**Towards a system to aid communication with Deaf**



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**Abstract**

Towards a system to aid communication with Deaf is an experimental system that aims to aid communication between a deaf person and an ordinary person by translating the ordinary person’s speech to sign language Using Sequence to Sequence Neural Machine Translation. A speech recognizer recognizes speech from the ordinary person and the system then synthesizes the appropriate sequence of signs in American Sign language (ASL) using a specially developed avatar. By using a phrase lookup approach to language translation, which is appropriate for the highly constrained discourse in society, we were able to build a working system that we could evaluate. We summarize the results of this evaluation (undertaken by deaf users and Ordinary people), and discuss how the findings from the evaluation are being used in the development of an improved system.

*Keywords: Machine Learning, Speech Recognition, Machine Translation, Sign Language, Avatar*

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**Problem Definition**

**Problem Statement:**

In our modern information and communication society, daily life would be unimaginable without technology. Information and Communications Technology (ICT) is also very useful for people with special needs.

Deaf are people who can’t talk and hear, hearing people are unfamiliar with Deaf because they don’t know their language. They think that if you cannot hear, you can easily access any necessary information by simply reading it in written form, and if you really need to communicate, you can always write your message down. [6]

But this system is not an efficient way to communicate, Deaf have their own language of communication (sign language), they can only understand this language and also they write and read Faster on sign writing.

According to survey in 2015, there are 121 “Deaf sign languages” in the world, but there is not such an efficient mechanism where Deaf can easily understand people thoughts. [7]

**Introduction**

**Background**

People who are Deaf have little or no hearing ability. The word “Deaf”, (often written with a capital “D”) typically refers to people who use Sign Language as a primary language – either directly with others who sign or indirectly through an interpreter with people who do not sign.

Sign language for deaf people has special features that are quite different from those of spoken language. Sign language is an iconic language compared to spoken language, which is more of an arbitrary one. Another crucial difference between the two languages is that sign language does not have its own writing system. Therefore, in order to write descriptions of signs, line drawings, photographs and illustrations have commonly been used, but these represent only a very small moment in the process of actual signing. [1]

They may hear environmental sounds, and may even understand some speech, but they identify with what is known as the “Deaf Culture” [2]. There has recently been considerable research activity in developing automatic systems which can understand and output speech to provide information services or to perform transactions with customers [3]. We have been developing a system which enable people to communicate with Deaf. It is an interactive translation system to assist in the completion of a conversation between an ordinary person and a deaf. The system translates the ordinary person speech into American Sign Language (ASL) and displays the signs using a specially-developed avatar. A comprehensive approach to the task of enabling humans who cannot sign to communicate using sign-language would clearly require the development of a general purpose speech to sign language converter. This in turn requires the solution of the following problems:

1. Automatic speech to text conversion (speech Recognition).
2. Automatic translation of English text into a suitable representation of sign language
3. Display of this representation as a sequence of Signs using computer graphics techniques.

For many people who have been profoundly deaf from a young age, signing is their first language so they learn to read and write English as a second language [4]. As a result, many deaf people have below-average reading abilities for English text and prefer to communicate using sign language [5].

We will specify how our system will reduce the gap between Deaf and people, which models can we used to automate this system for communication between them and we will describe how technology can facilitate this mechanism.

**Sign Language Representations:** [1]

A notation system for sign language is strongly needed to advance the study of its structure**,**

Two pioneers, William C. Stokoe, who proposed a notation system for American Sign Language (ASL), and Lynn Friedman, who analyzed ASL from a phonological point of view, worked towards this end. However, their notation systems are rather impractical for general users because they are too technical, much like phonetic alphabets in spoken languages. Therefore, it is necessary to employ another writing system to describe a sign or a signed sentence for everyday purposes. A more suitable sign writing method for this purpose is “SignWriting” by the American movement analyst Valerie Sutton. Her system was applied to Japanese Sign Language (JSL) and the results indicated that the system was effective enough to “write” Japanese Sign Language.

Indeed, there are newsletters and books written in SignWriting in some countries and the practical usage of the system in literacy education has had a great impact on the education of deaf children.

