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Comparative Analysis of Automatic Sign Language Generation Systems

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Abstract: More than 466 million people suffer from hearing disabilities comprising of 34 million children and 432 million adults worldwide. These people face so many problems at public places due to their hearing disability for the communication of their messages. The development of automatic sign language generation systems, which are very rarely available, is the need of the hour to solve their communication problem. Some researchers have tried to develop such systems for various public places using a smaller corpus rendering their works limited to a specific domain. In this paper, we tried to perform a study of available research studies from 2001 to 2020 for sign language generation systems for various public domains using different machine translation approaches. Seventy-two research papers on sign language generation were retrieved from our search. Afterward, these papers were shortlisted to 44 based on their titles, then 30 research papers were removed based on abstracts and conclusions, and finally, 14 research papers were selected based on full text. These 14 research papers were comparatively examined based on six comparison parameters. It is evident from our study that the lack of proper grammar rules of sign language and the non-availability of large bilingual corpora are the main hurdles in developing sign language generation systems for public places. A hybrid approach based announcement system prototype is developed for deaf people. The proposed system prototype produced 82% accuracy on translation of announcements into sign language.

Keywords: **example-based machine translation, statistical machine translation, interlingua, virtual avatar, SiGML, HamNoSys**

I. INTRODUCTION

Imagine the people in a world without hearing power: the frustration of striving to express their feelings, thoughts or need to others. This is the predicament of the hearing-impaired community. Just like normal people, the deaf person likes to express his ideas, messages and feelings with others. Conversation can be an arduous task for deaf people depending on whom they are talking with. If the conversion is between two deaf people with use of gestures or signs, there is no issue, but if the conversion is between a normal hearing person who is unable to understand sign language and a deaf person, then there arises a communication gap.

Sign language is a visual spatial language serves as primary source of communication of the people who suffers from hearing impairment problem. The three dimensional space is used by signer around his body involving his hands, different body postures, arms, mouth gestures, head movements and facial expressions. Sign language is not same in the world due to vast differences in spoken languages, geographical conditions, diverse cultures etc. in different countries, even in within a country or regions, as deaf people evolved this language rather than creating it. Therefore, different countries or regions have different signs, different grammar, syntax and rules of sign language used by hearing impaired people.

There are over 5% or 466 million people, worldwide, suffers from disabling hearing loss and from these 34 million children and 432 million adults suffers from this problem (World Health Organization) [25]. The situation becomes more alarming as there is very little or no access of education and other sources of information to around 90% of these people. These differently abled people have adopted different sign languages, as primary mean of communication, in different areas/parts of the world. Sign languages are widely used, while some people do not fully rely on these for communication, with an estimated 500,000 American Sign Language (ASL) users in the US and Canada (National Center for Health Statistics) [19], approximately 151,000 sign language users of British Sign Language (BDA: British Deaf Association) [3], 87,000 of these are Deaf, in the United Kingdom, and approximately 40,600 people primarily communicating in Greek sign language in Greece, and around 750,000 Deaf sign language users in the European Union for example, an estimated 5,000 SL users in Finland, in France 100,000 etc. (European center for Modern Languages) [7].

Like spoken languages of world, Sign languages are also equipped with their own grammar rules, syntax and linguistic

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attributes/structures. Therefore, the job of translation becomes a severe problem between spoken and sign languages, as it is not merely an exercise of word-to-word aligning of textual data to signs. There arises need of machine translation (MT) methods, taking into account the language models of both language, to discover a proper alignment between a spoken and sign language. There is need of building robust systems for translating sign languages into spoken languages and vice versa for facilitating effortless and smooth communication between the without hearing loss and hearing impaired ones. Sign Language Production (SLP) and Sign Language Recognition (SLR) are solution to this problem. Most of commercial applications for sign language, due to false belief that deaf people being more contended in reading spoken language and not in need of translating into sign language, mainly focus on SL Recognition, by mapping gestures/signs to spoken language, in the form of a text transcribed as a sequence of gestures/signs, such as Robotka [20], and Elwazer [6]. Furthermore, generation of sign language from natural spoken language is an arduous task and a simple one-to-one mapping is not just sufficient.

