

# **E-LEARNING SYSTEM FOR HEARING- IMPAIRED STUDENTS**

Project ID: Tmp\_2021\_176

## **PROJECT PROPOSAL REPORT**

Accash R. – IT18069600

**Bachelor of Science (Hons) Degree in Information Technology  
Specializing in Data Science**

**Department of Information Technology  
Faculty of Computing**

**Sri Lanka Institute of Information Technology**

# **E-LEARNING SYSTEM FOR HEARING- IMPAIRED STUDENTS**

Project ID: Tmp\_2021\_176

## **PROJECT PROPOSAL REPORT**

Accash R - IT18069600


**Supervised by – Miss. Janani Tharmaseelan**

**Bachelor of Science (Hons) Degree in Information Technology  
Specializing in Data Science**

**Department of Information Technology  
Faculty of Computing  
Sri Lanka Institute of Information Technology**

## DECLARATION

We declare that this is our own work and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Name	Student ID	Signature
Accash R.	IT18069600	

The above candidate is carrying out research for the undergraduate Dissertation under my supervision.

**Name of supervisor: Ms. Janani Tharmaseelan**

**Name of co-supervisor: Ms. Samantha Erang Siriwardene**

Signature of supervisor: \_\_\_\_\_ Date: \_\_\_\_\_

(Janani Tharmaseelan)

Signature of co-supervisor: \_\_\_\_\_ Date: \_\_\_\_\_

(Ms. Samantha Erang Siriwardene)

## **Abstract**

As of the current situation prevailing in the world due to COVID-19, it is very observable that most of the sectors are being converted into fully online systems, especially education. This online delivery system although being useful and easily accessible to various students, there is still a certain group who are unable to get adapted to this; the deaf and dumb. Even though the educational institutes are trying hard to provide them with understandable content, this prevails as a long-term problem.

Therefore, we are intending to introduce a solution to these students, which would help them continue their education through the online delivery method without any consequences. The proposed solution for the specific component of the research will enable the students to study the content provided by the lecturers, who do not know sign language. This will be done in the procedure where the contents in the Learning Management System (LMS), including notes, notices, announcements, etc. will be converted into sign language, in form of illustrations and signs. All these processing will be done using Natural Language Processing, Machine Learning, and Video Processing techniques.

**Keywords:** *Machine Learning, Natural Language Processing, Video Processing*

# TABLE OF CONTENTS

DECLARATION .....	3
Abstract .....	4
LIST OF FIGURES .....	7
LIST OF TABLES .....	7
1. INTRODUCTION .....	8
1.1. Background .....	8
1.2. Literature Review .....	10
1.3. Research Gap.....	16
1.4. Research Problem.....	19
2. OBJECTIVE .....	20
2.1. Main Objective .....	20
2.2. Specific Objective .....	20
3. METHODOLOGY .....	21
3.1. System Overview .....	21
3.2. Dataset Extraction .....	22
3.3. Feature Extraction and Selection.....	23
3.4. Classification and Recognition.....	23
3.5. Software Development Life cycle.....	24
3.6. Work Break Down Chart.....	25
3.7. Gantt Chart .....	26
4. PROJECT REQUIREMENTS .....	27
4.1. Functional Requirements and Non-Functional Requirements .....	27
4.2. Technology Section.....	27

5. BUDGET AND BUDGET JUSTIFICATION .....	28
REFERENCES .....	29

## **LIST OF FIGURES**

Figure 1.1 Survey question one	9
Figure 1.2 Survey question two	9
Figure 3.1 System overview diagram	21
Figure 3.2 Work break down chart	25
Figure 3.3 Gantt Chart	26

## **LIST OF TABLES**

Table 1.1 Comparison of similar research studies	17
Table 1.2 Comparison of similar research works and our solution	18
Table 5.1 Budget	28

## **LIST OF ABBREVIATIONS**

<b>Abbreviation</b>	<b>Description</b>
HMM	Hidden Markov Model
LMS	Learning Management System
ML	Machine Learning
NLP	Natural Language Processing
NLTK	Natural Language Tool Kit

# 1. INTRODUCTION

## 1.1. Background

The pandemic situation caused by the COVID-19 disease has taken over the entire world and has made everyone rely only on online communication systems from a certain point. This has also caused the other industries as well as the educational systems to switch to online delivery mode.

In the competitive world today, education and knowledge play a significant role in people's life. Thus, it is more essential to ensure that each person, especially the younger generation, gets the right to be educated. Yet, as mentioned earlier, due to the pandemic situation, many people are facing difficulties to get adapted to the ongoing online systems. There are a few common problems related to lack of technological equipment for studying, but with adequate observation and research, we encountered that the differently abled children, the hearing-impaired to be more specific, are going through some serious struggles.

As the number of students excluding the deaf and dumb are considerably in a higher number, the design of the e-learning systems is not to the expected standards of this community students. Due to this, the students are facing struggles in continuing their education as they had planned. This has been brought to our concern and we are aiming to take the necessary steps to provide them with the expected solution, which is the Learning Management System (LMS) for the hearing-impaired students.

Hence, in order to gather information and the needs of the hearing-impaired community, as a team we conducted a survey in form of an online questionnaire. Out of the 92 responses that were gained, 28.3 % of people have admitted that it would be very helpful if the lectures happened in sign language itself. On a scale of 1 – 5, of 1 being not helpful and 5 being very much helpful, 34.8% have voted for 4, 28.3% have voted for 3, 6.5% and 2.2% for 2 and 1 respectively. From this part of the survey, it is very evident that the majority of



the responders accept a medium that would provide lectures in sign language. Further details can be referenced in the image of the questionnaire below (Figure 1.1).

