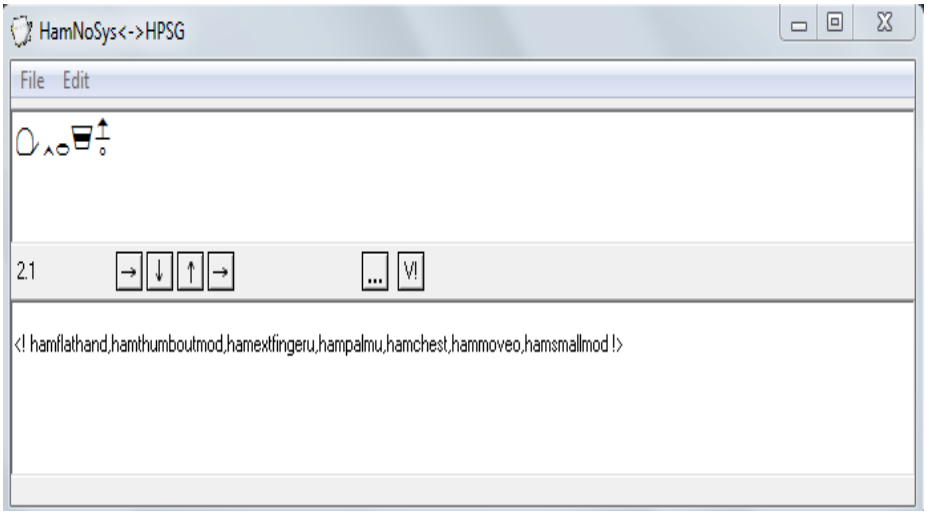


Figure 2.11: HamNoSys Editor showing textual representation of HamNoSys

2.3.3 Search-By-Example Tool

Elliott *et al.* (2011) had developed Search-by-Example tool for four national sign languages. These are Greek, German, French and British Sign Languages. The system has a sign gloss, HamNoSys notation and a video clip for each sign. It has a component for recognizing signs, which makes use of Kinect device for synthesizing signs in real-time. It also uses an animation avatar to show the generated signs to the users. In this system, user signs in front of the Kinect device, which acts as an input to it. The user selects the language, out of the four languages, in which he wants the sign to be animated. As an output, the system shows animations of signs recognized as similar to the signs inputted by the user. Along with the selected sign language, the sign animation is also available in other three languages.

The basic architecture of the system allows recognition and extraction of two main features for a given sign, *i.e.*, hand motion and location. The HamNoSys notation is written for the extracted features to express the sign in a more precise way. The HamNoSys notation is converted to h-SiGML, which maps the corresponding HamNoSys symbols into XML elements. This textual representation describes the sign gestures in the sequence in which they take place. The h-SiGML form is then converted by JA Signing into corresponding g-SiGML. The g-SiGML form contains additional information about timing and space. It is also provides the syntactic representation of the gestural description, corresponding to the phonetic composition of the given sign. The JA Signing application converts g-SiGML signs into a string of skeleton poses and

morph values. These values are used to provide signing information to the animation avatar in the form of subsequent gestural frames. For a given sign selected by user, the system will show four active instances of the animation avatar. Each avatar will show the signs for the corresponding word gloss in all the four languages [29].

2.3.4 Indian Sign Language Dictionary Tool

Dasgupta *et al.* (2008) had developed a tool for building sign language dictionary using multiple languages. It is used to produce signs for a given word or a phrase. The system also transcribes the signs in the form of HamNoSys notation. The transcribed HamNoSys string is used for automating signs by using animation avatars. The system architecture of ISL dictionary tool is shown in Figure 2.12.

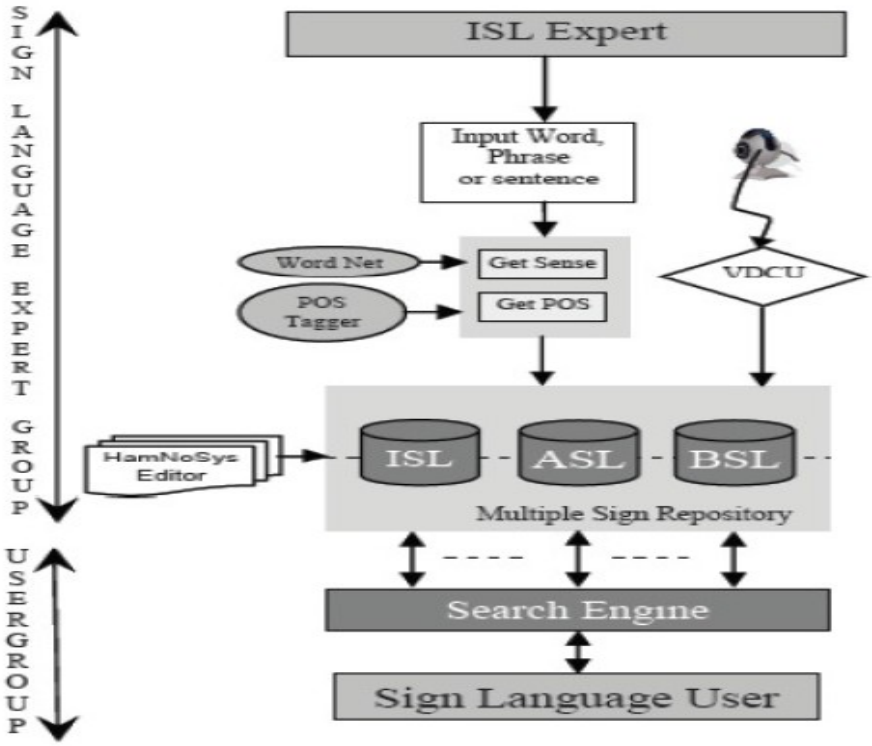


Figure 2.12: System Architecture of ISL dictionary [7]

The interface of the system is divided into Expert and User Module. The expert module is further divided into three units. These units are for processing input text, capturing visual data and for storing signs. In the Input Text Processing Unit, a Sign Language expert selects the spoken language such as English or Hindi. Then after selecting the desired language, the input text is

provided by the expert. The language for generating signs is also selected such as ISL or ASL. The input text may be in the form a sentence, phrase or word. The Visual Data Capture Unit (VDCU) is used for capturing the gestural features of the words signed by the users. The VDCU has a number of webcams attached to it. These are placed at various angular positions with respect to the signer.

The input text, linguistic specifications and the video clip of the sign are expressed in the form of HamNoSys and are stored in a database. The HamNoSys is then converted into SiGML type form. The input text is entered in the search engine of the system in English or Hindi. The system parses the entered sentence or phrase. After parsing, the system searches the root words, from the inputted text, in the sign language dictionary. If root words are matched with the words stored in the dictionary, then the signs corresponding to the selected words are displayed [7].

Chapter Summary

In this chapter, various systems and tools that are available for sign language automation are discussed. The various systems include ViSiCAST translator, TESSA, Zardoz system and Text-To-Indian Sign Language Translation system. The various systems using hidden Markov model for recognizing signs are also discussed. The Dicta-Sign Project is used for sign recognition for four European Sign Languages and can also be used for sign language to sign language translation. The system for Spanish Speech to Spanish Sign Language conversion uses Example-based and Rule-based translation methods for converting speech to sign language gestures. The different tools for sign language automation are ESIGN Editor, HamNoSys Editor, Search-By-Example tool for Multilingual Sign Language Databases and Multilingual Multimedia Indian Sign Language Dictionary Tool.

Chapter 3

Problem Statement

In I ndia, there are approximately 24 million people who are deaf or hard of hearing. There are very few sources in India that can impart knowledge about sign language among the deaf communities thus resulting in poor literacy level and language skills among deaf people. This effects the communication among deaf communities and also the economic growth of the country as in India only 5% of deaf people attend deaf schools [1]. There is need of a system that can provide the sign language content to the users and can also be used for learning Indian sign language both by hearing and deaf people, thus improving the literacy rate and language skills among deaf communities.

The sign language content in the form of text is complex and is not of much use to the deaf people. So the signed content was presented in the form of videos to the users. But the video approach is time and space consuming. Each time when there is a slight change in the sign language content, a new video has to be created from beginning which results in increasing costs [9]. There is a need to build a system for automation of sign language. So that it could also be used for learning Indian sign language both by hearing and deaf people, thus improving the literacy rate and language skills among deaf communities.

3.1 Objectives

The main objective of this research work is to develop HamNoSys based Indian Sign Language dictionary along with the automation of signs. For completion of this task, the following objectives have been framed.

- To study sign language, types of signs, Indian Sign Language (ISL), HamNoSys, SiGML and Non-Manual sign gestures.
- To understand the working of HamNoSys2HPSG v. 2.0 (HamNoSys2HPSG v. 2.0 is a HamNoSys generation tool), JA Signing URL App, SiGML URL Player and ESIGN Editor.
- To develop HamNoSys Input System, Non-Manual Components Selection System and to develop a Translator for HamNoSys to SiGML Conversion.

- To collect Indian Sign Language data for development of ISL Dictionary and to create HamNoSys of collected ISL words for dictionary.
- To locally install JA SiGML Player and development of signing avatar as per the requirements of ISL automation system.
- To develop a web portal for collaboration of all the tools being developed, to run under a single platform, for creation of HamNoSys based ISL dictionary.

3.2 Methodology

To achieve the objectives given in section 3.1 following methodologies have been adopted.

- The Literature survey has been carried out to learn Sign Language and to understand various types of tools and techniques used for automatic generation of sign language.
- An input system has been developed in Java for creating HamNoSys of the given signs. The HamNoSys input system has a user-friendly and easy to use interface, where HamNoSys symbols are represented as icons and caption is also provided on the buttons in the virtual HamNoSys keyboard. The various parameters in HamNoSys notation such as hand shape, orientation, location and movement are classified into seven different tabs. Thus the users having little or no knowledge can use the system for creating HamNoSys of the words in ISL.
- The system has a translator, written in Java, for converting HamNoSys to SiGML. The translator matches the entered HamNoSys string with the database of HamNoSys symbols. The HamNoSys symbols that match with the entered string are written in SiGML file.
- A Java application having animation avatars is developed for automation of signs. It makes use of Java applet technology for the animation avatar to run on the local server. The SiGML file is given as an input to the avatar which plays the corresponding signs.
- The ISL dictionary is created which stores signs in the form of HamNoSys along with their respective sign phrase or gloss. The signs that are transcribed by using HamNoSys notation are retrieved from ISL Dictionary and are converted into their SiGML form for animation. The 3-D animation avatar takes SiGML as input and animates the signs.

- A web based system has been developed from where the HamNoSys experts can create and store the signs in ISL dictionary. The web portal is designed by using Java Servlets and Java Server Pages (JSP). The users can easily retrieve the signs from the dictionary and need not to learn HamNoSys. Thus the web based system can be used by the people having little or no knowledge about HamNoSys or sign language.

Chapter 4

Implementation

4.1 Architecture of Proposed System for Creation of HamNoSys based Dictionary for Indian Sign Language Automation

A system has been proposed for the creation of ISL Dictionary for automation of sign language. In this system, HamNoSys of a word is inputted by the user and the system works on it to store it in ISL Dictionary for automation of the signs of the given word. Architecture of the proposed system for creation of HamNoSys based ISL Dictionary is shown below in Figure 4.1.