In comparison to spoken languages, sign languages uses the manual (i.e. hand shapes, upper body parts movements, and direction) and non-manual (i.e. face expressions, lip patterns, body posture) features, to convey messages or information. Some of the researchers such as Cox et al. [4] and Glauert et al. [8] in British Sign Language (BSL), Stein et al. [23] in German Sign Language (DGS), San-Segundo et al. [21] in Spanish Sign Language (LSE) and Goyal and Goyal [9] in Indian Sign Language (ISL) tried to tackle the problem of Sign Language Production generating animated avatars.

II. Facts About Sign Language

- Sign Language is not a universal language, varies from region to region, country to country.
- Sign of same word/alphabet can be demonstrated in different ways in different Sign Languages. E.g., Gesture/Sign of 'A' letter is demonstrated in American Sign Language with the single hand whereas it is demonstrated with two hands in Indian Sign Language and British Sign Language.
- It is a visual-Spatial language as the "signer often uses the 3D space around his body to describe an event and is understood through power of vision" [9].
- Sign Language is a full fledge natural language having their own grammar, syntax and rules.
- Sign Language is very much different from spoken language. E.g., word "Write" and "right" are homonyms (almost pronounced in similar way) but carrying a distinctive meaning in both spoken English and Sign language.
- Sign language can be learned in the same way as spoken language.
- Gestures or signs are performed by the single hand as well as both hands. In Indian Sign Language "A" and "B" letters are demonstrated with two hands but "C" letter is demonstrated with one hand.
- Sign Language uses hand shapes/gestures, face expressions and motioning of the body parts to represent signs/gestures.
- Fingerspelling is used for unknown words and for nouns like for person's name, cities names etc.

III. Machine Translation

Machine Translation (MT) may be termed as automating some or whole part of translation process of one natural language to another without any human assistance [10]. The primary goal of machine translation is to cover the gap between two different language models. It is an arduous and intriguing task as translation relies on several factors, like culture, jargons, domain knowledge, variations in spellings and proper names etc. A thorough and rich knowledge of the source language is a primary requirement. Similarly, creative and practical command over the target language is also imperative. Machine translation of source language to target language faces some challenges like typological differences such as morphology, syntax, argument structures, element dropping etc. and structural as well as lexical divergences. In the recent times, the demand for machine translation is growing rapidly all over the world owing to the increasing need for exchanging the information.

IV. Machine Translation Approaches

The various approaches of machine translation can be classified as follows:

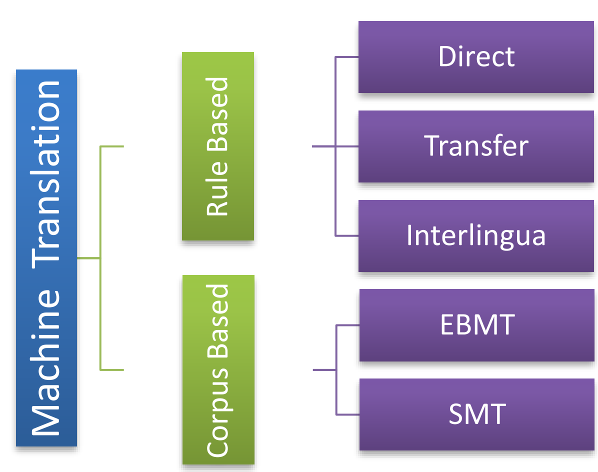


Fig.1 Machine Translation Approaches

A. Rule Based Approaches

In its earlier days, machine translation was considered as a one to one mapping of words only. However, later on it gave rise to a problem that need syntactic analyses, too. Rule Based Machine Translation, also known as Knowledge-Based MT, consisting of a set of rules, lexicon and software programs, is to process the rules of both the source as well as the target language. It is used mainly in different analysis stages of translation like syntactic, semantic and contextual. From the Dorr's Pyramid [5] as shown in Fig 2 classical approaches of MT can be categorized into three approaches such direct translation shown in red color transfer and Interlingua approach shown in green and blue color respectively.

1) Direct Translation

This system is designed specifically, ignoring the syntax, semantics, and morphology, for a specific pair of languages. The output of the system, due to differences in their word order and morphology, may not be desired one. These kind of systems produces an output with direct one to one replacement for corresponding words.