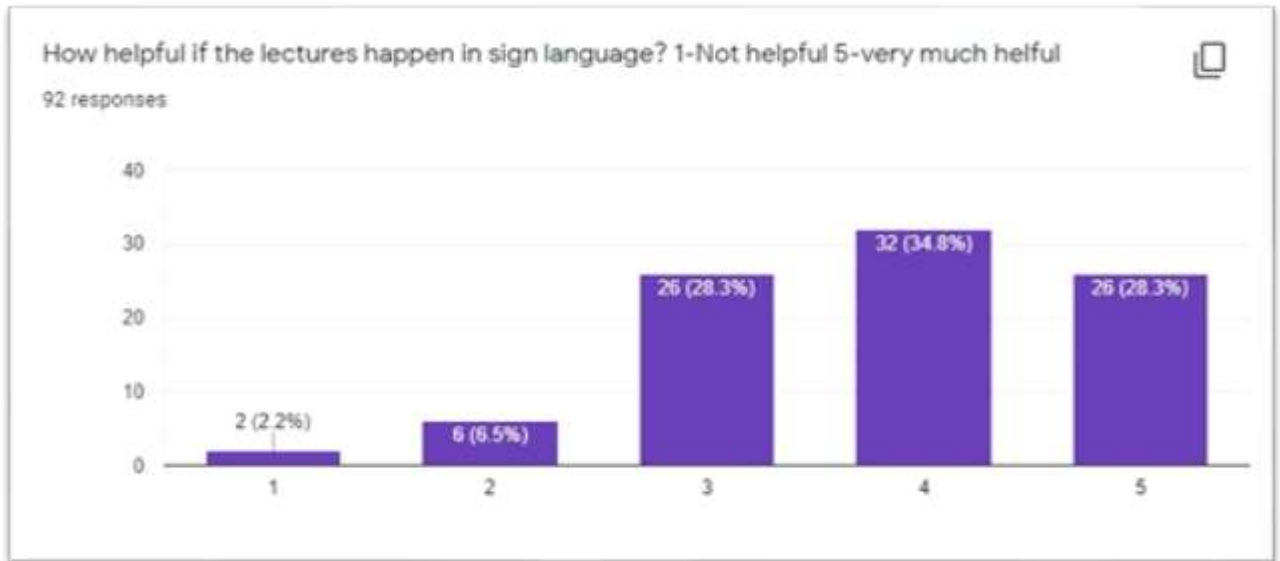


Figure 1.1 Survey question one

Further, the second question, as of Figure 1.2, the responders were asked if it would be helpful if the interpreter could detect the face expression of the user (hearing-impaired user). The result as stated is highly positive for the research, that 81.5% people have replied positively, and 8.7% and 9.8% people have replied 'no' and maybe, respectively.

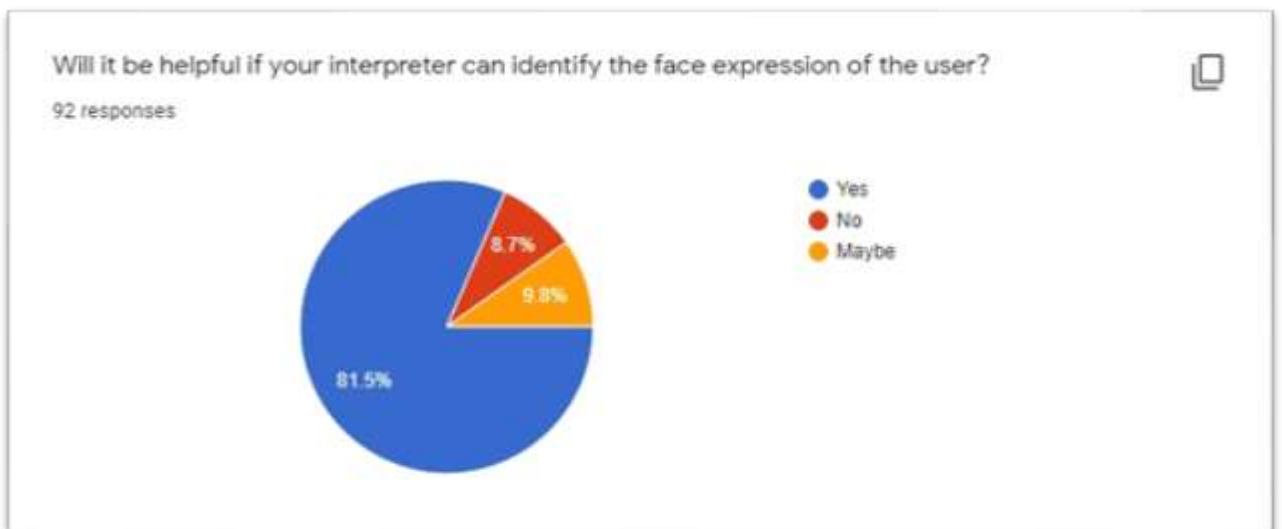


Figure 1.2 Survey question two

The LMS will be developed in order to cater the needs of these students in specific, adhering to the survey results obtained. This component of the research will focus on translating the text forms in the system into sign language formats. The materials would include lectures, notes, notices, announcements, etc. so that they will not have to depend on anyone else to translate for them anymore. The process will be done using Natural Language Processing techniques and Machine Learning.