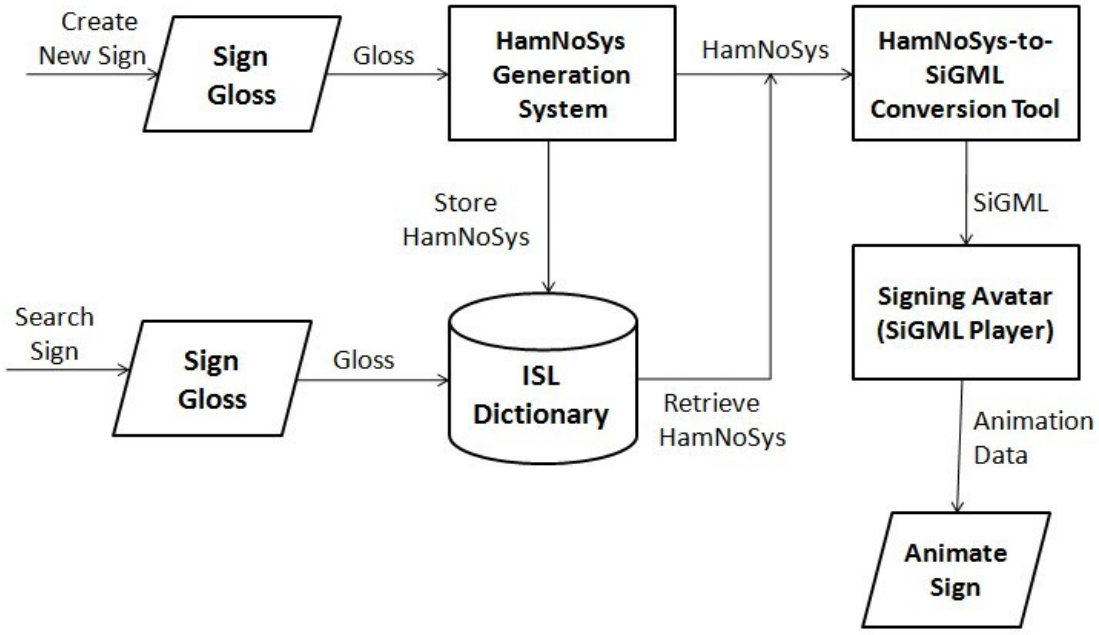


Figure 4.1: Architecture of Proposed System

The basic architecture of the given system allows the user to provide sign gloss and HamNoSys for creating new signs, which are to be thereafter stored in ISL Dictionary. The proposed system has a HamNoSys generation tool for creating HamNoSys, an input system for selecting non-manual components, a translator for converting HamNoSys to SiGML, an avatar player for automating the signs and a dictionary for storing the sign language content which is being generated. These all applications are collaborated together in the proposed system and are represented in the form of a web based portal. The HamNoSys notation of a sign is created from HamNoSys Generation System, which provides iconic relationship between HamNoSys symbols

and their referents. After HamNoSys generation, a sign can be stored in ISL dictionary and can be retrieved when searched using its sign gloss. The SiGML file is generated from the translator for HamNoSys to SiGML conversion. The SiGML representation of a sign comprises of a more tractable illustration of HamNoSys which is served as an input to the Signing Avatar that animates the signs.

There are basically two phases for automatic generation of sign language from inputted text. The first phase focuses on parsing the input sentence into a string of tokens. The parsing is done by using the shallow parser, which extracts the root words from the input sentence. There are various intermediate stages through which a sentence is passed to extract the root words from it. These stages include Tokenization, Morph Analysis, Parts-of-Speech Tagging and Chunking [30]. After all these stages, the root words are extracted from the input sentence. The second phase includes sign animation for the root words. The HamNoSys is generated for the extracted root words and it is converted into its SiGML form. The SiGML is then given as an input to the virtual avatar, which animates the signs. In this thesis, the second phase has been considered and a web based system has been developed for automation of signs.

4.2 Need for creation of HamNoSys based ISL Dictionary for Sign Language Automation

There is a need for the development of a system which can generate, automate and store the Indian Sign Language data. The approach of generating signs by human users and capturing the videos of the signs generated is very expensive as well as time and space consuming. There are various tools available for sign language automation for ASL and BSL. But, these tools are not of much use for ISL as sign language used in India is different from that of ASL and BSL. So, the proposed system is developed particularly for Indian Sign Language to overcome all these shortcomings.

Earlier the users need to use different tools for HamNoSys generation, SiGML conversion and sign automation, which make the sign language automation process very complex. But in the proposed system, a number of tools have been developed to be collaborated in a web based portal so that the users can easily generate and automate the sign language content at the same time. The tools developed for sign language generation are HamNoSys Input System, Non-Manual Components Selection System and SiGML Translator. The JA Signing SiGML Player is

developed for sign language automation. There was earlier no method available for storing the generated sign language data, so a dictionary is created for storing the signs for ISL words. The system provides a single platform for creating, automating and storing the sign language content. Thus the system is easy to use and time saving for users, who can also use it for learning HamNoSys and Indian sign Language.

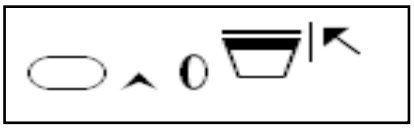
4.3 Creation of HamNoSys based ISL Dictionary for Sign Language Automation

The users can create HamNoSys for a given word in ISL from the HamNoSys Input system and Non-Manual components selection system. The ISL word can be stored in dictionary along with its HamNoSys and Sign Gloss. The stored word and its HamNoSys can be retrieved from the dictionary later on when required by the users. The SiGML translator is used to convert that retrieved HamNoSys to SiGML. The SiGML file is given as an input to the JA Signing virtual player for automation of the sign of the word selected from dictionary. The HamNoSys of the selected word can also be updated and stored in dictionary from the web portal itself.

4.4 Implementation of HamNoSys based ISL Dictionary for Sign Language Automation

The system for creation of HamNoSys based ISL Dictionary for Sign Language Automation is implemented through a web based portal developed in Java. In this system, various tools are developed and collaborated together for sign language generation and automation. The various signs generated are stored in ISL dictionary which is also maintained through the web portal developed for ISL automation.

(a)



(b)

Figure 4.2: a) Avatar showing sign for word “Power” b) HamNoSys Notation for “Power”

The HamNoSys notation of a sign is transcribed in the ISL dictionary along with its sign gloss which can be retrieved later. The ISL dictionary is available in both English and Hindi versions. The various tools developed in the proposed system are explained below in detail by taking example of word "Power" in ISL. The sign and HamNoSys notation for "Power" are shown in Figure 4.2.

4.4.1 HamNoSys Generation System

An input system has been created from which the HamNoSys Notation of a given sign can be created. The input system for HamNoSys consists of a virtual keyboard having the HamNoSys symbols as icons on it. The HamNoSys symbols are broadly classified into 7 different categories ranging from Hand-Shape, Extended Finger Orientation, Palm Orientation, Location, Straight Movement, Curved Movement and Two-Handed symbols. These seven categories are represented as seven different tabs in the HamNoSys Generation Tool, so that the user can easily select the required symbols while creating HamNoSys of a given word in ISL. The HamNoSys Generation tool in Figure 4.3 is showing HamNoSys for ISL word "Power (ताकत)".

Figure 4.3: HamNoSys Generation System showing HamNoSys for word "Power"

The HamNoSys Generation System consists of 200 HamNoSys symbols which are used for transcription of signs in ISL Dictionary. The system allows the user to create signs using various hand forms, thumb variations, bending of finger, flat and round hand shapes, different hand and wrist orientations, hand movements and location of hands for any given word which makes of

manual-components while signing. Thus, the given system can be used for creating HamNoSys Notation of any given word from its sign representation in ISL. The various HamNoSys parameters along with their respective number of symbols in HamNoSys generation tool are shown in Table 4.1.

Table 4.1: HamNoSys Parameters with their corresponding number of symbols

HamNoSys Parameter	Number of HamNoSys Symbols
Hand-Shape	32
Extended Finger Orientation	18
Palm Orientation	8
Location	40
Straight Movement	43
Curved Movement	34
Two-Handed	25
Total	**200**

4.4.2 Non-Manual Components Selection System

A system has been developed from which a user can select the non-manual components, which are used while signing, after generation of HamNoSys of a given word. The non-manual components are mainly classified into three different categories, *i.e.*, mouth gestures, limbs and face expressions. The non-manual components selection system is shown in Figure 4.4.

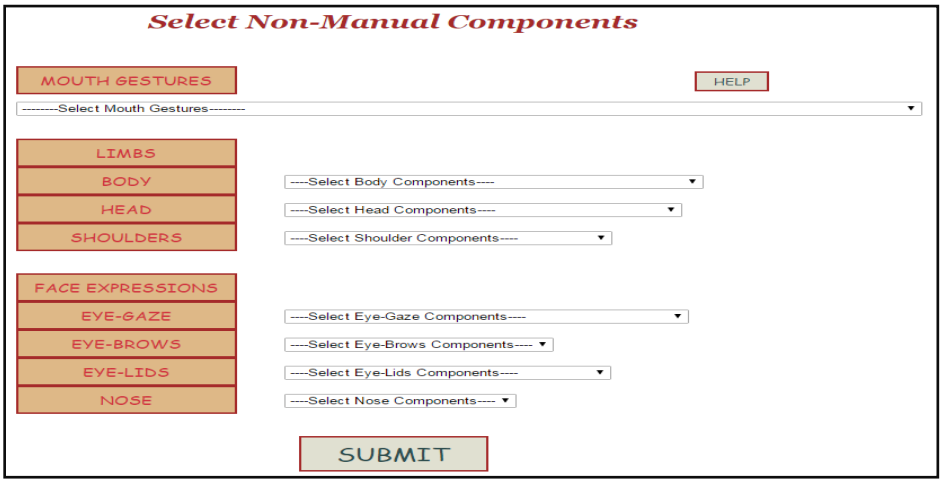


Figure 4.4: Non-Manual Components Selection System

The non-manual components are selected from the system for the given words whose signs make use of mouth gestures, eye-gaze or other expressions of face while signing. The various components that are available in the Non-Manual components selection system are given below.

4.4.2.1 Mouth Gestures

There are various tags available for mouth gesture components in this system which can be used while signing as shown in Figure 4.5.

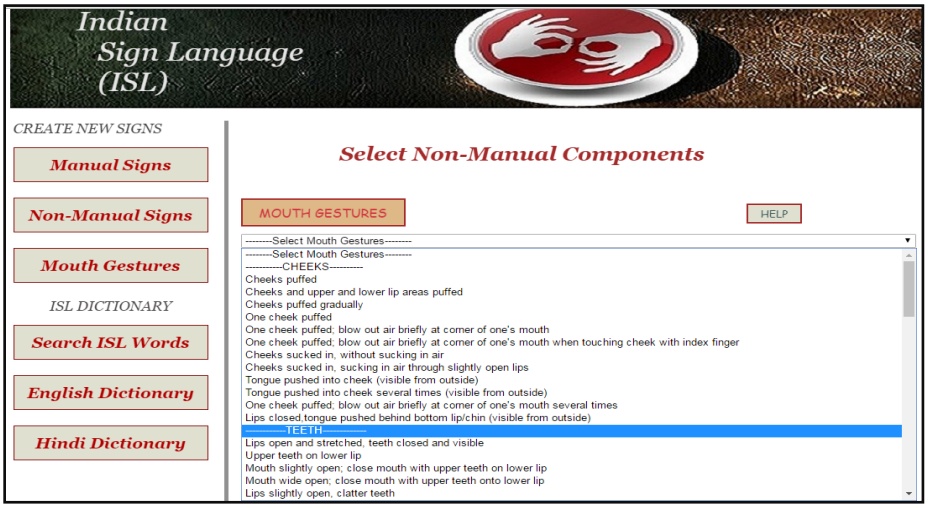


Figure 4.5: Mouth-Gestures in Non-manual components

The mouth gestures components are divided into groups according to five different categories. These categories are cheeks, teeth, jaw, tongue and lips. The various categories of mouth gestures along with their respective number of tags in Non-Manual Components selection system are shown in Table 4.2.