Sutton’s Center for Sutton Movement Writing, Inc. has created the following writing systems

**1. Sutton Movement Writing**

Sutton Movement Writing is the International Movement Writing Alphabet (IMWA) used to record all human and animal gestures. The IMWA records the details of movement-based languages. The IMWA has been specifically designed for the following five fields:

a. SignWriting: for writing the movements of sign languages

b. DanceWriting: for writing dance choreography

c. MimeWriting: for writing classic pantomime

d. SportsWriting: for writing ice skating and gymnastics routines

e. ScienceWriting: for gesture-based research.

**2. Sign-Symbol-Sequence (formal sign writing):**

The sign symbol sequence (FSW) is the official sequence of symbols in Sutton movement writing. The FSW is used in computer to sort and look up movements in Movement Writing.

1. **Sutton’s SymbolBank**

Sutton’s SymbolBank Database is the official source for all symbols in Sutton Movement Writing.

Sutton’s writing system of sign language is composed with symbols for head and face cues, hand shape, Movement (direction and manner), qualification and punctuation. Signed words written in SignWriting are created by compounding symbols of a highly pictorial design. This system has the following advantages:

1. It is aimed at enabling us to write every sign or signed sentence of every country;

2. Because the Writing is pictorial, natural shapes and movements of signs can be realistically shown;

3. Face expressions and body movements can be depicted, too.



**Literature Review:**

This chapter is based on research that we have done to solve the problems such as differences between this system and other similar systems already been built. In this system, we tried our best to overcome challenges we observed in current systems. So according to our researches and findings, there were not any system to convert text/speech or ordinary people into sign language and represent it using an avatar. Briefly, there are systems for Deaf like Tessa but they are limited to a Post Office and they used British Sign language (BSL) instead of American Sign Language (ASL).

**Area 1: TESSA**

TESSA is an experimental system that aims to aid transactions between a deaf person and a clerk in a Post Office. These systems are designed to provide translation of conversational speech between languages with a potentially very large vocabulary. It is an interactive translation system but it operates in a very restricted domain and is designed to assist in the completion of a transaction between a Post Office (PO) clerk and a deaf customer. The system translates the clerk's speech into British Sign Language (BSL) and displays the signs using a specially-developed avatar. [8]

In addition, concatenation of signing is more fluent and controlled for avatar than for video signing, as the exact positioning of the avatar can be manipulated. For these reasons, we decided to display the signs using an avatar, TESSA. Research into methods for capturing signing movements directly from video has been reported.

The alternative is to capture signs using separate sensors for the hands, body and face. This technique appears to capture sufficient movement to generate true and realistic signing from a virtual human. The motion is captured as follows:

1. Cyber gloves with 18 resistive elements for each hand are used to record finger and thumb positions relative to the hand itself.

2. Polhemus magnetic sensors record the wrist, upper arm, head and upper torso positions in three-dimensional space relative to a magnetic field source.

3. Facial movements are captured using a helmet mounted camera with infra-red filters and surrounded by infra-red light emitting diodes to illuminate Scotch light reflectors stuck onto the face. Typically 18 reflectors are placed in regions of interest such as the mouth and eyebrows.

**Area 2: HandTalk**

Founded in 2012, Hand Talk performs digital and automatic translation into the Brazilian Sign Language. HandTalk, which is internationally awarded and a reference in the segment, is run by a friendly virtual interpreter, Hugo, a 3D character that makes communication interactive and easy to understand. <https://www.handtalk.me/sobre>

**Area 3: Braille**

This system includes a smart glove that translates the Braille alphabet, which is used almost universally by the literate deaf blind population, into text and vice versa, and communicates the message via SMS to a remote contact. It enables user to convey simple messages by capacitive touch sensors as input sensors placed on the palmer side of the glove and converted to text by the PC/mobile phone. The wearer can perceive and interpret incoming messages by tactile feedback patterns of mini vibrational motors on the dorsal side of the glove. The successful implementation of real-time two- way translation between English and Braille, and communication of the wearable device with a mobile phone/PC opens up new opportunities of information exchange which were hitherto un-available to deaf blind individuals, such as remote communication, as well as parallel one-to many broadcast. The glove also makes communicating with laypersons without knowledge of Braille possible, without the need for trained interpreters. [9]