Additionally, the lecture videos that would be posted by the lecturers/instructors to the LMS will be translated into sign language illustrations and animations too. And this is supposed to be done by retrieving the subtitles/captions of the video from the database. Hence, the component is totally based on text to sign conversion.

## **1.2. Literature Review**

According to the literature survey conducted on the existing research regarding sign language conversions, some of the most important works are elaborated below.

In 2005, James Ohene-Djan and Saduf Naqvi, on “*An Adaptive WWW-based System to teach British Sign Language*” [1] research paper, have presented the idea of implementing a WWW based system named KSO (Kids Sign Online), to facilitate the educational needs of deaf children under the age of ten. This has been built in order to facilitate the children on an individual basis, with progression time, and thus has been proved to give successful results too. The system basically consists of digital video content that converts from English to British Sign Language, which includes materials such as assessment exercises, children’s fairy tales and personalized online diaries too. This research paper talks about the lack of online materials for hearing-impaired students and the importance of making available of more content in the future. Also, for my part of the research, which is converting the text to sign languages, the idea of creating digital video content and making an adaptive system for each individual child was much useful.

In 2005, Oya Aran, Cem Keskin, Lale Akarun, on “*Sign Language Tutoring Tool*” [2] research paper, have presented a system that can teach the basics of sign language. This is implemented by using a simple sign language recognizer, that would help the user to learn sign language, which is useful for hearing-impaired and mute people as well as people with no disabilities too. It is also said that this will gradually improve the communication rate between the hearing-impaired and non-deaf people. The system requires the user to wear colored gloves to distinguish the hand gestures from the rest of the environment. It has two interfaces, that are the learning interface and practice interface, where a pre-recorded sign video is played for each selected sign and the practice phase will initiate the recording for that selected sign, when the user is ready to demonstrate. According to the performance of the user, a feedback will be given. For these processes, the idea behind Hidden Markov Models (HMM) has also been used in detecting the hand gestures. As the sign language involves various body movements, it is complex to build a recognizer. The factors that affect creating a proper sign video, and the use of HMM and connected components algorithm in this recognizer tool will be useful in order to carry on the text to sign conversion part on our research.

In 2016, Malu S Nair, Nimitha A P, Sumam Mary Idicula, on “*Conversion of Malayalam Text to Indian Sign Language Using Synthetic Animation*” [3] research paper, have presented a machine translation system that converts Malayalam text to Indian Sign Language (ISL) and output as 3D character animation, with the HamNoSys (Hamburg Notation System for Sign Language) structure as an intermediate representation. This also allows tutoring that will enable the non-deaf to learn the sign language and thus promote the communication between people. The system uses synthetic animation approach rather than motion capture approach, as it has too many visible advantages when compared. This allows real-time generation of motion data which makes the user very interactive with the system. Also, the system can store the signs in form of HamNoSys symbols in a large database which could be further populated too. This feature is made available for the ISL experts through an interactive Sign Editor, to further extend the vocabulary of the system. This work explains the text to signs conversion in detail, including the techniques and their

advantages and disadvantages. Therefore, it will help a great deal in wisely choosing the technologies according to the available data and other depending factors on the research. Additionally, the separation of the work into modules such as the sign editor module and the translator module help to identify the best approach to work with the research works systematically.

In 2020, Tariq Jamil, on “*Design and Implementation of an Intelligent System to translate Arabic Text into Arabic Sign Language*” [4] research paper, has discussed about an intelligent system that was developed to convert the Arabic text to Arabic Sign Language (ArSL). It has been designed to fulfil the need of integrating the Arabic deaf community with the society and to be able to communicate with them without any difficulties. The system is implemented in four crucial steps in order: the text-input, parsing, word-processing, ArSL output. Basically, the sentence that needs to be translated will be passed to the translator user interface and the system will identify each part such as, noun, verb, adjective, and consequently eliminate the words that are meaningless. Then the other meaningful words will be checked with the already updated system’s database full of signs, and hence display the correct output in GIF format. The translator’s user interfaces have been designed with ScreenBuilder application and Java programming language for the implementation. A toolkit named ‘Farasa’ was used for quick and accurate text-processing, which also contributes to identifying the parts of a sentence. Finally, an animated character provided by MindRockets, Inc has been used to display the ArSL signs output. This research work clearly outlines the implementation process, where the tools and software used for development are given too. This paper has been useful for identifying them and to grasp the idea of text-processing in easy ways.

In 2005, A.S. Drigas, D. Kouremenos, S. Kouremenos and J. Vrettaros, on “*An e-Learning System for the Deaf people*” [5] research paper, have presented a learning system that converts all the text in the learning environment into Greek Sign Language (GSL) videos. It allows deaf community people to learn in their own sign language, and therefore to minimize the unemployment issues among them as they have communicative problems

and inadequate performance issues in the workplace. This is specifically made in order to resolve the problems of learning of the targeted group of people. The system consists mainly of images and videos in the GSL, which is of a higher quality to ease the learning experience. It also provides all the additional facilities that a usual LMS would give, like selecting video speed, downloading options, student activity tracker, content extraction, etc. Hence according to this study, it resembles how a learning system for the deaf community could be equally good as a usual learning system and the methodologies that make the process easier. Also, the way of allocating various user levels in the system for making it progress for a long period, helps me to identify the roles and responsibilities properly.