Table 4.2: Mouth Gesture Parameters with their corresponding number of tags in Non-Manual components system

Mouth Gesture Parameter	Number of tags
Cheeks	12
Teeth	10
Jaw	4
Lips	37
Tongue	17
Total	**80**

The system contains code for 80 expressions of mouth which can be done by the signer while signing. The video clip for each expression is also provided so that the user can easily select the required component. The selected mouth gesture component shown in Figure 4.6 is "Lips rounded, tense and slightly open (like closed 'o')". The video clip for the selected mouth gesture is shown in Figure 4.7.

Figure 4.6: Selecting Mouth-Gesture component

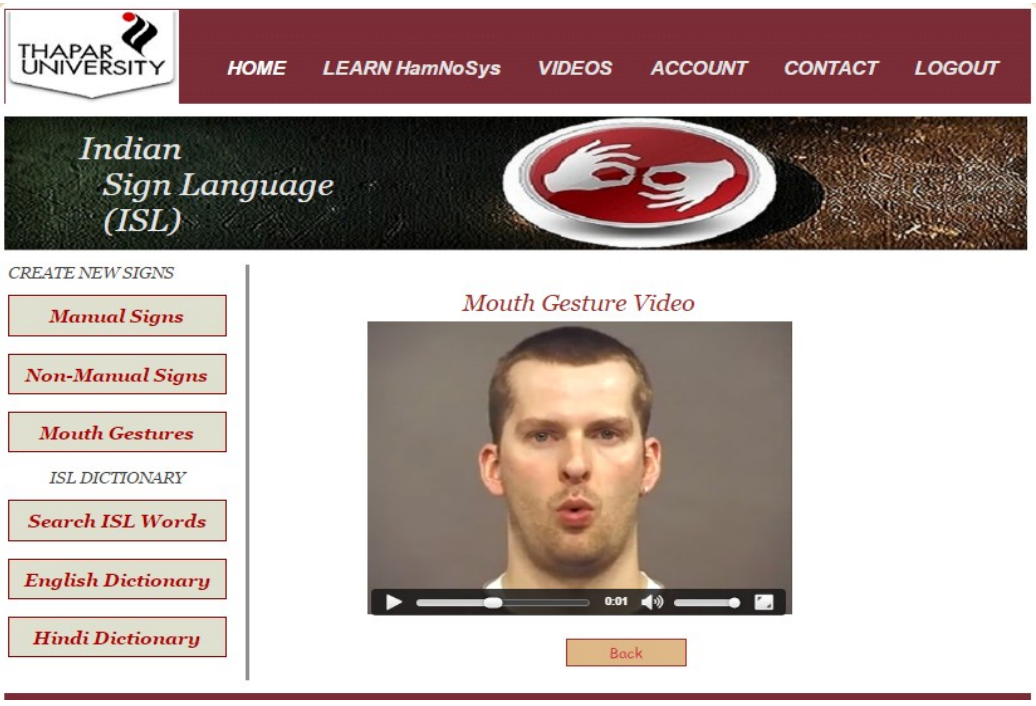


Figure 4.7: Video clip for selected for Mouth Gesture component

4.4.2.2 Limbs Postures

The signer can make different postures while signing to convey the meaning of the words being signed more accurately, so the proposed system has tags for different possible postures of limbs that can be used by the signer as shown in Figure 4.8.

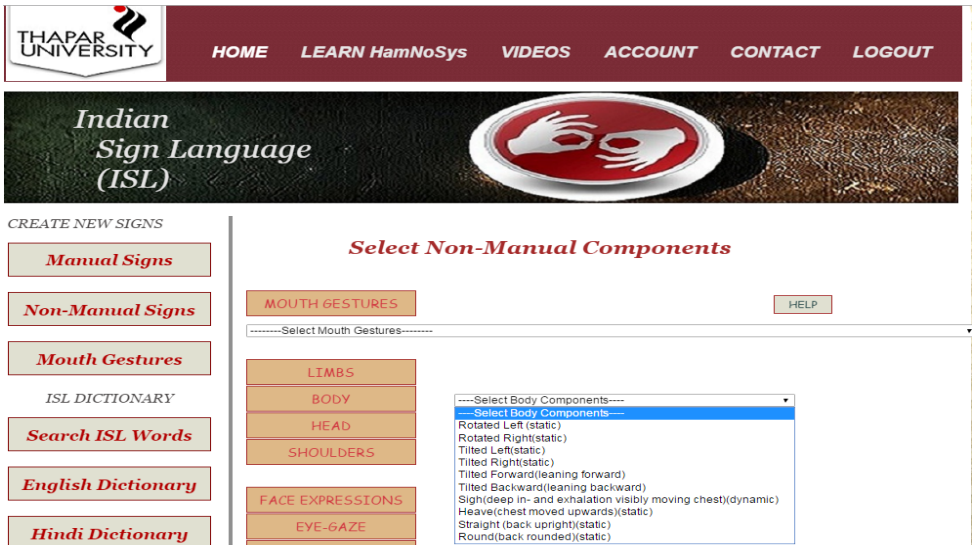


Figure 4.8: Limbs in Non-manual components

The limbs postures are classified into three different categories, *i.e.,* head, shoulders and body postures as explained below.

a) Body Components

There are 10 tags for body components in this system such as postures for body rotated (left or right), tilted (left, right, forward or backward), straight and round body postures.

b) Head Components

The head components include 12 tags for dynamic nodding of head from up to down, dynamic shaking of head from left to right, turned head (left or right), tilted head (left, right ,forward or backward),head pushed forward or backward and dynamic head movement linking to eye-gaze of the signer.

c) Shoulder Components

The system has 9 tags for describing various possible positions of shoulders that can be used by the signer. These positions include static and dynamic postures for raised, hunched and shrugged

shoulders. These postures are available for left, right or both shoulders for up, down, forward and backward movements.

4.4.2.3 Face Expressions

The signer can make different face expressions while signing to convey the meaning of the words being signed more accurately, so the proposed system has tags for different possible face expressions that can be used by the signer as shown in Figure 4.9.

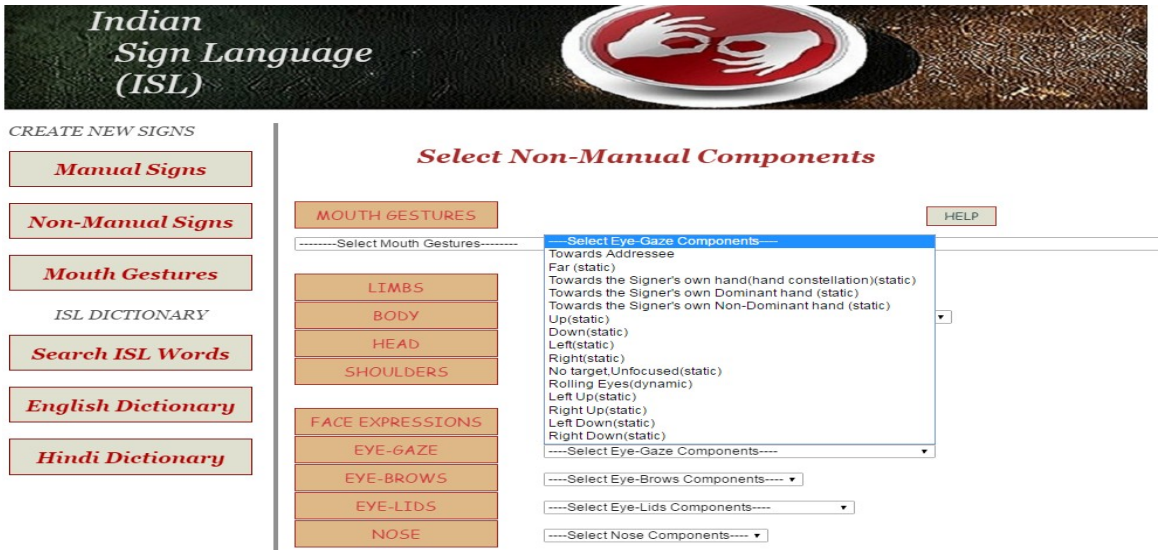


Figure 4.9: Face Expressions in Non-manual components

The face expressions are classified into four different categories, *i.e.,* eye-gaze, eye-brows, eye-lids and nose expressions which are explained below in detail.

a) Eye-Gaze

The various components available for eye gaze are eyes towards or far from addressee, unfocused eyes, eyes towards signer's dominant or non-dominant hand, dynamically rolling eyes and various other eye-gaze expressions in up, down, left and right direction . The users can select any of these components depending on the sign of the given word.

b) Eye-Brows

The eye brows can be raised or furrowed while animating a given sign in ISL. The tags are available for left, right or both eye raised and for both the eyes furrowed in the non-manual components selection system for face expressions.

c) Eye-Lids

The various tags are provided for wide open eyelids, narrowed eyelids, closed eyelids and tightly shut eyelids. The users can select these tags for either left, right or both eyes depending on the sign's eyelid expressions.

d) Nose

There are three possible nose expressions for a given sign including wrinkled nose, widened nostrils and dynamic twitching of nose. Any of these tags can be selected by the user for the sign of the given word in ISL.

4.4.3 HamNoSys to SiGML Translator

A translator has been written to convert HamNoSys of the given word to its SiGML form, to make it available to the signing avatar for animation. In this conversion system, the user enters HamNoSys of a given word and the system converts it into SiGML format automatically by matching the HamNoSys symbols to the corresponding SiGML tags. A database is maintained which contains SiGML tags for all the 200 HamNoSys symbols that are available in HamNoSys Generation System as discussed in section 4.1.1. Then the translator matches the entered HamNoSys symbols with those which are stored in the database. The SiGML tags of the entered HamNoSys symbols which are matched with the database file are written in a separate SiGML file. The file is generated with dot SiGML extension and its name is same as provided by the user for the sign gloss of the given word. The file is saved automatically in the desired format which is accepted by the SiGML URL player**.** The steps for generation of SiGML from its HamNoSys form are shown in Figure 4.10.

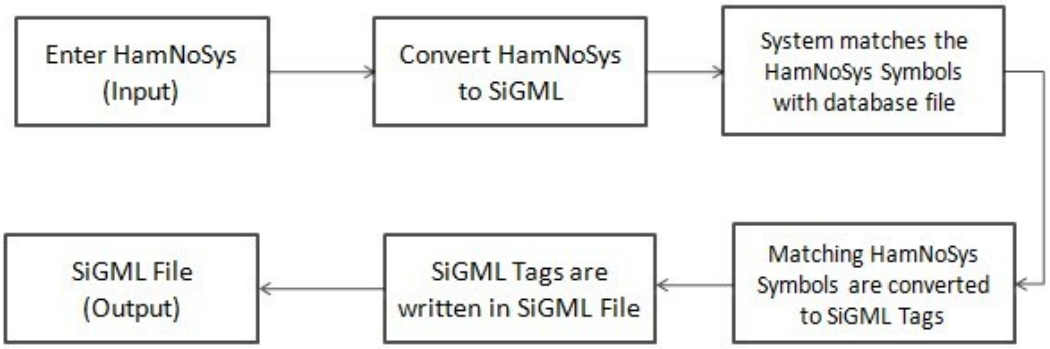


Figure 4.10: Working of HamNoSys to SiGML Translator

The HamNoSys for word “Power” shown in Figure 4.2 in HamNoSys Generation system is converted to its SiGML format by the HamNoSys to SiGML translator. The SiGML file that is generated for the word “Power” corresponding to its HamNoSys notation is shown in Figure 4.11.