2) Transfer-based Architecture

These kind of systems performs translation on the basis of specified transfer rules for syntax, semantic, lexical selection, morphology analysis and generation. These systems, however, are dependent on the specific language pair with the need of the adding of novel transfer rules for the sign languages.

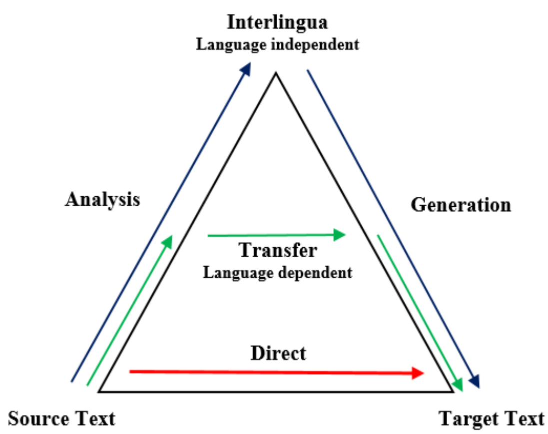


Fig. 2 Rule Based Approaches

3) Interlingua-based Architecture

In this translation approach, firstly the source language is translated into an Interlingua form that is language-independent representation, then generating target sign language from this Interlingua. This approach economizes a great amount of work with respect to other translation approaches if there exists number of target languages with well-developed modules.

B. Corpus Based Approaches

This approach is an alternative, with an intuition of learning translation mechanism by machines, from large parallel corpuses of sentence-aligned human translations, to remove the knowledge acquisition problem faced in the classical machine translation approaches. This corpus based approach gathers knowledge for new incoming translation using plenty of raw data in the form of parallel corpora. Corpora based approach can be further classified as:

1) Example-based Machine Translation (EBMT)

This approach may be termed as storing parallel translation pairs such as, complete sentences or complete parse trees, or matching relevant examples, then modifying and integrates these isolated fragments for generation of accurate output, producing good results if test sentence is found exactly or closely matched from the bilingual translation pairs. However, if source sentence finds no close matches in corpora, it fails.

2) Statistical Machine Translation (SMT)

Unlike finding equivalent of whole sentences, the approach of matching only the words for unseen sentences can give promising results. Therefore, Statistical Machine Translation (SMT) uses, to find out word-to-word mappings according to language model and arranging the target words following the word sequence according to translation model, statistical learning methods. Both the translation and language model does a great job of taking care of faithfulness of translation, and catering for fluency of the output sentence, respectively.

V. NEED OF THE STUDY

Hearing impaired people faces so many problems at the public places like railway stations, post offices, airports, banks and other government offices for lack of communication due to their hearing disability. So automatic sign language generation systems that can make their jobs easy at these places, is the need of hour. Although, not full-fledged systems have been developed yet to address these problems, some of the researchers tried to facilitate the automatic sign language generation from spoken languages in limited domains for making communication between deaf and with hearing people feasible at public places. We have made our utmost efforts to collect and summarize these works in this review paper.

VI. SELECTION CRITERIA

The survey includes research studies reported in almost last 20 years from 2001 to 2020 related to automatic sign language generation systems developed for public domain use. The research studies were examined and inclusion and exclusion criterions of research works have been designed as shown in Fig. 3 for choosing selective research works. The "Sign Language Generation Systems for Public Places" keyword has been used to look out for research works on online databases. Our search has retrieved 72 research papers on sign language generation from the various sources like IEEE, ACM Digital Library, Elsevier, Springer, e-journals and conferences publications. The fetched data have been shortlisted to 44 based on their titles, after that 20 research papers have been removed reading out their abstracts and conclusions, and in the end, 14 research papers have been selected after reading out full text of research papers. The selection criteria for selecting research works for our review study has been shown in Fig. 3. Table 1 illustrates summarized comparative study of automatic sign language generation systems for public places.