In 2010, Mona M. Nasr, on “*An Enhanced e-Learning Environment for Deaf/HOH Pupils*” [6] research paper, has proposed the design and implementation of a e-learning system for the deaf community, based on the Chinese Sign Language. It provides many learning activities which could help the deaf people to perform as equal as the other students in their learning environment. The system provides virtual classrooms for students, where they can learn as well as interact with others using chat rooms and discussion forums. There is also translation facility where the course material could be translated to the Chinese Sign Language and re-uploaded for others to use. They can be translated into animation or video formats. Also, it has several user roles for maintaining the system, which includes the administrator, instructor and the student. This e-Learning system has proved to be helpful for identifying the other elements of a LMS that needs to be converted into sign language too, i.e., discussion forms.

In 2007, S. Khwaldeh, N. Matar, and Z. Hunaiti, on “*Interactivity in Deaf Classroom Using Centralised E-learning System in Jordan*” [7] research paper, have presented a centralized e-learning system based on the Jordan Sign Language for the deaf community in Jordan. The system is mainly built, in order to address a few common problems faced by them in the learning environments: teacher-pupils exchange, limited feedback, unmotivated students, etc. Hence as a solution it consists of discussion groups, feedback sections,

questionnaires, pre-tests and post-tests. The language is converted into Jordan Sign Language in video formats of high quality and improved consistency of video picture. There is also illustrations and animations of sign language in the system. This research study represents the significance of ensuring good user experience throughout the usage period (E.g., video quality).

In 2018, Amirita Dewani, Sania Bhatti, Mohsin Ali Memon, Wajiha Arain Arif, Quratulain Arain and Sayyid Batool Zehra, on “*Sign Language e-Learning system for hearing-impaired community of Pakistan*” [8] research paper, have presented a web-based e-learning system for the hearing-impaired in Pakistan and for normal people to communicate with them. The work had two main objectives; to teach the sign language to deaf people and to develop a text-translation system that translates English to Pakistan Sign Language (PSL) gestures. As the Pakistan Sign Language combines of hand shapes, orientation and movement of the hands, arms or body, and facial expression, a much efficient system has been developed. A convenient user interface is provided to the user and prompted for a text input in English and the equivalent PSL will be displayed as output. The input here will be categorized into two: catalogue based and non-catalogue based. If an input word is catalogue based it will be directly mapped to the corresponding word in the database of PSL and be displayed. Or if the word is non-catalogue based, it will be analyzed character by character and the output will be displayed as a series of PSL gestures. Further, the e-learning system is also capable of allowing to create user accounts, learn sign language and provide feedbacks. This has been tested among a targeted deaf group of people and based on expert opinions, using Web Evaluation Framework and has shown positive results too. This research work emphasizes the importance of categorizing the English input words as catalogue and non-catalogue based, so that the misinterpretation of meanings could be minimized and thus provide a better user experience.

In 2002, Katja Straetz, Andreas Kaibel, Vivian Gramley, Marcus Specht, Klaudia Grote and Florian Kramer, on “*An E-learning environment for deaf adults*” [9] research paper, have presented an e-learning system for the deaf adults in Germany. This is said to help

the deaf adults in learning and improving their mathematical and reading/writing skills. This has taken the factors like bilingual information (text and sign language), high level of visualization, interactive and explorative learning into consideration. The main advantages of the system are that the information is presented in both text and sign language, the user interface of the system is designed according to the requirements of the deaf researchers, various kinds of exercises, quizzes and tests are incorporated, a communication module for encouraging peer interaction and use of templates for pages, exercises and tests. The German Sign Language (GSL) videos that are converted from the text is available in different qualities, so that the user can choose according to the strength of their internet connection. The system requires the user to install a plugin 'QuickTime' in their browser to play the videos. The system designed here is a mere example of the significance of both text and the sign language to the deaf community, which will help them mingle with the others in the society. Further the use of a communication mode within the system is beneficial to create a common atmosphere among them by allowing to socialize.

### 1.3. Research Gap

With regards to the literature surveys conducted for the research papers listed in the previous section, the following research gaps were identified.

- Unable to distinguish between nouns and verbs for certain words which could result in a different meaning in a particular sentence. [4]

E.g.: The noun 'play' and verb 'play' has two different meanings, which can be misinterpreted in a sentence "A play is being staged at the auditorium today".

- Lack of clarity in facial expression and lip movement in the translated sign illustration/video, which could also result in a different meaning. [3]

E.g.: Saying the word 'don't' angrily and the same word politely are completely two different situations, which could be misinterpreted in a context.

- Unable to produce a complete LMS by fulfilling the needs of the hearing-impaired students. [6]



<b>Research Reference No.</b>	<b>Main objective</b>	<b>Accuracy rate</b>	<b>Research Gap</b>
[1]	A WWW-based system to teach British Sign Language	Not given (But positive result)	
[2]	Build a sign language tutoring tool		The system requires the user to wear colored gloves. Also limited signs are fed into the database.
[3]	Conversion of Malayalam text to Indian Sign Language using synthetic animation	82%	Further implementation of facial expressions and hand movements for better recognition of signs.
[4]	Design and implementation of an intelligent system to translate Arabic text into Arabic Sign Language	Positive result	Distinction between noun and verb of the same word is not implemented.
[5]	Build an e-learning system for the deaf people	Not mentioned	
[6]	An enhanced e-learning environment for Deaf/HOH pupils	Not yet tested	Incomplete system without the aimed requirements
[7]	Interactivity in deaf classroom using centralised E-learning system in Jordan	Not yet tested	

*Table 1.1 Comparison of similar research studies*

Features	System proposed by			Our solution
	M. S. Nair, N. A. P and S. M. Idicula	T. Jamil	A.S. Drigas, D. Kouremenos, S. Kouremenos and J. Vrettaros	
Sign language tutoring	X	-	-	✓
Availability of study materials like tests, quiz, etc.	-	-	X	✓
Reliable translation of words	-	X	-	✓

*Table 1.2 Comparison of similar research works and our solution*

#### **1.4. Research Problem**

Education has become a significant part in every human's life, or to be more specific it is the knowledge. The more they gain knowledge, the more it will become useful to them to lead their life. In such a competitive world, it would not be fair if the deaf and dumb children are laying back in their respective study fields, due to lack of resources to cater their needs. It is more obvious that it would be difficult for these children to continue their studies through the online teaching, in form of lecture videos and written notes.