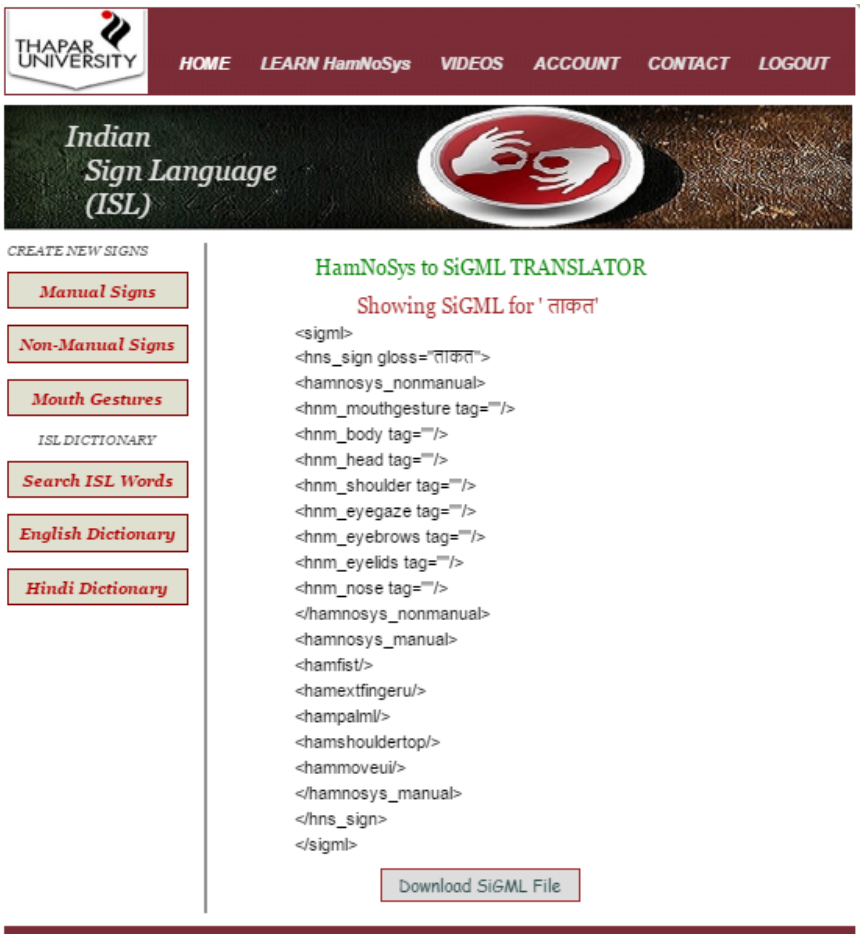


Figure 4.11: HamNoSys to SiGML Translator showing SiGML for word “Power” in ISL

4.4.4 SiGML Player

The JA SiGML URL App consists of Avatars that are used to play signs. The SiGML File generated from HamNoSys to SiGML Conversion system is provided as input to the virtual signing system that produces natural sign language using virtual human characters.

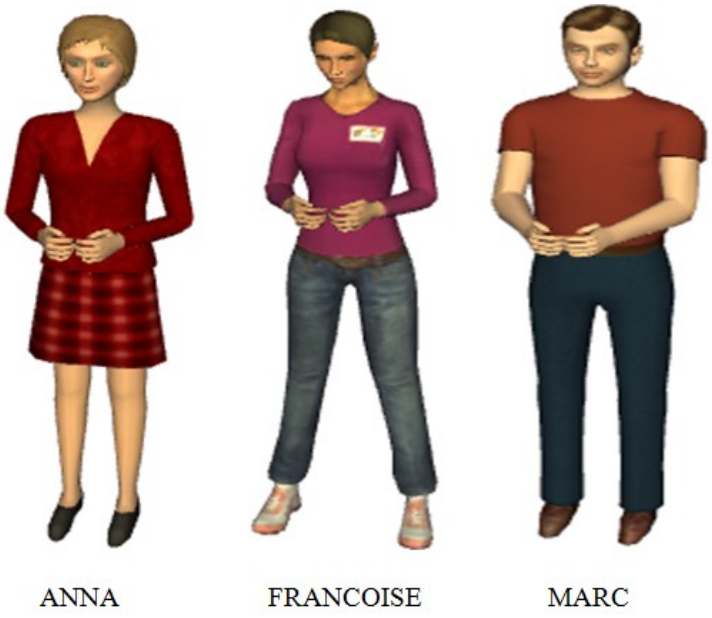


Figure 4.12: Virtual Signing Characters in SiGML Player

The JA Signing software having the SiGML Player has been installed locally to run on local host server. There are several avatars available for animating the signs in the JA Signing software. But in case of the signing avatar for Indian Sign Language, there are three basic avatars which are used for animating the signs. The three basic avatars namely Anna, Francoise and Marc are shown in Figure 4.12.

The proposed system has the JA Signing software embedded in it to animate the signs whose HamNoSys is inputted in the system. The JA Signing project which is developed for Indian Sign Language is configured in a very simplified way so that the user can easily animate the signs. When the user provides the Sign Gloss and HamNoSys for a given word, the HamNoSys to SiGML translator generates the SiGML file which is automatically stored with the same name as that of the Sign Gloss provided by the user in the previous step. The translator stores that SiGML file in the file path set in the sign language project. Then the Virtual Avatar Player automatically selects the SiGML file and the file path and the user need not to specify it. When the user clicks on play button provided in the GUI of JA signing project, the SiGML Player automatically plays the corresponding signs. The SiGML Player for ISL automation given in Figure 4.13 is showing sign for word "Power (ताकत)".

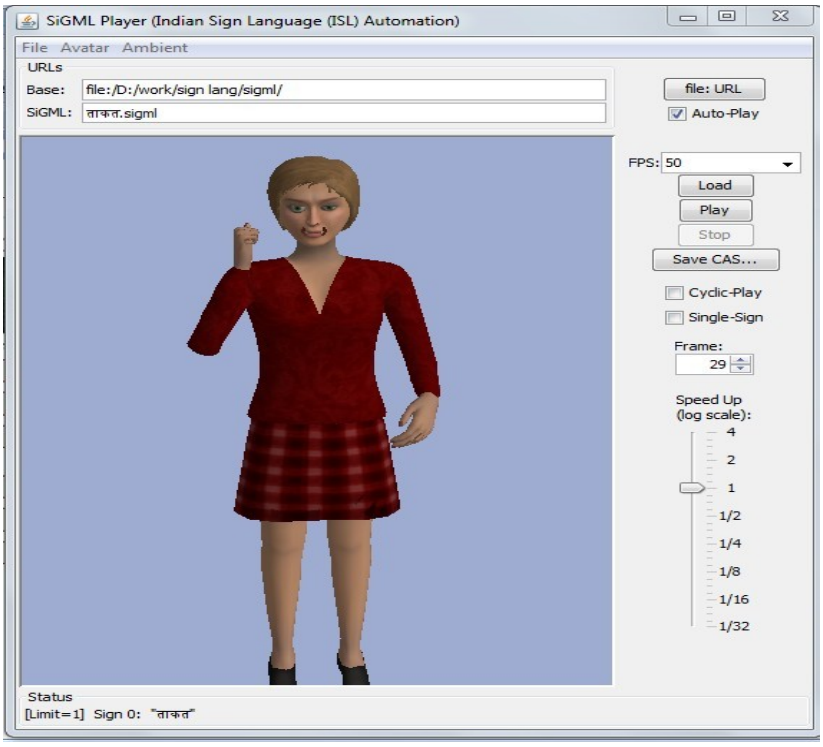


Figure 4.13: GUI of SiGML Player for ISL Automation

4.4.5 Creation of HamNoSys based ISL Dictionary

The sign language content is created through the web based portal developed in the proposed system for Indian Sign Language. The interface of the web portal showing the results for the given signs is shown in Figure 4.14.

Figure 4.14: GUI showing results for ISL word “Power”

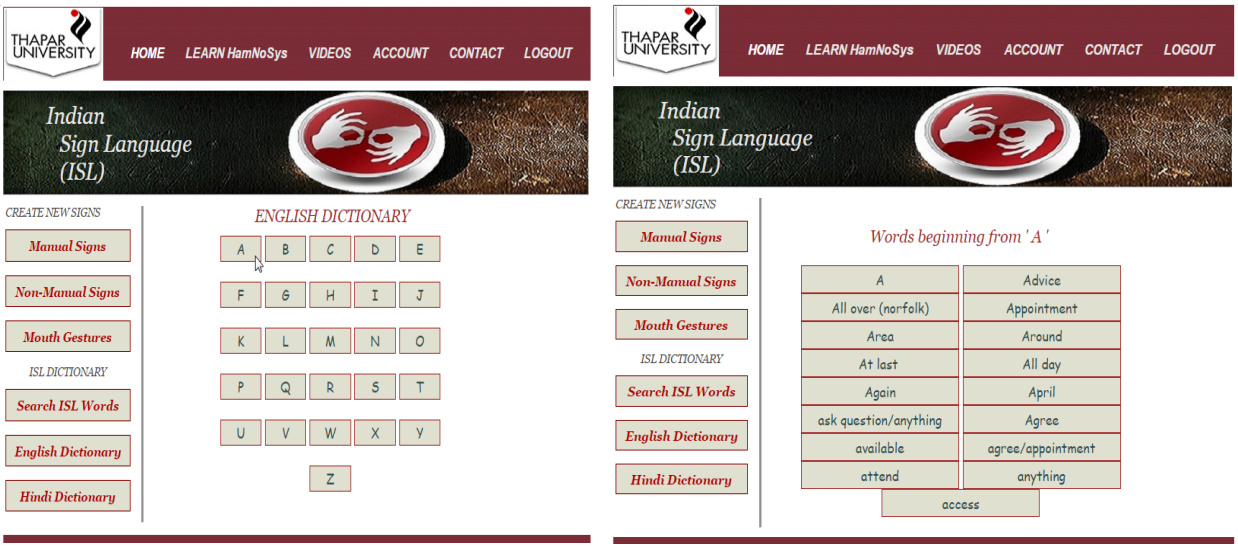
There must be a way to store the signs of the words being created for future use. Thus a dictionary has been maintained through the proposed web portal for storing the signs that are being generated. The sign for a given word in ISL is stored by transcription of HamNoSys along with its sign gloss in the dictionary. The admin module of the proposed web portal has the authority to store the signs in the ISL dictionary.

The users can search for the sign of any given word in ISL dictionary by entering the required word in the textbox or by selecting the required alphabet from which the word begins. The system will display all the words beginning from that alphabet. The ISL dictionary is provided in English as well as Hindi. So, the user has three options for selecting a word from ISL Dictionary for sign automation as shown in Figure 4.15.

Figure 4.15: Search Features in ISL Dictionary

4.4.5.1 ISL Dictionary for English Words

The English Dictionary provides a list of all the alphabets in English, from which a user can select an alphabet for the word being searched. The system will display all the words, from ISL dictionary, starting from the selected alphabet. The user can click on the required word and as a result the system will display all the details of that word. The details include its HamNoSys, SiGML and JA Signing avatar for sign automation of the selected word. The interface of English dictionary showing words beginning from alphabet "A" is shown in Figure 4.16.