Fig. 3 Selection criteria used in this review study

VII. STATE-OF-THE-ART

Cox et al. [4] developed TESSA, an experimental system, for the conversion of input speech of a post office clerk to British Sign Language (BSL) in the restrained domain of post office to help the deaf people while performing post office transactions. The designed system was evaluated to translate the words uttered by a clerk to sign language for the understanding of deaf people. The proposed system used 115 phrases of daily business transactions extending to 370 phrases after some trials and used virtual avatars for animating the generated signs. The designed system used Entropic Speech Recognizer requiring a set of acoustic models and a network. 61% accuracy resulted from identified signed phrases for complete phrases and 81% for sign units. Glauert et al. [8] developed VANESSA system to provide speech-driven assistance for limited domain of eGovernment transactions in British Sign Language. The designed system facilitated easy communication between CIC assistants and their respective Deaf clients in local government Council Information Centers (CIC's) allowing input in the form of speech or text to be translated into BSL using an avatar, which is generated synthetically, for clients. Text communication can also be performed with VANEESA using computer keyboards and a user interface similar to internet chat room software. Three separate evaluations of CIC evaluation, laboratory evaluation and phrase recognition were performed on the developed system that produced 50%, 60% and 61% results respectively. Stein at el. [23] presented a novel approach for the automating translation of written German language text into German sign language (DGS) in the specific weather forecasting report domain. The proposed system used phrase-based SMT with the addition of pre- and post-processing steps taking into account morpho-syntax analysis of German language. The proposed system consisted of Lexicon Model, Alignment Model and Language Model for translation of source language to target language, used gerCG parser for various pre-processing steps and tried to avoid typical errors during translation with post processing steps. The system was experimented on the Phoenix corpus of 2468 sentences and exhibited best scores of WER and PER 38.2, 27.4 respectively. Kar et al. [11] developed a system specifically for the limited domain of railway enquiry named INGIT, which is a Sanskrit word means signed. INGIT translates Hindi strings into equivalent Indian Sign Language (ISL) form. The system creates a thin semantic structure from the input taken from reservation clerk and passes it to ellipsis resolution module for the removal of unnecessary words and produces a saturated semantic structure. The ISL generator generates an appropriate ISL-tag structure based on the type of the sentence after applying the ISL grammar rules. HamNoSys dictionary is used to replace each word of the ISL glossed string with matching HamNoSys notation that are further converted to SiGML tags to generate graphical simulation. INGIT uses Fluid Construction Grammar (FCG) for construction of grammar for sign language. The system was evaluated using very limited corpora of 230 utterances and even limited to represent non-manual features of some utterances that restricts it from general-purpose use. Morrissey & Way [18] developed an automatic sign language machine translation system for hearing impaired community that converts spoken Irish language text into Irish Sign Language in the restricted domain of airport information announcements using data driven approach. The developed SLMT system uses the MATREX MT system [24] which combines Example-Based MT (EBMT) and Statistical MT methodologies having a standardized design. The decoder in the proposed system act as main engine that accepts an English sentence as input and generates the most appropriate ISL sentence it finds in annotated format. The decoder performs its translation estimations based on three information pools of aligned data: groups of aligned sentences, aligned words and aligned chunks extracted from the bilingual corpus. The developed system was tested on a very limited dataset of 118 sentences producing around 70% correct translation rate by a human-like mannequin on larger screens as output in real Irish Sign Language. San-Segundo et al. [21] applied rule based as well as statistical approach for development of first Spanish to sign language generation system facilitating assistance to deaf people while applying or renewing their identity card in a real domain. The developed translation system comprises of three modules, a speech recognizer decoding the spoken words into a word sequence, a natural language translator translating a word sequence into corresponding signs sequence of the sign language, and an eSIGN three-dimensional avatar animation module animating signs. The developed system focused only on the representation of manual features excluding facial expressions and was validated on a limited corpus of 416

Table 1 Comparative study of automatic sign language generation systems for public places