These study materials may facilitate for a certain extent, but that would require an extra support for them which might make them dependent on someone else. Therefore, to address such issues of not being dependent and being able to learn content whenever needed, the proposed solution in the Learning Management System will be much helpful. While implementing the LMS, there are a few considerations like what the best software would be to be used for the LMS, what machine learning techniques would be apt for this research study, how can the data be obtained, how effective will the obtained data be for training and testing sets, what algorithms could be used for analyzing the data, will this LMS be worth and will it make an improvement to the students of the hearing-impaired community, etc. Therefore, by intaking all of these questions and requirements, our proposed system will be developed in an accommodating way, especially the translation process being main in my component of the research. This will make the students to ensure a bright future for themselves by helping to achieve their dreams and goals, without having to stop or delay, seeking for help from others.

## **2. OBJECTIVE**

### **2.1. Main Objective**

The main objective of this component of the research is to provide a user-friendly Learning Management System for the hearing-impaired community. This will eliminate the difficulties in trying to understand the common language used by most people, and instead providing them with information in their respective sign languages. This will include all the text-related data in the LMS and the captions from the video lectures uploaded by the lecturers/instructors, being converted into sign language.

### **2.2. Specific Objective**

With regards to the main objectives mentioned, the following are the specific objectives that need to be fulfilled.

- Perform a complete analysis of the most used sign language which will be helpful to implement in the system.
- Design a user-friendly system to improve user interaction and user experience.
- Build a reliable translator within the system to ensure correct conveyance of the study material.

### 3. METHODOLOGY

The basic functionality of the component of this Learning Management System is to convert the text materials into sign language illustrations. This will have to fetch the subtitles/captions of the lecture videos from the database and be processed, where it will go through the steps of tokenization, stemming, lemmatization and stop words removal in sequence. Later the feature extraction will be performed in order to classify the words and recognize to display them in the respective signs.

#### 3.1. System Overview

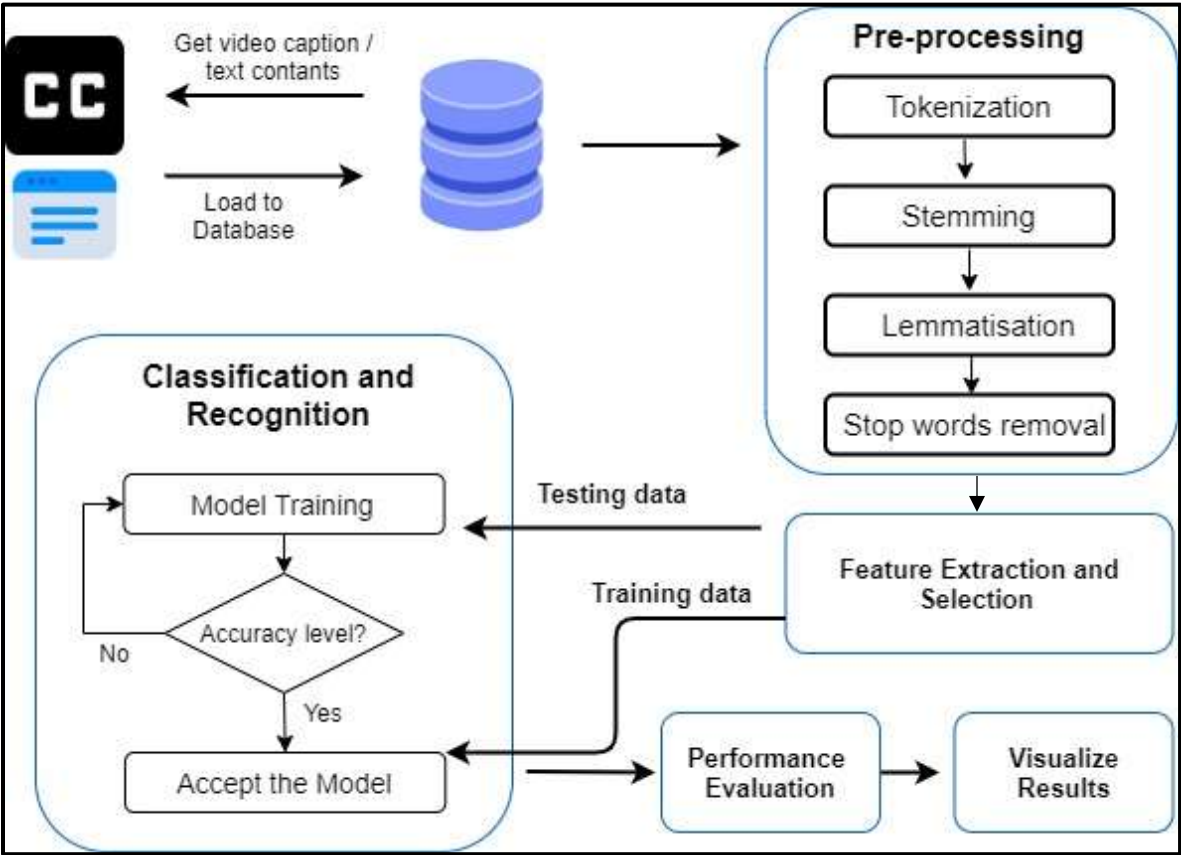


Figure 3.1 System overview diagram

### 3.2. Dataset Extraction

Data (video captions/ web contents) are extracted and used as the input for converting the text into sign language.