(a) (b)

Figure 4.16: a) Searching English Dictionary for 'A' b) Showing search results for 'A'

4.4.5.2 ISL Dictionary for Hindi Words

The Hindi Dictionary provides a list of Hindi alphabets, from which a user can select an alphabet for the word being searched. The system will display all the words, from ISL dictionary, starting from the selected alphabet. The user can select any of the given words and view its HamNoSys, SiGML and can also animate its sign. The interface of Hindi dictionary showing words beginning from alphabet "स" is shown in Figure 4.17.

(a) (b)

Figure 4.17: a) Searching Hindi Dictionary for 'स' b) Showing search results for 'स'

4.5 Description of Proposed System for ISL word 'Read' as an example

The steps given below show the automation of the signs using ISL Dictionary, beginning from HamNoSys creation to sign animation. The following steps will take the example of ISL word "Read (पढ़ना)" to explain the process of sign automation.

Step 1: Providing Sign to a Concept

The Sign Concept is the exact name of the sign or the part of it, which will be used for referring the words from the Dictionary. The figure below shows the sign concept entered for word "Read".

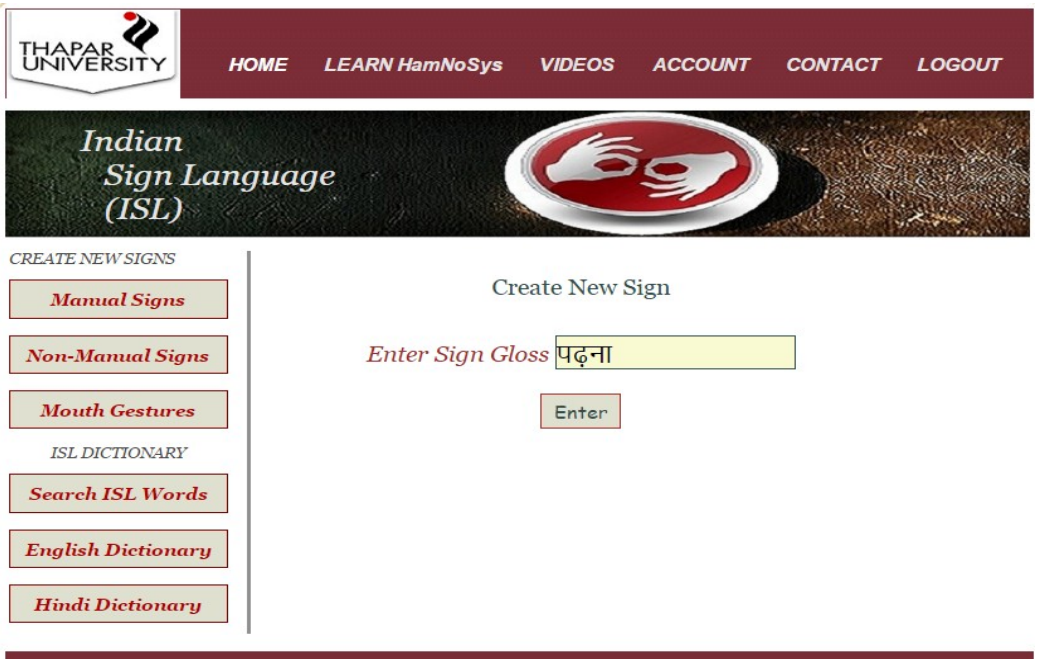
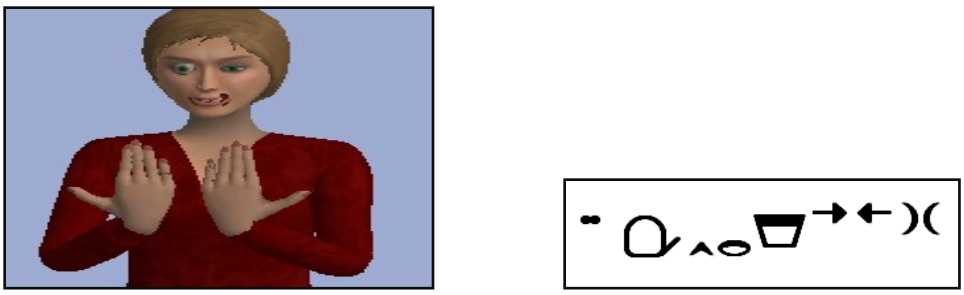


Figure 4.18: Sign Concept for word 'Read" in ISL Dictionary

Step 2: Generating HamNoSys

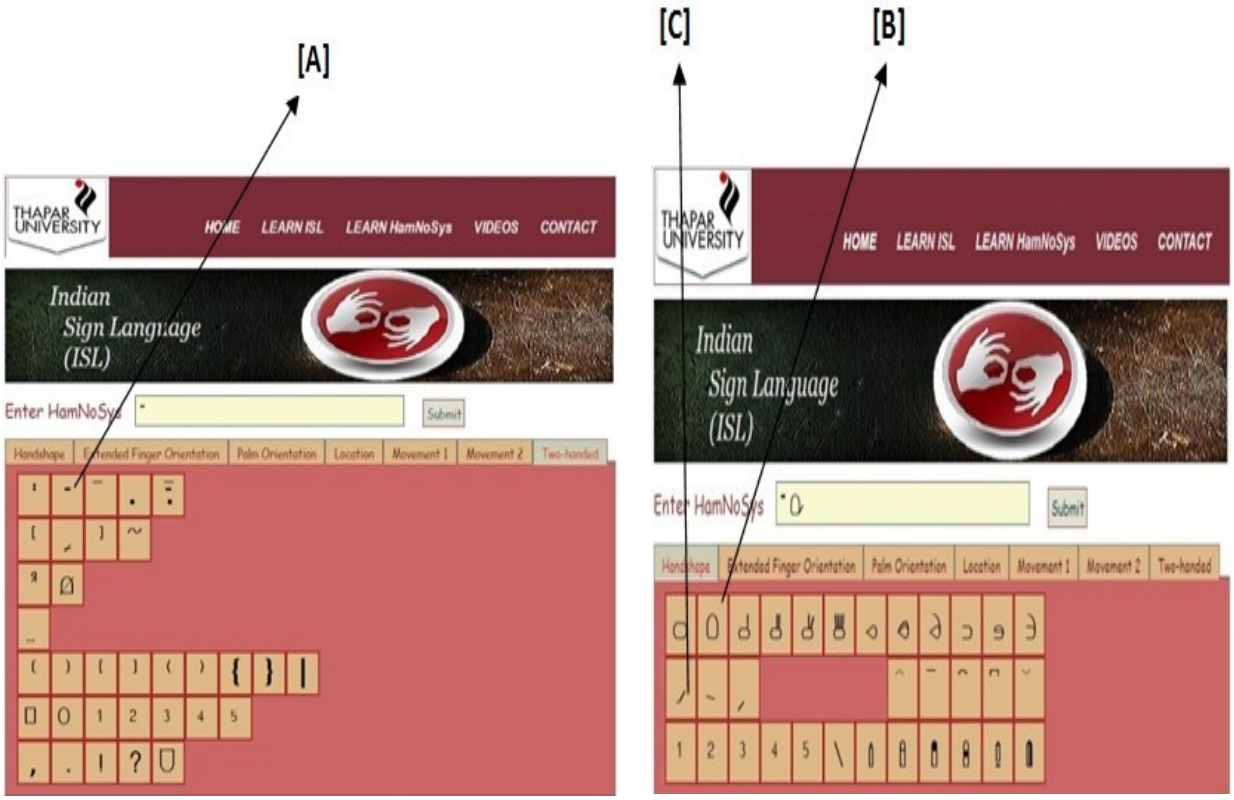
HamNoSys creation tool used for selecting manual components consists of 200 HamNoSys symbols as icons. These symbols are precisely classified into 7 different categories ranging from shape of hand, orientation of extended finger and palm, location of hand, straight and cyclic movements to two-handed components. The HamNoSys notation for word "Read" in ISL is shown in Figure 4.19.



(a) (b)

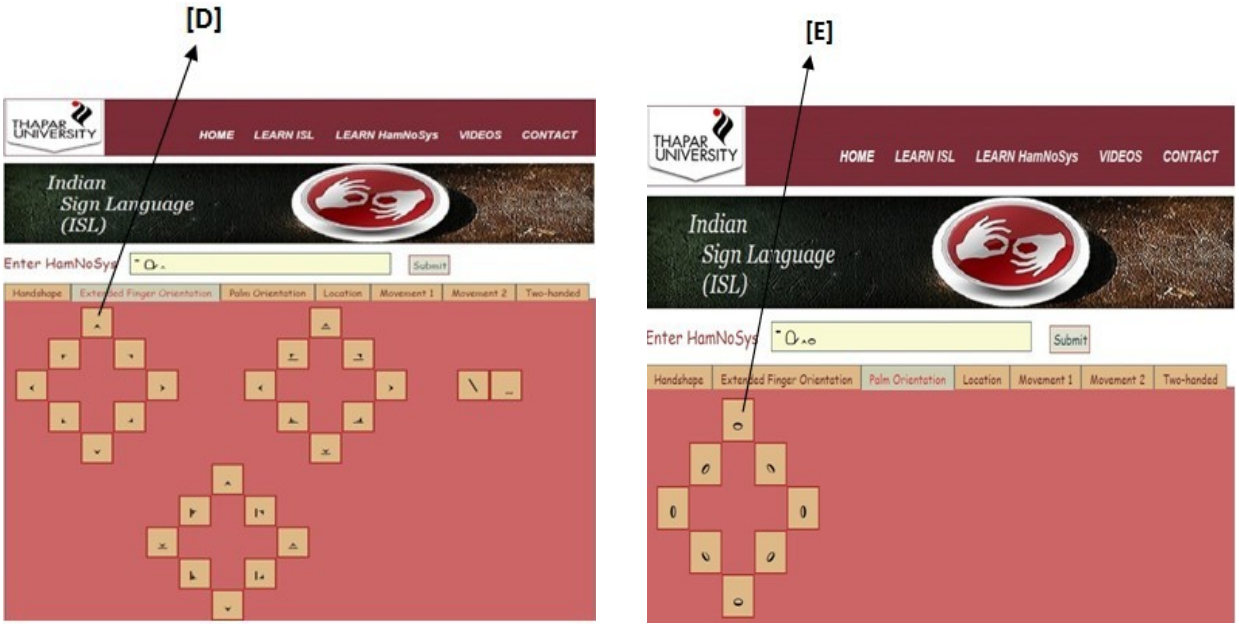
Figure 4.19: a) Avatar showing sign for word “Read” b) HamNoSys of word “Read”

The figures below show stepwise illustration for generating HamNoSys from HamNoSys Input System for word “Read”. The selected HamNoSys symbols after being combined together will give the resultant Indian sign Language representation of word “Read” in terms of HamNoSys notation.