Authors	Sign Language	Application Area	Translation Technology	Parsing Source Language	Non Manual Features	Corpus	Results/ Output Form
Cox et al. [4]	British Sign Language	Post Office Domain	Phrase-based	No Parser	NR*	370 phrases	61% Translation Rate
Glauert et al. [8]	British Sign Language	Council Information Centers	Phrase-based	No Parser	NR*	NR*	Average 60%
Kar et al. [11]	Indian Sign Language	Railway Ticket Counter	Hybrid Formulaic Grammar	Domain Specific Construction Grammar for Hindi	Yes, through extending HamNoSys	230 Utterances	Virtual Human
Stein et al. [23]	German Sign Language	Weather Forecast Domain	Phrase-based, Statistical Machine Translation	gerCG Parser	No	2468 Sentences of Phonix Corpus	38.2 WER 27.4 PER, An Avatar
Morrissey & Way [18]	Irish Sign Language	Airport Information Announcements	Example-based Machine Translation	No Parser	No	118 Sentences	Around 70%
San-Segundo et al. [21]	Spanish Sign Language	Applying or Renewal of Identity Cards	Rule-based Translation	No Parser	No	416 Sentences with 650 Different Words	eSIGN Avatar: VGuido BLEU 0.5780
Anuja et al. [2]	Indian Sign Language	Railways and Banking	Rule-based Translation	Stanford Parser	No	250+ Phrases	60%, Translation Rate, 3-D animation using Maya Software
San-Segundo et al. [22]	Spanish Sign Language	Renewal of Driver's License	Example-based, Rule-based and Phrase-based Technologies	No Parser	Yes	2,124 Sentences	90% Translation Rate, BLEU 0.7
Lopez-Ludena et al. (2012)	Spanish Sign Language	Renewal of IDs and Driver's License	Phrase-based and Stochastic Finite State Transducer	No Parser	NR*	4080 Spanish sentences	BLEU: 81.0% of PBT and 78.4% of SFST
Ali et al. [1]	Indian Sign Language	Railway Reservation Counters	Direct Translation System	No Parser	No	100 words	An Avatar using 3ds Max Software
Lopez-Ludena et al. (2014)	Spanish Sign Language	Bus Customer Information Office	Example-based and Statistical Translation	No Parser	NR*	1938 Sentences	91.56% Translation Rate
Mishra et al. [17]	Indian Sign Language	Railways Announcements and conversation in Public	Statistical Machine Translation	No Parser	No	537 Glosses of 326 Sentences	Used IBM-1 IBM-2,Ibm-3 Model tool MOSES

		Assistance Counters					
Luqman and Mahmoud [16]	Arabic Sign Language	Medical Centers of Health domain	Rule-based Translation	CamelParser	Yes	600 Sentences	80% Translation Rate As a sign sequence of GIF images
Kouremenosc et al. [12,13]	Greek Sign Language	Weather Reports Domain	Rule-based Translation	AUEB's POS Parser	No	1,015 sentences	Evaluation: 84% for 4-gram and 90% for 1-gram