To process raw data, it takes several steps to make raw data into a proper dataset. This technique is called as preprocessing. In preprocessing, unstructured data will be converted into data that can be processed easily according to the needs. In general, after loading data using python (panda library), preprocessing has several stages of the process: tokenization, stemming, lemmatization, stop words removal.

- a) **Tokenizing:** Tokenizing is the decomposition of social network contents from sentences into words and omits dots (.), commas (,) spaces and characters in the word.
- b) **Stemming:** Stemming is the process of reducing a word to its word stem that affixes to suffixes and prefixes or to the roots of words known as a lemma.
- c) **Lemmatization:** Stemming and Lemmatization both generate the root form of the inflected words.
- d) **Stop words removal:** Stop words are words that are filtered out before or after the natural language data (text) are processed, while “stop words” typically refer to the most common words in a language.

### **3.3. Feature Extraction and Selection**

In this research component of translating the text into sign language gestures, the data after pre-processing will be used for feature extraction by using various Natural Language Processing techniques. These extracted features will be used for classification. In the feature selection step, the number of attributes is reduced so that the time spent for training a classifier and the complexity of the algorithm can also be reduced. These reduced attributes are usually of data that includes irrelevant features. The previously extracted features will be combined, labeled and put into folders. Hence, they can be later used by the classifier when a text input is given for translation.

### **3.4. Classification and Recognition**

This phase is regarding classifying the data that was obtained from the previous phase, feature extraction. This is important to predict the target class or category that the data would belong to and helps to retrieve, sort and store them for future use [10]. The extracted data will be divided into two sets: training sets and testing sets. The training sets are important to build up a model, while the test sets are used to validate that model [11]. The classifier will be trained using the extracted features from the training data set and then the testing data set will be used for predicting the data.

### **3.5. Software Development Life cycle**

The objective and the requirements of the research work tend to be confusing at the beginning stage, as they get modified or completely changed due to various factors, while doing the research. Therefore, it is necessary to follow a more precise and ideal methodology to be followed throughout the process. Hence, the agile scrum methodology will be made use here. It will eventually provide more flexibility to the software development life cycle and organization to the works, especially when it is a team project. It also allows the team members to implement the changes quickly without having to wait for long or for updates. [12]

The Agile methodology follows an iterative development approach, where it requires for a working product to be delivered at the end of each sprint, by adding more functionalities and data sets to it. Therefore, it will be easier for the team to disclose any confusions or irrelevant features, at the end. Further, by organizing daily scrum meetings for the team, the development and research will become more productive and efficient too.