**Area 4: Deaf-Mute Communication Interpreter**

The project aims to facilitate people by means of a glove based deaf-mute communication interpreter system. The glove is internally equipped with five flex sensors, tactile sensors and accelerometer. For each specific gesture, the flex sensor produces a proportional change in resistance and accelerometer measures the orientation of hand. The processing of these hand gestures is in Arduino. The glove includes two modes of operation –training mode to benefit every user and an operational mode. The concatenation of letters to form words is also done in Arduino. In addition, the system also includes a text to speech conversion (TTS) block which translates the matched gesturesi.e. Text to voice output. [10]

**Area 5: Arabic Sign Language Interpreter**

The real difficulties arise when a deaf person wants to communicate with a non-deaf person. Usually both will get frustrated in a very short time. For this reason, there have been several attempts to design smart devices that can work as interpreters between the deaf people and others. These devices are categorized as human-computer-interaction (HCI) systems [11].

The adaptation of mobile devices makes sign language translation more attractive and more valuable. Using mobile devices instead of PC-base in sign languages presents several advantages. With PC base, term of anywhere and any place in deaf learning cannot be applied. With mobile devices one can obtain communication more realistic, a wider usage of sign language applications becomes possible and practical.

In recent years, several research projects in developing sign language animations system have been developed [12]. Some previous projects have made efforts in translating English text into Sign Language Animation, but none have proposed practical systems for translating Arabic text into Arabic Sign Language use mobile technologies and mobile devices. And also, most of the previous systems are PC-base. The adoption of mobile devices in developing sign language animation systems is motivated by several considerations: they help deaf to upgrade quality of human-human communication by evolving animations; they have a positive impact on factors such as human-mobility and likeability; they can have a positive effect on a deaf perception of deaf learning experience because they can attract deaf attention. [13]

**Area 6: Scribe4Me**

Sound plays an important role in communication and contextual awareness about interesting events and information. For this reason mobile support for better sound information awareness would be of great value to the deaf and hard-of-hearing. This system present the design and evaluation of a mobile sound transcription tool for the deaf and hard-of-hearing called Scribe4Me. When a user presses a button on her Scribe4Me PDA, the last 30 seconds of sound is uploaded, transcribed and sent back to her as a text message. Transcriptions include dialog and descriptions of environ-mental sounds. Scribe4Me is unique in providing support for both speech and text. [16]

**Area 7: A Spanish speech to sign language translation system for assisting Deaf-Mute People**

In Spain, during the last 20 years, there have been several proposals for normalizing Spanish Sign Language, but none of them has been accepted by the deaf-mute people community. From their point of view, these proposals tend to constrain the sign language, limiting its flexibility. In 1991, MA. Rodríguez [14] carried out a detailed analysis of Spanish Sign Language (SSL). She showed the differences between the sign language used by deaf-mute people and the standardization proposals.

This system translates officer explanations into sign language for deaf-mute people. The translation system is composed by a speech recognizer (for decoding the spoken utterance into a word sequence), a natural language translator (for converting a word sequence into a sequence of gestures belonging to the sign language), and a 3D avatar animation module. [15]

**Area 8: ATLAS**

Sign Languages (SLs) are visual languages used by deaf people to convey meaning. SLs rely on signs as lexical units instead of words used in common languages. Italian deaf people resort to Italian Sign Language (LIS) within their communities and it can be considered as the main way of communication of 60.000 Italian deaf individuals [17].

A system for the computer-assisted translation from Italian Language to LIS that provides the output of the translation resorting to a virtual avatar. [19]

The ATLAS system is designed to get written text as input and to perform the translation, resorting to two different translators: a statistical one and a rule based one. The statistical translator is based on MOSES [18], an open source statistical translator that automatically trains the translation models for any language pair. The Rule Based translator is based on a traditional rule-based approach. The input sentences are interpreted in terms of an ontology-based logical representation, which acts as input to a linguistic generator that produces the corresponding LIS (Italian Sign Language) sentence.

**Objectives:**

We will suggest an efficient mechanism/system that Deaf can easily communicate with ordinary people to understand their thoughts. As Deaf is a part of society and they need to make a connection with people around them. Our system gets the text/speech from smart phone, convert it to sign language using Sequence to Sequence Neural Machine translation and represent the speech using 3D character.

**Dataset:**

The dataset used is a sample of common words and sentences that deaf are using daily.

The font that we used is American Sign Language which is published on 2014.