* Not Reported

sentences with 650 different words using two approaches of rule-based translation and a statistical translation. The developed translation system reported 0.5780 BLEU and 31.6% SER as best configuration scores. Anuja et al. [2] designed a Frame based MT system for specific domain of railways and banking using rule based approach. The designed system comprises of three modules, Speech Recognition Module which takes clerk's speech as input and generates corresponding text, Language Processing Module that is capable of parsing inputting text using stanford parser by removing unwanted tokens and generating root form of words and then reordering the phrases to generate ISL gloss as per grammar rules of Indian Sign Language, and Three Dimensional Animation Module that displays the three dimensional virtual human from pre-recorded motion capture data to translate the generated glosses form of ISL into animation. The designed system is only capable of representing manual features and is evaluated on a very limited corpus of 250+ phrases used at railway stations and banks and produced 60% correct translation as complete phrases. San-Segundo et al. [22] in their other work, implemented combination of three translation technologies of an example-based, a rule-based translation and phrase-based translation for limited domain of applying or renewal of Driver's License. In Example-based translation, system checks the similarity between two sentences by computing heuristic difference between them. One confidence value for the whole sign sequence (output) sentence is generated by translation module. In rule-based translation, different rules are applied after mapping of each word to into syntactic–pragmatic categories to translate the tagged words into signs by means of grouping concepts or signs. In statistical translation, a Phrase-based Translator and a Stochastic Finite State Transducer (SFST) are used for translation following steps of word alignment computation, phase extraction and phase scoring. The developed system with combination of all three-translation technologies yielded a BLEU score of 0.9456 and translation rate more than 90% on the corpus of 2124 Spanish sentences. Lopez-Ludena et al. [14] proposed integration of a preprocessing module for the improvement of San-Segundo et al. [21]'s statistical translation system developed for communication of government employees with deaf people in a restrained domain for the renewal of Driver's License and Identity Documents. Two statistical translation architectures of a phrase-based system and a Statistical Finite State Transducer (SFST) has been enhanced with incorporation of preprocessing module system which replaces Spanish words with associated tags for the evaluation of developed system on corpus of 4080 Spanish sentences and corresponding LSE translations. The preprocessing module exhibited a remarkable increase in the BLEU score from 73.8% to 81.0% and 70.6% to 78.4% in the phrase-based and in SFST system respectively. Ali et al. [1] proposed corpus based translation system using direct machine translation approach for limited domain of reservation counters of railway for enquiry purpose. The system comprises of six modules, input module taking text as input, tokenizer splitting text into words, resource as a repository for ISL signs of different words, translator picking sign from resource for the corresponding word, accumulator combining words to be translated, and display module that uses 3ds max software to create avatar that simulates the visual of the sign for the respective words. The system perform the machine translation of English text to ISL by direct word-to-word mapping and even ignoring tenses. The sign repository contains only 100 words used at railway reservation counters. Lopez-Ludena et al. [15] described the application of different language translation technologies in Spanish Sign Language (LSE) for generation of bus information for deaf people of Madrid. The development of two systems (1) the translation of text messages from information panels and (2) for translation of spoken Spanish language into natural conversations between deaf people and bus company workers at the information desk of the bus company is proposed. The devolved systems consists of a natural language translator that uses an example-based and a statistical translator, and a three dimensional avatar animation module for animating the signs. During translation of spoken Spanish utterances, a speech recognizer is used for decoding the spoken utterances into text before the passing to translation module. The field evaluation of developed system carried out at customer information office in specified domain between deaf people and real bus company workers producing result of less than 10% SER (Sign Error Rate) and a BLEU score exceeding 90%. Mishra et al. [17] applied statistical machine translation approach for translation of English text into ISL using a corpus. The system consists of translation module that receives source text and performs tasks of tokenization after process of filtration, A specific module performing Named Entity Recognition (NER) functions, parallel corpora for choosing the corresponding glosses for each of the tokens, IBM Model-1, 2, 3 processing alignment of words, a learning algorithm Expectation Maximization Algorithm, and a SMT Decoder to decode aligned words along with a language model that specifies the most suitable translation for a word order. The corpus is made of 537 glosses and 326 conversation sentences used in railways announcements and public assistance counters. The developed system implemented 3-gram model using the tool MOSES for the best possible outcome of ISL glosses. Luqman & Mahmoud [16] in their work, proposed a semantic rule-based machine translation system for health domain to facilitate the translation of Arabic text into Arabic Sign Language (ArSL). The proposed system translates Arabic sentences to ArSL sentences after performing a morphological analysis using MADAMIRA toolkit, syntactic as well as semantic analysis using CamelParser following the grammar rules and structure of ArSL. A gloss system for transcription of Arabic Sign Language (ArSL) is proposed to represent ArSL, which displays a sign sequence of GIF images as output of the system. The proposed translation system is evaluated on corpus consisting of 3294 words from 600 real life sentences used at medical centers and system is successful in providing an accuracy of more than 80% of the translated sentences. Kouremenos et al. [12,13] proposed a new prototype RBMT system for the creating of large qualitative corpus of written Greek Sign Language (GSL) glosses. Different tools and technologies such as AUEB's POS Parser, Natural Language Toolkit (NLTK) Java and Perl scripts have been incorporated into the proposed system under the supervision of professional translator of Greek Sign Language to generate different variants of GSL glossed corpus. Morphological rules and Word ordering are applied to the transferred constituency tree so generation stage generates sequential written glosses with morphological as well as non-manual components. The proposed RBMT system was evaluated in the restricted domain for forecasting of the weather reports on the generated corpora of 20,284 tokens and 1,015 sentences where developed RBMT system produces a relative score of 84% and 90% for 4-gram and for 1-gram evaluation respectively.

VIII. Results and Discussions

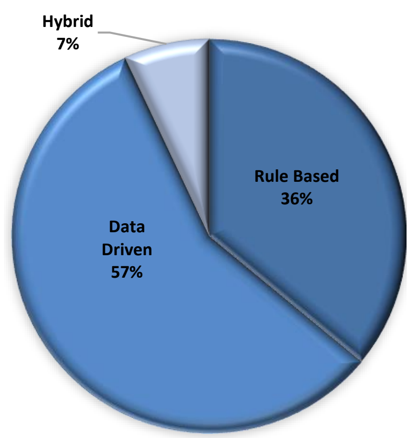
The main objective of this research study is to carry out a comparative study of all the existing research works in sign language generation for public places. The summarized report of sign language generation systems developed for public places on the results of our research study is presented below.