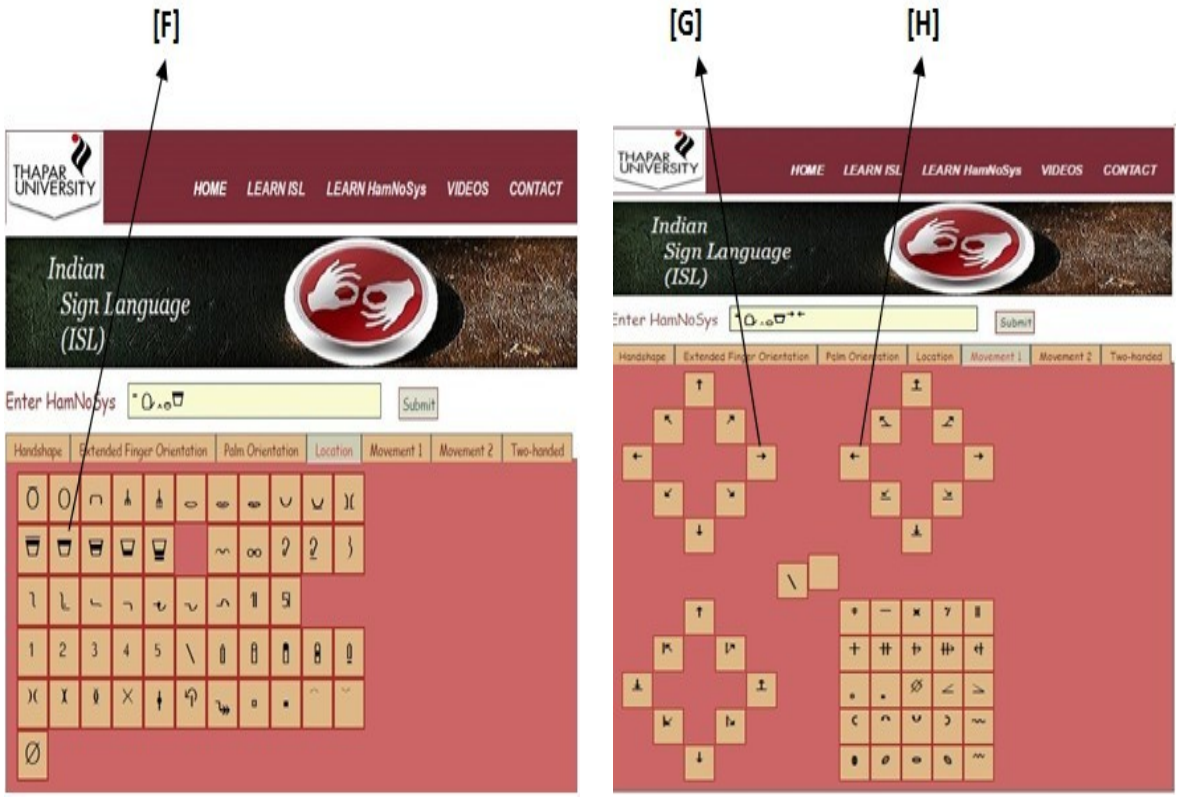
(a) (b)

Figure 4.20: a) Selecting Hand symmetry component b) Selecting Hand-Shape for “Read”



(a) (b)

Figure 4.21: a) Selecting Extended Finger Orientation b) Selecting Palm-Orientation



(a) (b)

Figure 4.22: a) Selecting Hand Location with respect to body parts b) Selecting Hand-Movement

Figure 4.23: Selecting Hand Location with respect to closeness to the selected body parts

The selected HamNoSys Notation for the given word is then stored in the ISL dictionary along with its sign gloss, from where it can be retrieved later. The table shown below gives detailed description of each HamNoSys symbol selected for word "Read".

Table 1: Illustrating HamNoSys Symbols along with their meanings for word "Read"

Symbol	Meaning	Figure
‥	**Two-handed** symmetrical signs(Both Hands Show the same shape)	Fig. 4.20(a) [A]
⍝	**Hand-Shape** is flat hand	Fig. 4.20(b) [B]
⍝◞	**Hand-Shape** is flat, thumb is extended outside the hand	Fig. 4.20(b) [C]
^	**Orientation** of extended finger is upwards	Fig. 4.21(a) [D]
⍥	**Orientation** of palm is upwards	Fig. 4.21(b) [E]
⍃	**Location** of hand is near shoulders	Fig. 4.22(a) [F]
→	**Movement** of hand is rightwards	Fig. 4.22(b) [G]
←	**Movement** of hand is leftwards	Fig. 4.22(b) [H]
)(	**Location** of hand is near/close to body	Fig. 4.23 [I]

Step 3: Selecting Non-Manual components for "Read"

The non-manual features include the mouth gestures, facial expressions and the postures of the body which are used while signing. The facial expression used while signing the word "Read" is the eye gaze being down (statically) and the limbs chooser component includes the head being shaking slowly from left to right (dynamically) during signing. The figure below shows the selected non-manual components which are used for word "Read".

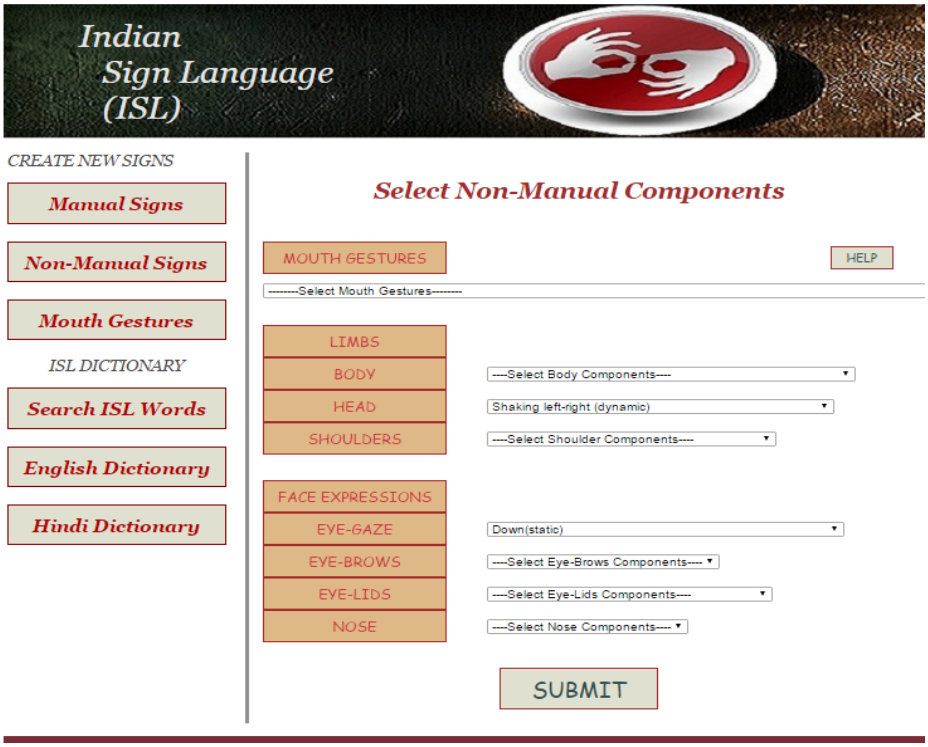


Figure 4.24: Non-Manual components for word "Read"

Step 4: Generating SiGML for "Read"

The HamNoSys to SiGML translator is used for generating the SiGML. The SiGML file being generated from the HamNoSys symbols and Non-Manual components selected in the previous steps for word "Read" is shown in the Figure 4.25.

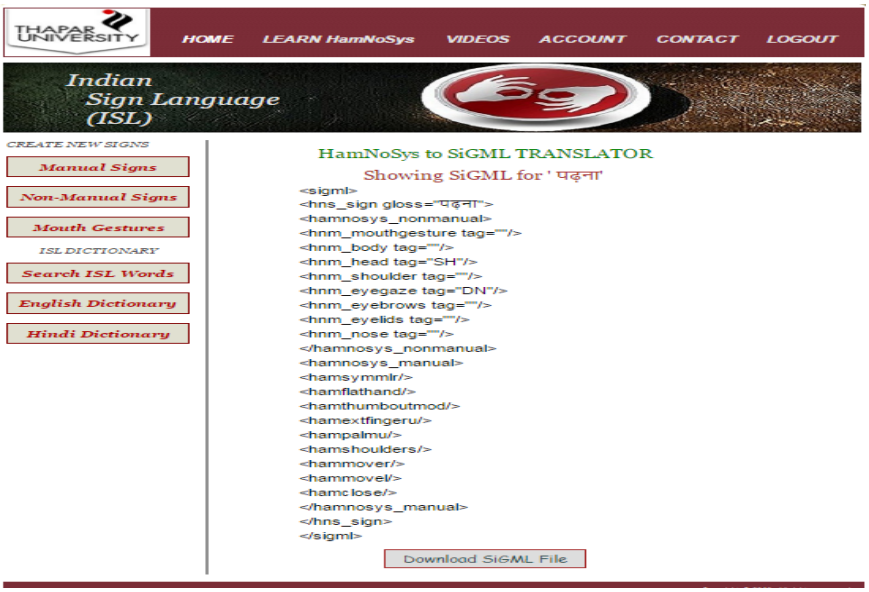


Figure 4.25: SiGML for word "Read"

Step 5: Avatar Playing Sign for "Read" in ISL

The JA Signing SiGML Player which is installed locally is used to simultaneously animate the signs for the given ISL words. The SiGML file generated in the previous step is given as an input to the virtual signing player. The avatar in the figure given below is showing the sign for ISL word "Read".

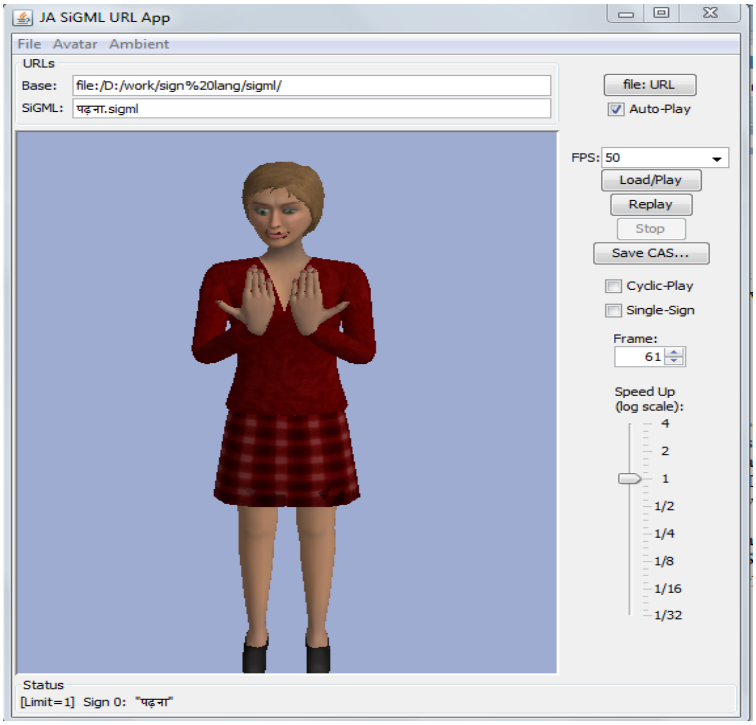


Figure 4.26: Avatar showing sign for word "Read"