We have searched many sources for gathering dataset such as Wikipedia pages, some books like (Goldilocks & the Three Bears in American Sign Language, The Book of Jonah) , Signbank and other sources, but the dataset that was used for this project is a subset of a much larger dataset, as described in <http://www.signbank.org/signbank.html> . As dataset in this website was so diffused so we gathered and sorted dataset first. In this website there are more than 10000 words in ASL and has the following feature vectors:

𝠀񀀁񀀉񈗥񈗵񋸦𝠃𝤝𝤨񀀁𝤎𝣤񀀉𝣰𝣮񈗥𝤏𝤇񈗵𝣱𝤑񋸦𝤆𝤜 Come

𝠀񀀁񆇡񈗥񋾡𝠃𝤘𝤰񋾡𝣴𝣵񀀁𝣹𝤒񈗥𝣣𝤇񆇡𝤋𝤘 Disappointed

𝠀񀀁񆕁񇆥񆡁񆡁񍘡𝠃𝤧𝤺񆡁𝤜𝤲񍘡𝣴𝣵񆡁𝤐𝤲񆕁𝤔𝤔񇆥𝤎𝤢񀀁𝣹𝤑 Red

𝠀񀀁񆨡񋲡񍦁𝠃𝤟𝤬񍦁𝣴𝣵񀀁𝣾𝤎񆨡𝤓𝤚񋲡𝤓𝤤 Throw in mouth

𝠀񀀙񈁑񋾡𝠃𝤘𝤵񀀙𝣝𝣲񋾡𝣴𝣵񈁑𝣟𝤗 He

𝠀񀀙񈁑񋾡𝠃𝤘𝤵񀀙𝣝𝣲񋾡𝣴𝣵񈁑𝣟𝤗 She

𝠀񀀡񀀁񆫡𝠃𝤛𝤚񀀁𝤄𝣼񆫡𝤉𝣲񀀡𝣱𝣼 111

𝠀񀀡񂤁񁳑񈙇񇆥𝠃𝤯𝤡񀀡𝣝𝣬񂤁𝣱𝣶񁳑𝤆𝣫񈙇𝤑𝤇񇆥𝤈𝤓 155

𝠀񀀡񂤁񁳑񈙇񇆥𝠃𝤯𝤡񀀡𝣝𝣬񂤁𝣱𝣶񁳑𝤆𝣫񈙇𝤑𝤇񇆥𝤈𝤓 One hundred fifty five

𝠀񀀡񂤁񁳑񈙇񇆥𝠃𝤯𝤡񀀡𝣝𝣬񂤁𝣱𝣶񁳑𝤆𝣫񈙇𝤑𝤇񇆥𝤈𝤓 One-hundred-fifty-five

𝠀񀀡񂤁񃋁񀭡𝠃𝤰𝤖񀀡𝣜𝣷񂤁𝣰𝤁񃋁𝤅𝣹񀭡𝤙𝣷 163

Till now we gathered 1500 small sentences with their sign representation informal sign writing.

**Implementation:**

As we mentioned above a comprehensive approach to the task of enabling humans who cannot sign to communicate using sign-language would clearly require the development of a general purpose speech to sign language converter. This in turn requires the solution of the following problems:

1. Automatic speech to text conversion (speech Recognition).
2. Automatic translation of English text into a suitable representation of sign language.
3. Display of this representation as a sequence of Signs using computer graphics techniques.

As we mentioned, the most suitable sign representation is “international sign writing”, we try to found all sources that we can use to gather “English – sign writing” combination sentences for our dataset.

In first try we gathered 1500 words and small sentences combinations, and we use it to build our first experimental model.

We use a sequence to sequence (seq2seq) model and after training the model we were able to input an English word, such as \*"¿translator ", and return the sign:

\*" 𝠀񀀁񀀩񆙡񋎩񋎽񂈁񂈉񆿅񆿕񋸥𝠃𝤨𝥇񆙡𝣪𝣟񀀁𝤅𝣕񀀩𝣿𝣚񋎽𝣥𝣱񋎩𝣦𝣆񂈁𝤚𝤌񂈉𝤁𝤌񆿅𝤛𝤮񆿕𝤀𝤮񋸥𝤍𝥁 "

Which is the representation of word “translator” in American Sign Writing.