It is evident from our comparative study that 57% research work in sign language generation systems for public places has been carried out using data driven approaches (direct translation, statistical machine translation and EBMT/PBMT approaches), followed by rule based approaches (36%) and only 7% of research work using hybrid approaches as shown in Fig. 4a.

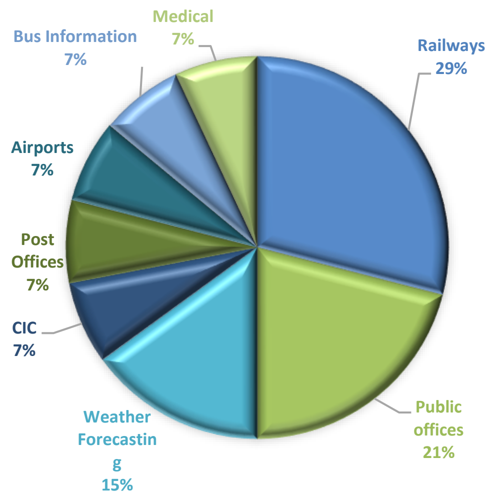
It has been observed that researchers has chosen different application areas for developing systems to be used at railways stations (29%), followed by public offices for renewal and issuance of license and ID cards (21%), weather forecasting (15%), 7% each in post offices, council information centers, airport information systems, bus information systems and medical domains as shown in Fig. 4b.

It is evident from our comparative study that 36 % researchers has used parsers/grammars in sign language generation systems for public places and 64% has not used any parser/grammar for these systems as shown in Fig. 4c.

It has been observed that most of the researchers have developed systems only using manual features (78%) and only 22% of researchers have developed systems taking into consideration non-manual features also as shown in Fig. 4d.



(a)



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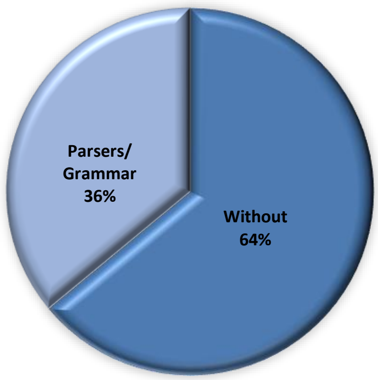

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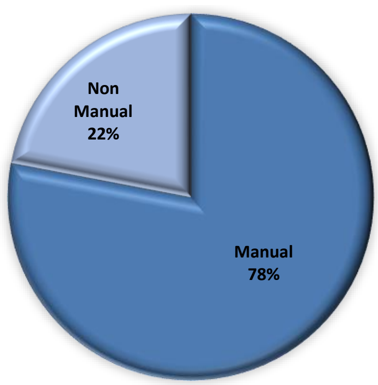

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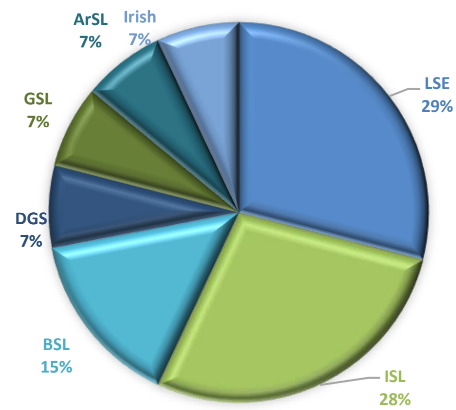

(e)

Fig. 4 **a** Percentage of various machine translation approaches used b Percentage of usage of various application areas **c** Percentage of usage of parsers and grammars in research works **d** Percentage of usage of manual as well as non-manual features **e** Percentage of research works carried out in different sign languages.

It is apparent from our comparative study that 50% of the researchers have developed systems using avatars and 50% of the researchers have used sign notations as output form in these systems.