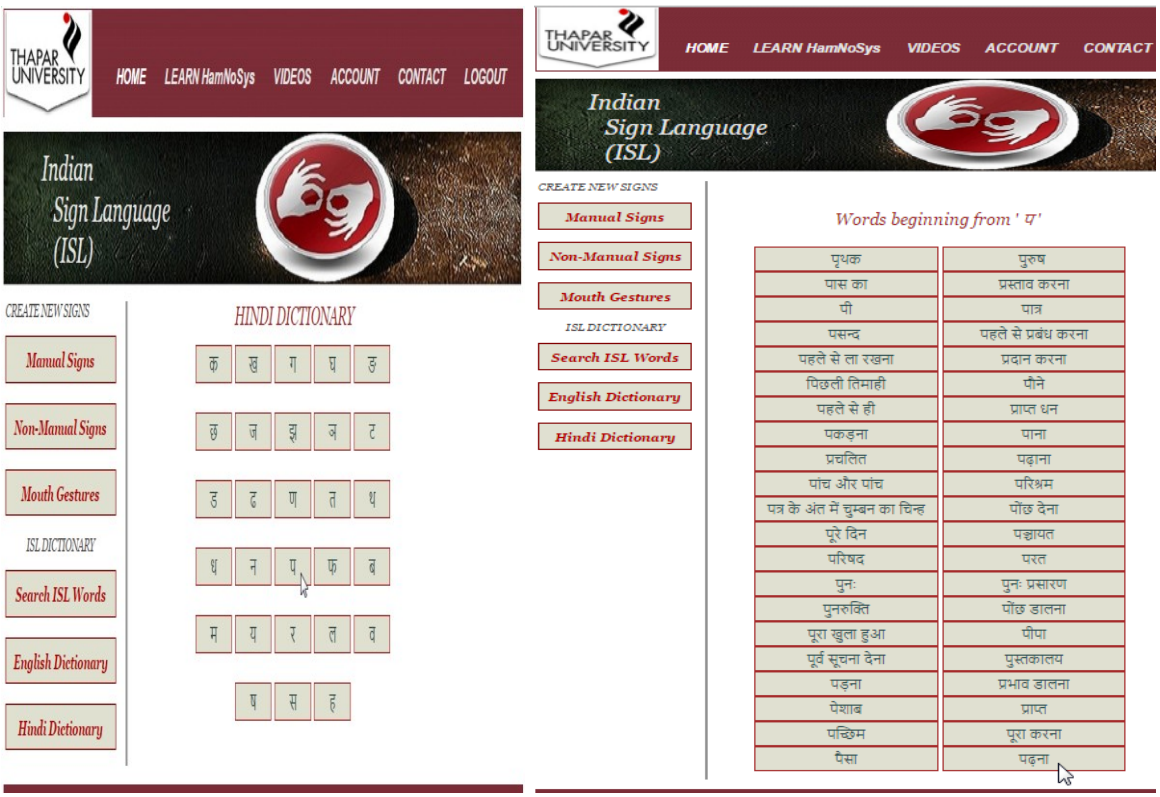
Step 6: Storing sign for "Read" in ISL Dictionary

The HamNoSys Notation of the sign created by the user from HamNoSys Generation system can be verified from the sign animated by the avatar in the previous step. If the sign being animated is as required by the user, then the user can store the word with its HamNoSys and Sign Gloss in the dictionary. But if the sign is not as required then the HamNoSys of the sign can be updated and can be stored in dictionary after verification of the new sign animated by the virtual avatar player. The figure given below is showing the web portal interface of results shown for storing the word "Read" in dictionary.

Figure 4.27: Showing results for storing sign for word "Read" in Dictionary

Step 7: Retrieving the sign from ISL Dictionary

The signs of words stored in ISL dictionary can be retrieved by the users when required by either entering the word in the search tab or by selecting English or Hindi dictionary. The word stored in step 6 is searched in Hindi dictionary as the sign gloss provided for it in step 1 is in Hindi itself. The Figure 4.28 shows the results for the word "पढ़ना" when searched by alphabet "प" in Hindi dictionary for ISL words.



(a) (b)

Figure 4.28: a) Searching Hindi Dictionary for 'प' b) Showing search results for 'पढ़ना'

4.6 Documentation for Indian Sign Language web portal

The proposed web portal for ISL automation provides the HamNoSys for basic hand-shapes which are used most commonly for generating signs. The image for a given hand-shape along with its HamNoSys notation is provided. The hand-shapes include different types of hand bending, wrist bending, thumb variations (thumb extended and across hand), bending and rounding of fingers and joints. The HamNoSys for various possible extended finger, palm and wrist orientations is also described along with the hand-shapes. The basic hand-shapes are shown in Figure 4.29.

The web portal also consists of automated lessons in Indian Sign Language. It includes animation of the basic hand shapes and other sign language content by the SiGML player. The figure given below shows the interface of web portal for learning ISL.

Figure 4.29: HamNoSys for basic Hand-Shapes

Figure 4.30: GUI of Indian Sign Language content in web portal

Chapter Summary

In this chapter, the implementation of the proposed system for creation of HamNoSys based ISL dictionary is discussed. The steps for creation of HamNoSys for a given sign are described. After HamNoSys input system, the system for non-manual components is introduced by taking an example of a sign. Then the SiGML translation process is shown for the HamNoSys generated for the sign. These signs are animated by the signing avatar. The process for storing signs in ISL dictionary through the web portal is discussed. The various other modules for learning ISL and HamNoSys are also provided in the proposed web portal for ISL automation.

Chapter 5

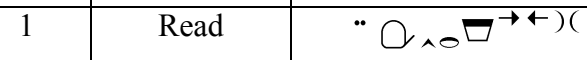
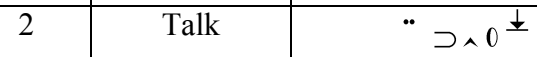
Results and Discussion

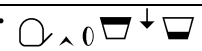
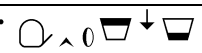
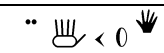
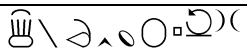
5.1 Testing of Sign Language Automation System

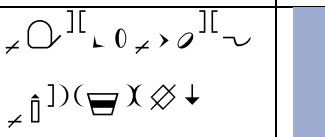
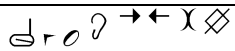
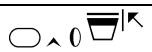
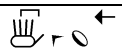
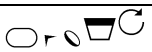
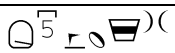
Sign Language system has been tested on 350 words. These 350 words have been created by using HamNoSys Input system and are stored in ISL dictionary. The words stored in ISL dictionary includes basic hand-shapes, commonly used words in daily day-to-day communication such as names of birds and animals, body parts, colors and shapes, dishes and spices and also the words used in school items and in basic behavior norms. The signs for all these words have been taken from the books on Indian Sign Language, which are published by an organization for deaf people, *i.e.*, Bhagat Puran Singh School for Deaf, Pingalwara Manawala Complex, Amritsar, Punjab. The sign language experts were asked to rate the proposed system on the basis of tested words. On the scale of 1 to 5, they rated the proposed system as 4.2. The results are really very encouraging and are worth to be used for easy communication among deaf people. The system can be used for automating the entire Indian Sign Language content and also for learning sign language in a very easy and economical way.

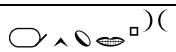
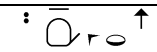
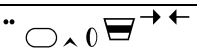
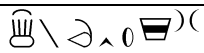
Some of example words are retrieved from ISL dictionary and their HamNoSys is converted to SiGML by using HamNoSys to SiGML translator. The signs are then automated by using animation avatars. These signs with their sign gloss, HamNoSys and avatar animation generated by the system are illustrated in table 5.1.

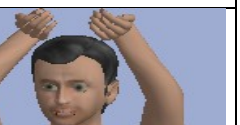
Table 5.1: Example words with their Animated Signs and HamNoSys used for testing Sign Language Automation System

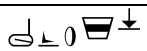
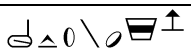
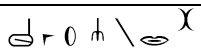
Sr. No.	Word	HamNoSys	Animated Sign
1	Read		
2	Talk		

Sr. No.	Word	HamNoSys	Animated Sign
3	Tap		
4	Body		
5	Eat		
6	Fear		
7	Flood		
8	Fruit		
9	Home		
10	Jealous		

Sr. No.	Word	HamNoSys	Animated Sign
11	Letter		
12	Mind		
13	Power		
14	Child		
15	Roof		
16	Run		
17	Bus		

Sr. No.	Word	HamNoSys	Animated Sign
18	Water		
19	Up		
20	Tight		
21	Tub		
22	One		
23	Three		
24	Zero		

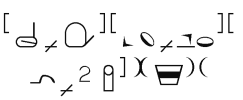
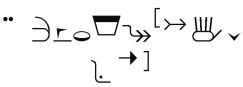
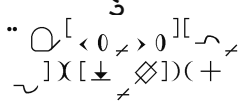
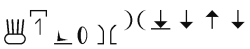
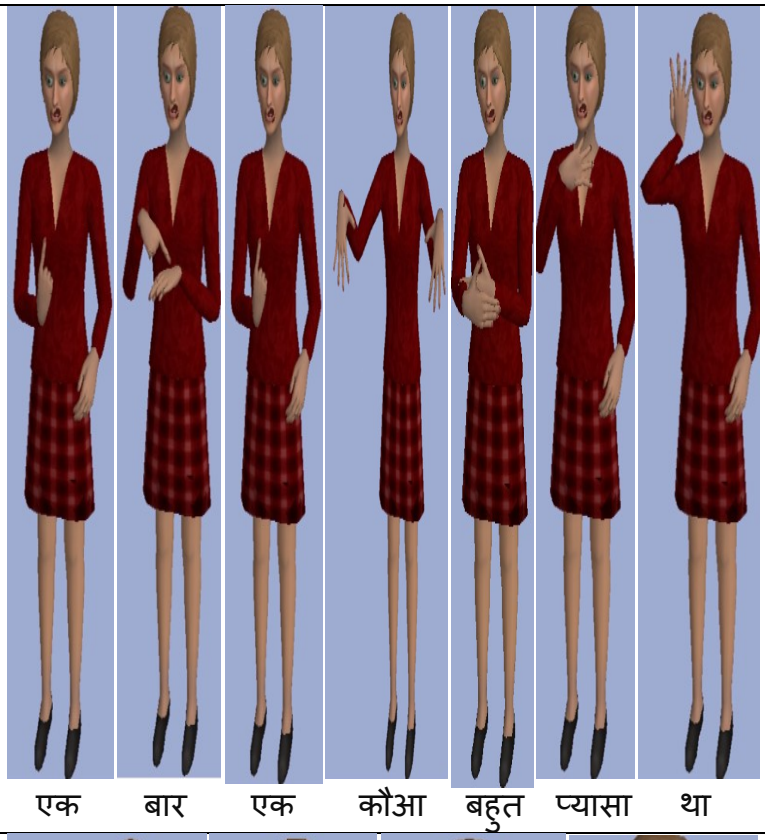
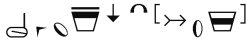
Sr. No.	Word	HamNoSys	Animated Sign
25	Bird		
26	Time		
27	See		
28	Glass		
29	Pot		
30	Computer		