# To train our model we used Tensor flow in “google Colab” and we followed steps in “Neural Machine Translation with Attention” Notebook available at:

# <https://colab.research.google.com/github/tensorflow/docs/blob/master/site/en/r2/tutorials/text/nmt_with_attention.ipynb>

The steps are as follow:

**A: prepare the dataset:**

We stored the dataset in a “.txt” file in Unicode format, every line in this file is an “English + American sign language” sentence and they are separated with tab “/t”

Example:

𝠀񀀁񀀉񈗥񈗵񋸦𝠃𝤝𝤨񀀁𝤎𝣤񀀉𝣰𝣮񈗥𝤏𝤇񈗵𝣱𝤑񋸦𝤆𝤜 ¿come

1. Add a \*start\* and \*end\* token to each sentence.

2. Clean the sentences by removing special characters.

3. Create a word index and reverse word index (dictionaries mapping from word → id and id → word).

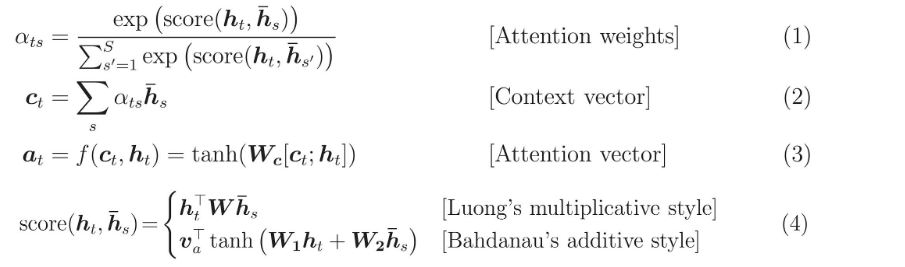
4. Pad each sentence to a maximum length.

### **B: Create a tf.data dataset**

## **C: Write the encoder and decoder model:**

The input is put through an encoder model which gives us the encoder output of shape (batch\_size, max\_length, hidden\_size) and the encoder hidden state of shape (batch\_size, hidden\_size).

Here are the equations that are implemented:



If we consider this notation:

* FC = Fully connected (dense) layer
* EO = Encoder output
* H = hidden state
* X = input to the decoder

The pseudo-code:is as follow:

* score = FC(tanh(FC(EO) + FC(H)))
* attention weights = softmax(score, axis = 1). Softmax by default is applied on the last axis but here we want to apply it on the *1st axis*, since the shape of score is *(batch\_size, max\_length, hidden\_size)*. Max\_length is the length of our input. Since we are trying to assign a weight to each input, softmax should be applied on that axis.
* context vector = sum(attention weights \* EO, axis = 1). Same reason as above for choosing axis as 1.
* embedding output = The input to the decoder X is passed through an embedding layer.
* merged vector = concat(embedding output, context vector)
* This merged vector is then given to the GRU

## **D: Define the optimizer and the loss function:**

## **E: Checkpoints (Object-based saving)**

## **F: Training:**

1. Pass the input through the encoder which return encoder output and the encoder hidden state.
2. The encoder output, encoder hidden state and the decoder input (which is the start token) is passed to the decoder.
3. The decoder returns the predictions and the decoder hidden state.
4. The decoder hidden state is then passed back into the model and the predictions are used to calculate the loss.
5. We Used teacher forcing to decide the next input to the decoder.
6. Teacher forcing is the technique where the target word is passed as the next input to the decoder.
7. The final step is to calculate the gradients and apply it to the optimizer and back propagate.

## **G: Translate:**

* The evaluate function is similar to the training loop, except we don't use teacher forcing here. The input to the decoder at each time step is its previous predictions along with the hidden state and the encoder output.
* Stop predicting when the model predicts the end token.
* And store the attention weights for every time step.

Note: The encoder output is calculated only once for one input.

**Conclusion**

**Summary**

We conclude that the dataset is not a complete space, and there are still other feature vectors missing from it.Our goal in developing this trial system was to establish whether the introduction of a limited speech-to-sign translation system for ordinary people would be beneficial to deaf whose primary means of communication was sign language. Moreover, we are using International sign writing mechanism but for testing our first version of our system we are using American Sign Language, in future it is possible to fit any sign wiring language with our system. In addition, concatenation of signing is more fluent and controlled for avatar than for video signing, as the exact positioning of the avatar can be manipulated. For these reasons, we decided to display the signs using an avatar (3D character).

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