### 3.6. Work Break Down Chart

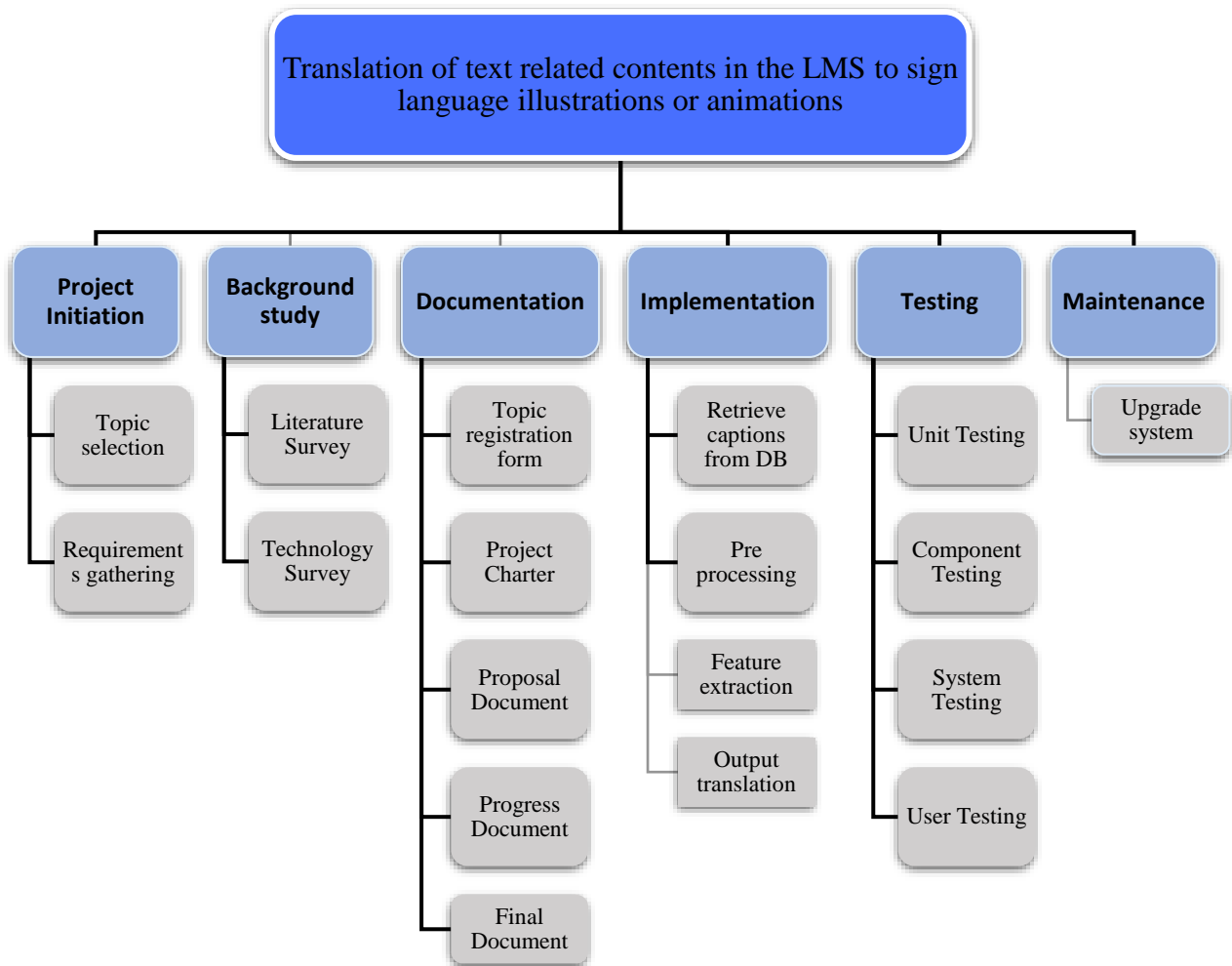


Figure 3.2 Work break down chart

### 3.7. Gantt Chart

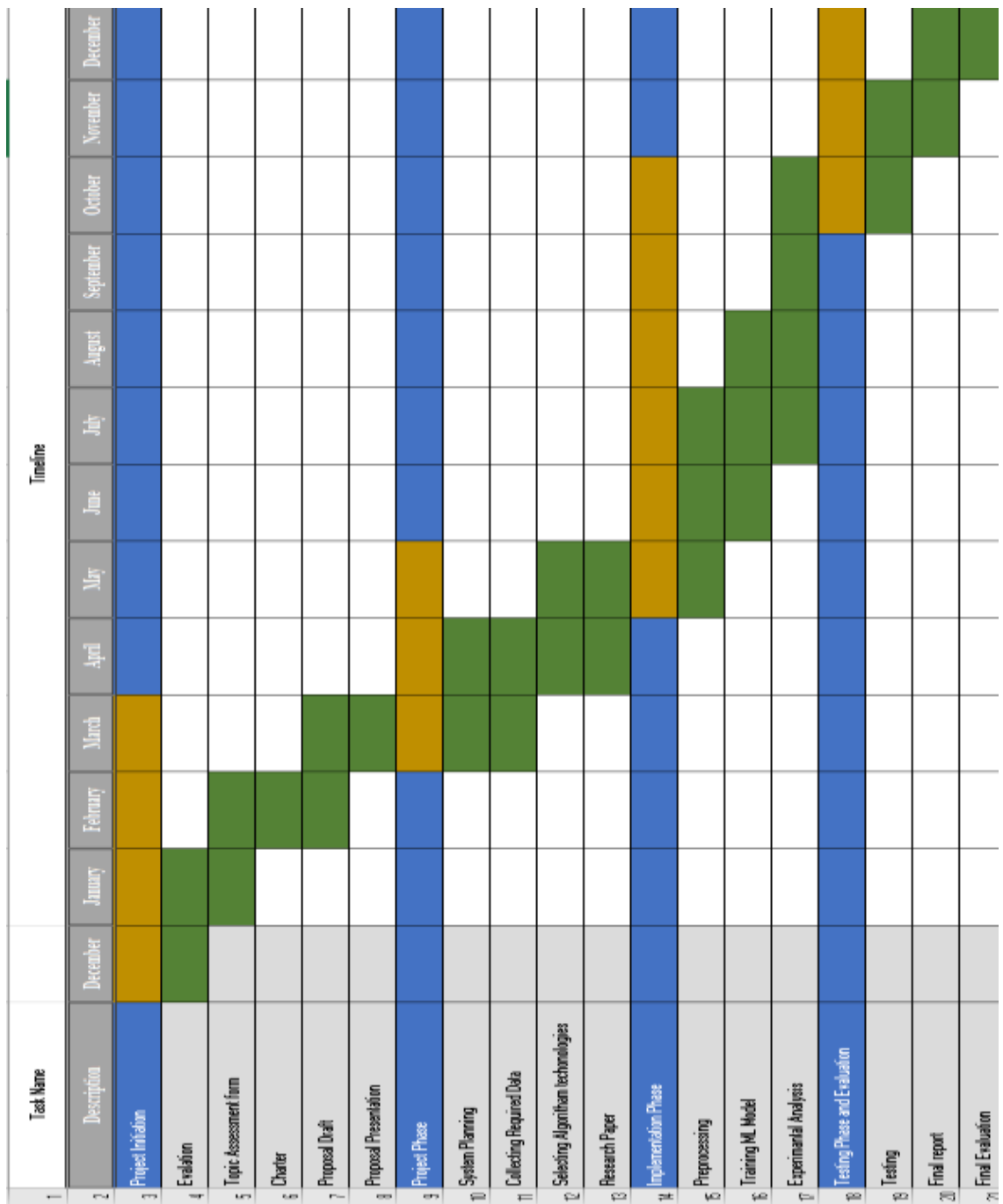


Figure 3.3 Gantt Chart

## **4. PROJECT REQUIREMENTS**

### **4.1. Functional Requirements and Non-Functional Requirements**

Functional requirements

- Converting the extracted text / captions to the sign language.