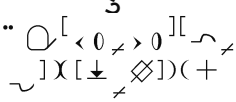
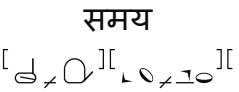
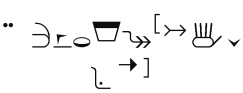
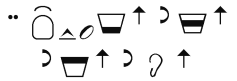
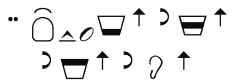
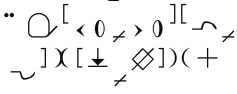
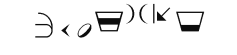
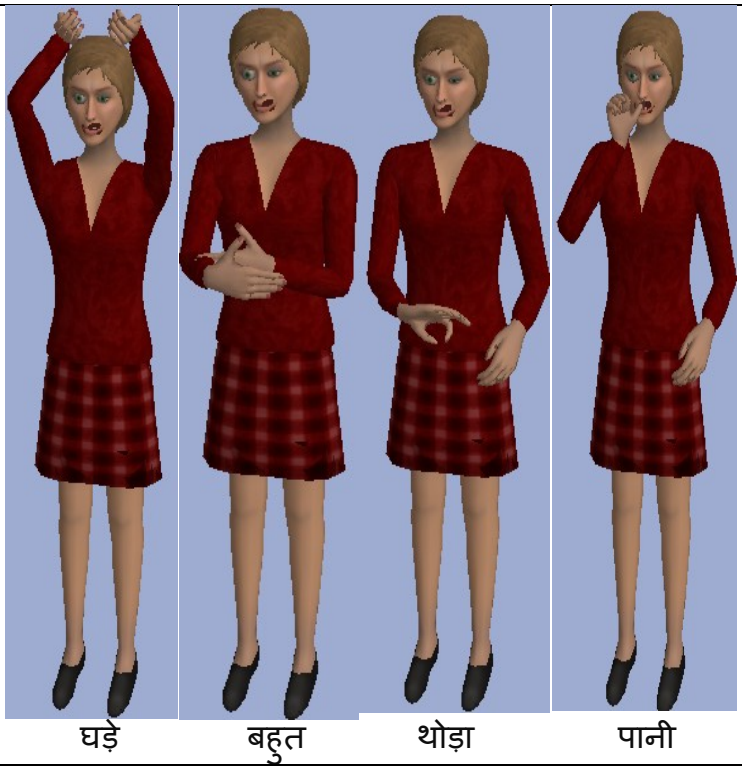
Sr. No.	Word	HamNoSys	Animated Sign
31	Me		
32	You		
33	Teeth		
34	Deaf		
35	Pick		

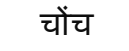
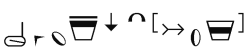
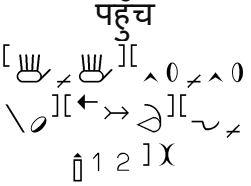
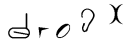
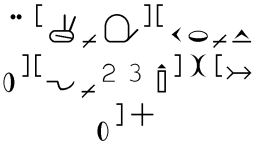
5.2 Testing Sign Language Automation System for "Thirsty Crow Story" in ISL

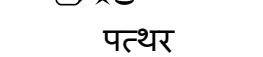
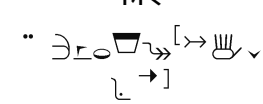
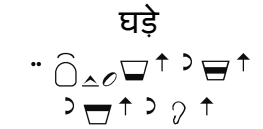
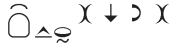
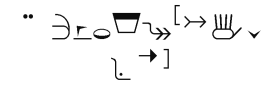
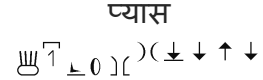
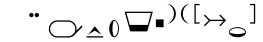
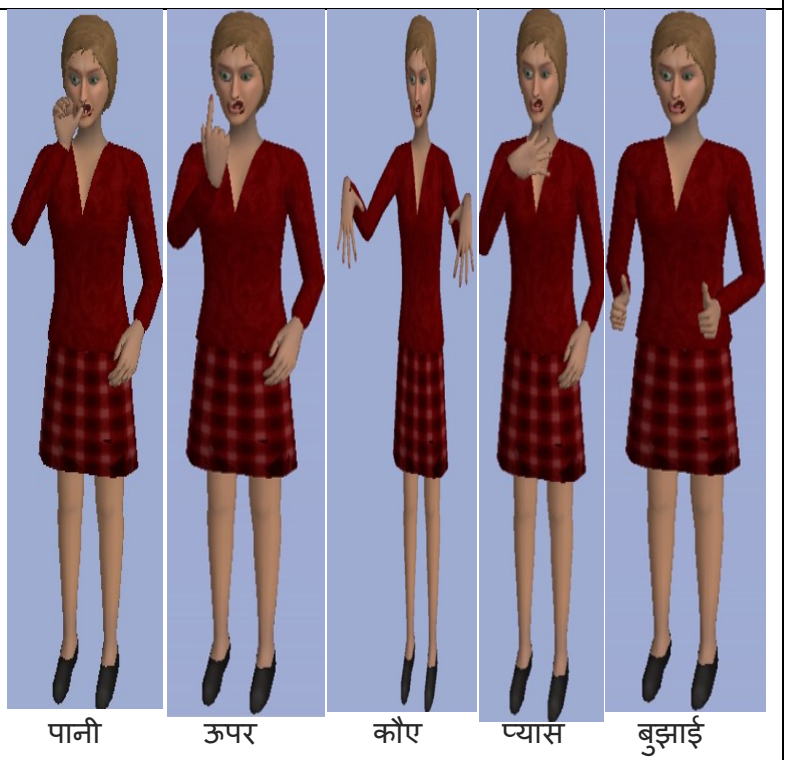
The system has also been evaluated by another organization for deaf, dumb and blind children, *i.e.*, Patiala School for Deaf Blind, Village Saifidipur, Patiala, Punjab. The sign language experts at the organization provided us with the natural signs (signed by human user) for "Thirsty Crow" Story. The system is then used for the automation of "Thirsty crow" story for the purpose of learning for deaf children. The sign language experts were asked to rate the proposed system on the basis of animated "Thirsty Crow" story. On the scale of 1 to 5, they rated the proposed system as 3.5. The system can be used at various educational institutions for deaf children to make them learn Indian Sign Language easily. The URL for video of animated Thirsty Crow Story in ISL is **https://youtu.be/wKFoGV-FWz.**

Table 5.2: HamNoSys creation and Sign Animation for “Thirsty Crow Story” in ISL

Input Sentence	HamNoSys	Signing Avatar Showing Animated Signs
Hindi Sentence: एक बार एक कौआ बहूत प्यासा था। Transliterated sentence: ek baar ek kauaa bahut pyaasaa thaa Equivalent English Sentence: Once, a crow was very thirsty.	एक  बार  एक  कौआ  बहुत  प्यासा  था 	 एक बार एक कौआ बहुत प्यासा था
Hindi Sentence: उसको कहीं पानी नहीं दिख रहा था। Transliterated sentence: usko kaheen paanee naheen dikh rahaa thaa. Equivalent English Sentence: He could not find the water anywhere.	कौए  पानी  नहीं  दिखा 	 कौए पानी नहीं दिखा

Input Sentence	HamNoSys	Signing Avatar Showing Animated Signs
Hindi Sentence: बहूत समय तक ढूँढने पर उसको एक घड़ा दिखाई दिया। Transliterated sentence: bahut samay tak dhoondhne par usko ek gharaa dikhaaee diyaa Equivalent English : At last he saw a pot.	बहुत  समय  कौए  एक  घड़ा  दिखा 	 बहुत समय कौए एक घड़ा दिखा
Hindi Sentence: घड़े में बहूत थोड़ा सा पानी था। Transliterated sentence: ghare men bahut thoraa saa paanee thaa Equivalent English Sentence: The pot has very little water in it.	घड़े  बहुत  थोड़ा  पानी 	 घड़े बहुत थोड़ा पानी

Input Sentence	HamNoSys	Signing Avatar Showing Animated Signs
Hindi Sentence: कौए की चोंच पानी तक नहीं पहुँच पा रही थी। Transliterated sentence: kaue kee conc paanee tak naheen pahunc paa rahee thee. Equivalent English Sentence: His beak could not reach down to the water.	कौए  चोंच  पानी  नहीं  पहुँच 	 कौए चोंच पानी नहीं पहुच
Hindi Sentence: वह बड़े ध्यान से सोचने लगा और उसे एक उपाय सूझा। Transliterated sentence: voh bare dhyaan se socne lagaa aur use ek upaay soojhaa. Equivalent English Sentence: He started thinking and got a plan.	कौआ  सोचने  उपाय  सूझा 	 कौआ सोचने उपाय सूझा

Input Sentence	HamNoSys	Signing Avatar Showing Animated Signs
Hindi Sentence: पास ही पत्थर के कुछ टुकड़े पड़े थे,कौए ने एक एक पत्थर उठाया और घड़े में डालता गया। Transliterated sentence: paas he patthar ke kuch tukre pare the, kaue ne patthar uthaaya ghare men daaltaa gayaa Equivalent English Sentence: He dropped a few pebbles in the pot.	पास  पत्थर  कौए  उठाया  घड़े  डाला 	 पास पत्थर कौए उठाया घड़े डाला
Hindi Sentence: जल्दी ही पानी ऊपर आ गया और कौए ने अपनी प्यास बुझाई। Transliterated sentence: jaldee pani opar aa gayaa aur kaue ne apnee pyaas bujhaae. Equivalent English Sentence: The water level rose and the crow drank the water.	पानी  ऊपर  कौए  प्यास  बुझाई 	 पानी ऊपर कौए प्यास बुझाई

Chapter 6
Conclusion and Future Scope

6.1 Conclusion

There are very few sources in India that can impart knowledge about sign language among the deaf communities thus resulting in poor literacy level and language skills among deaf people. So a system for creation of HamNoSys based ISL dictionary is developed for generation and automation of sign language.

The proposed system has a virtual keyboard for creating HamNoSys, an input system for selecting non-manual components, a translator for converting HamNoSys to SiGML and an avatar player for automating the signs.

The system works both for manual and non-manual signs that are used in Indian Sign Language. Earlier the sign language automation process was achieved by using various different tools for HamNoSys creation, SiGML generation and sign automation. But this system totally overcomes this flaw and reduces the dependency on various other tools.

There was earlier no way to transcribe or write the sign language, but the system also provides a dictionary which can be used for storing the signs along with their HamNoSys. The ISL dictionary which is available in English and Hindi can be maintained easily through a web portal. Thus the system can be used by a person who has little or no knowledge about HamNoSys or sign language.

The ideal method for sign language creation is by transcription of HamNoSys and its related SiGML form is used for automation of signs. In this method, HamNoSys is generated corresponding to the ISL words and is stored in ISL dictionary. The HamNoSys is further converted into XML type form known as SiGML. The HamNoSys to SiGML Conversion System reduces the dependency on eSIGN-Editor tool which is for ASL or BSL as signs in American or British Sign Language are different from that of Indian Sign Language. Virtual human player takes input as SiGML and plays corresponding signs. In this way, the proposed

system can be used to create new signs as well as to automate the existing signs stored in the dictionary.

6.2 Limitations and Future Scope

- The ISL dictionary currently has an entry for 350 ISL words. It can be extended further for storing the entire Indian sign language content.
- For generating HamNoSys of any given word, HamNoSys expert is required. The expert should have a proper understanding and knowledge of HamNoSys for storing the signs in dictionary.
- A system can be developed for sign language recognition, which can directly convert text or image to its SiGML form, thus reducing the complexity involved in creating HamNoSys.
- A mobile application can also be developed for generation of sign language using HamNoSys of the inputted text.
- The users need to have prior knowledge about HamNoSys for generating the signs. So, there is a need to build an avatar animation system from which the users can directly generate the signs without creating HamNoSys of the words.

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List of Publications

Research Paper Accepted

- Khushdeep Kaur and Parteek Kumar, "HamNoSys to SiGML Conversion System for Sign Language Automation" *in Twelfth International Multi Conference on Information Processing*, IMCIP 2016, Bangalore, India.

Research Paper under Review

- Khushdeep Kaur and Parteek Kumar, "Creation of HamNoSys based Indian Sign Language Dictionary" *in The 8th IEEE International Conference on Technology for Education*, 2016, Mumbai, India.

Video URL

A video has been uploaded on YouTube to describe the working of HamNoSys based Indian Sign Language Generation System. The URL of the video is as follows:

https://youtu.be/fXd_H8w1d2s

801431010_KhushdeepKaur_ME_SE

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