It has also been observed that researchers of different sign languages have shown their interest in developing sign language generation systems for public places such as Spanish sign language (29%), Indian sign language (28%), British sign languages (15%) and 7% each for German, Irish, Arabic and Greek sign languages as shown in 3e.

IX. Open Issues and Challenges

Moreover, some open challenges and future directions in automatic sign language generation have been identified from our study that are as follows:

1. ***Lack of Hybrid Sign Language Generation Systems**:* The use of hybrid systems combining both rule-based as well as statistical machine translation can contribute with better results rather than following a single approach for automatic machine translation of spoken language to sign language.
2. ***Less Interest in Handling of Non-Manual Components**:* More focus towards handling of non-manual features in synthetic animations can provide help in generating realistic expressions in sign languages.
3. ***Absence of Large Multilingual Dictionaries**:* The easy availability and use of large bilingual or multilingual dictionaries can help in covering a wide range of signs of any sign language.
4. ***Non-Availability of Standard Grammar Rules of Sign Language**:* Researchers should focus on constructing grammatical and linguistic rules of sign language. Non-availability of these rules is a big hindrance in highly accurate sign language generation systems.

X. PROPOSED SYSTEM

Keeping in view the open issues and challenges in automatic sign language translations systems, we have developed a system prototype combining both rule based and corpus based approaches. We have also focused on generating non-manual components in synthetic animations. Moreover, some grammar rules are also devised for our system prototype.

1. *System Architecture*

The proposed system will have three modules. The proposed system categories the Input sentences as static, dynamic or randomly generated sentences with the help of bilingual dictionaries of various announcements used at public places.

a) **Mapping Module:** This module is responsible for mapping of static as well as dynamic announcements into Indian Sign Language sign notation using bilingual dictionary and passes the static sentences immediately to translation module to generate ISL signs using synthetic animations. It replaces the dynamic parts of dynamic announcements prior passing to translation module.

b) **Text Processing Module**: This module is responsible for parsing the randomly generated sentences using Stanford parser. Then it uses phrase recording and eliminator module for reordering of sentences and for removing unwanted word according to ISL grammar rules. Then lemmatization rules are applied to extract the root form of English word and then sentence is forwarded to translation module for producing ISL signs using synthetic animations.

c) **Translation Module:** This module is responsible for translating all the ISL words generated from mapping and text processing module into HamNoSys notations, which are then transformed into SiGML codes. Then a SiGML URL application is used to transform SiGML tags into virtual avatars generating synthetic performing animations in ISL.

2. Result and Discussions

The proposed announcement system prototype for deaf people is tested on approximately 1146 words obtained from various announcements used at public places. The proposed system prototype produced 84% accuracy on simple announcements and 82% accuracy in case of complex and compound announcements. The proposed prototype has been demonstrated to ISL interpreters and various ISL experts and the response received was very encouraging and motivating.

XI. CONCLUSION AND FUTURE DIRECTIONS

It is apparent form our comparative study that research works related to automatic machine translation of spoken languages into Sign Languages, used at public places, are still very few and very limited. Despite the contribution of researches to some extent, absence of proper grammar rules of the sign language and non-availability of sufficient bilingual parallel corpora developed for domain of public places leaves translation of speech or text to sign language as an arduous task in any country. Our research study also brings out the fact about these developed systems of public domain even though using a smaller corpus sign language translation rate are not too much encouraging. It is evident from our research findings that for the automatic machine translation of spoken (speech or text form) to sign language, two main approaches of rule-based translation and corpus based or statistical translation have been evolved. The latter approach requires large bilingual parallel corpora of both the languages, which acts as an obstacle to success of this approach due to the lack of large bilingual parallel corpora specifically designed for public places despite leading to better results. The former approach is rule-based, using the syntactic as well as grammar rules of both the source and target language, which suffers from lack of well-defined grammar rules and the analysis making this approach fragile as development of proper grammatical rules of sign language is a very challenging task. It is also evident that output form of these research works that is either the recorded human videos or the synthetic animations, also affects the efficiency of translation process. Although synthetic animations are not up to mark representing non manual features in comparison to recorded human videos but these turned out to be efficient in terms of computer memory consumption and conversion time while the recorded videos consumes so much memory and time. Synthetic animations can emerge as a better way to get spoken language to sign language production at public places.

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