- Non-functional requirements

- Less manual work to translate into sign language.
- Take less time to convert text to the sign language.
- Accurate translation.

### **4.2. Technology Section**

- Software component:-
  - Machine Learning : Jupyter Notebook
  - Natural Language Processing : NLTK Tools
  - Version controlling: Git
- Project Management:- Azure board

## 5. BUDGET AND BUDGET JUSTIFICATION

The research involves the requirement of various resource types and the budget allocation is given below.

<b>Resource type</b>	<b>Amount (LKR)</b>
Preparation of reports and printing	Rs. 400
Internet usage for researching	Rs. 2000
Cloud charges	Rs. 2000
AWS Cost	Rs. 3000
Total	Rs. 7400

*Table 5.1 Budget*

## REFERENCES

- [1] James Ohene-Djan and Saduf Naqvi, "An Adaptive WWW-based System to teach British Sign Language," July 2005. [Online]. Available: <https://ieeexplore.ieee.org/document/1508627>. [Accessed February 2021].
- [2] O. Aran, C. Keskin and L. Akarun, "Sign Language Tutoring Tool," 2005. [Online]. Available: <https://ieeexplore.ieee.org/document/7078517>.
- [3] M. S. Nair, N. A. P and S. M. Idicula, "Conversion of Malayalam Text to Indian Sign Language Using Synthetic Animation," September 2016. [Online]. Available: <https://ieeexplore.ieee.org/document/7854002>. [Accessed February 2021].
- [4] Tariq Jamil, "Design and Implementation of an Intelligent System to translate Arabic Text into Arabic Sign Language," September 2020. [Online]. Available: <https://ieeexplore.ieee.org/document/9255774>. [Accessed February 2021].
- [5] A. Drigas, D. Kouremenos, S. Kouremenos and J. Vrettaros, "An e-Learning System for the Deaf people," July 2005. [Online]. Available: <https://ieeexplore.ieee.org/document/1560236>. [Accessed February 2021].
- [6] M. M. Nasr, "An Enhanced e-Learning Environment for Deaf/HOH Pupils," November 2010. [Online]. Available: <https://ieeexplore.ieee.org/document/5646421>. [Accessed February 2021].
- [7] S. Khwaldeh, N. Matar and Z. Hunaiti, "Interactivity in Deaf Classroom Using Centralised E-learning System in Jordan," January 2007. [Online]. Available: [https://www.researchgate.net/publication/253968268\\_Interactivity\\_in\\_Deaf\\_Classroom\\_Using\\_Centralised\\_E-learning\\_System\\_in\\_Jordan](https://www.researchgate.net/publication/253968268_Interactivity_in_Deaf_Classroom_Using_Centralised_E-learning_System_in_Jordan). [Accessed February 2021].
- [8] A. Dewani, S. Bhatti, M. A. Memon, W. A. Arif, Q. Arain and S. B. Zehra, "Sign Language e-Learning system for hearing-impaired community of Pakistan," February 2018. [Online]. Available: DOI: 10.1007/s41870-018-0105-4.
- [9] K. Straetz, A. Kaibel, V. Gramley, M. Specht, K. Grote and F. Kramer, "An E-learning environment for deaf adults," January 2002. [Online]. Available: [https://www.researchgate.net/publication/228694600\\_An\\_E-learning\\_environment\\_for\\_deaf\\_adults](https://www.researchgate.net/publication/228694600_An_E-learning_environment_for_deaf_adults). [Accessed March 2021].
- [10] L. Fitzgibbons, "Data classification," October 2019. [Online]. Available: <https://searchdatamanagement.techtarget.com/definition/data-classification>.

- [11] S. Lhessani, "What is the difference between training and test dataset?," 28 September 2019. [Online]. Available: <https://lhessani-sajid.medium.com/what-is-the-difference-between-training-and-test-dataset-91308080a4e8>. [Accessed 19 March 2021].
- [12] Olha Anurina, "Agile SDLC: Skyrocketing Your Project with Agile Principles," 15 January 2021. [Online]. Available: <https://mlsdev.com/blog/agile-sdlc>. [Accessed 20 March 2021].
- [13] Siming He, "Research of a Sign Language Translation System Based on Deep Learning," October 2019. [Online]. Available: <https://ieeexplore.ieee.org/document/8950864>. [Accessed 15 March 2021].
- [14] N. Takayama and H. Takahashi, "Data Augmentation Using Feature Interpolation of Individual Words for Compound Word Recognition of Sign Language," October 2020. [Online]. Available: <https://ieeexplore.ieee.org/document/9240545>. [Accessed March 2021].
- [15] Paula Maria Escudeiro, Nuno Filipe Escudeiro, R. Reis, F. Maciel-Barbosa, J. Bidarra and B. Gouveia, "Automatic Sign Language Translator Model," February 2014. [Online]. Available: [https://www.researchgate.net/publication/258993179\\_Automatic\\_Sign\\_Language\\_Translator\\_Model](https://www.researchgate.net/publication/258993179_Automatic_Sign_Language_Translator_Model). [Accessed February 2021].
- [16] Adithya V, Vinod. P.R. and Usha Gopalakrishnan, "Artificial neural network based method for Indian sign language recognition," April 2013. [Online]. Available: <https://ieeexplore.ieee.org/document/6558259>. [Accessed February 2021].