ONLINE LEARNING PLATFORM FOR HEARING IMPAIRED PEOPLE

Final (Draft) Report

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The dissertation was submitted in partial fulfillment of the requirements for the BSc (Hons) in Information Technology Specializing in Data Science

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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.

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

…… …….

Signature of the supervisor Date

(Dr. Lakmini Abeywardhana)

ABSTRACT

Sign language is the primary means of communication for the hearing-impaired community. Introducing a learning platform can result in many ways to make learning more accessible for the hearing-impaired community of Sri Lanka. Although there are many approaches that are being made to build such systems, the proposed learning platform, is aimed to provide a more interactive outcome by introducing a component that converts YouTube videos to sign language which is the video captioning in sign language and a Chatbot component that acts as an intermediate between a hearing-impaired user and a Google Search Engine. Furthermore, it includes a game-based learning platform and a gesture translation component from Sri Lankan to American Sign Language while the results are displayed to the users in the form of an animation.

The video captioning module focuses on converting the content of a YouTube video to sign Sri Lankan sign language along with emotion analysis to provide a complete sign language translation for the user. The proposed methodology is achieved by using Natural Language Processing, speech recognition, and machine learning techniques. This web-based application has been effective in increasing interaction between the student and the system making it an effective learning environment for the hearing impaired.

Key words: *Hearing Impaired, Sign Language, Sri Lankan sign language, Online learning, Natural Language Processing*

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LIST OF ABBREVIATIONS

SSL	Sri Lankan Sign Language
HI	Hearing Impaired
MLPC	Multi-Layer Perceptron
MFCC	Mel Frequency Cepstral Coefficients
SER	Speech Emotion Recognition
WHO	World Health Organization
ASL	American Sign Language
BSL	British Sign Language

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1. INTRODUCTION

1.1 Hearing impaired and Sign Language

Hearing impairment is defined as the inability of an individual to hear sounds adequately. This includes people with any degree of hearing loss along with individuals who have loss hearing completely by birth or later life. The main communication method of these individuals is using sign language. Sign language is the mean of communication using hand gestures and body movements. One of the main misconceptions regarding the use of sign languages is that it is same wherever you go. But it is not the case. According to an article published by Richard Brooks [1] there are 138 to 300 sign language variations used around the world today. Among these variations the variation used in Sri Lanka is known as Sri Lankan sign language [2].

1.2 Features of sign language

Facial expressions are an important factor in sign language [3]. Facial expressions are used to express the emotions when communication. For example, if a person is happy the greeting “Good morning” would be said with a smiling face and if sad it would be said with a sad facial expression just like people who are able to speak greet with a happy tone when happy and with a sad tone when sad. In sign language if a person is right-handed the right hand is used as the dominant hand to gesture signs.

1.3 Area of Research

A lot of research has been done in breaking the barrier between HI and who are not hearing impaired. Many chat applications [4], translating applications [5] and sign language teaching applications [4], [6] ,[7] has been developed over the years. This research focuses on studying and developing an automated learning platform for the hearing impaired taking some issues that they face to give them the opportunity to learn using online tools adapting to the new normal situations due to the pandemic.

1.4 Component Overview

The focus of this research component is to develop a way for the HI to gain knowledge using video resources. Although some video resources provide sign language translations along with the video for accessibility, they are more focused on ASL or BSL rather than SSL. This component will provide a solution so that the HI will be able to understand the content of a video in you tube through the embedded avatar who will be translating the content to sign language with facial expressions.

2. LITERATURE REVIEW

2.1 Background Study

Since the end of 2019 the world has been dealing with the pandemic which was caused due to the Covid-19 virus outbreak. This had initially caused a lot of trouble for people around the world, and many had to suffer huge losses due to this. But with time many industries began transformation towards online platforms to provide services and continue with their targets without being affected by the pandemic. As mentioned earlier schools and other educational institutes adapted online learning to provide education to their students without being interrupted due to the pandemic. In Sri Lanka Schools, universities and other educational institutes used MS Teams, Zoom and in some cases had their own systems which were customized to cater their way of providing education. Even though these systems were used they were based on traditional education system (Teacher to student). This transformation was a successful for majority, but it was not an ideal solution for some groups such as the HI.

According to the article [8] the author has stated that according to the WHO approximately 9% of Sri Lankans suffer from hearing loss while 15% of them are completely deaf according to Sri Lanka Federation of Deaf. These numbers will keep increasing as for the statistics mentioned by author of [9] from 131 million to 267 million by 2050 in South Asia region where south Asia region consists of Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Maldives, Myanmar, Philippines, Sri Lanka, Thailand, Timor-Leste and Vietnam. According to these factors it is evident that the issues faced by this group of people needs to be addressed

Currently as the covid-19 situation is at minimum state most educational institutes move towards a hybrid delivery of education (on premises and online according to guidelines provided by health authorities). But according to a survey done by the research team of [10] 50% of students prefer online education in the future as well which is shown by the figure 2.1.1.

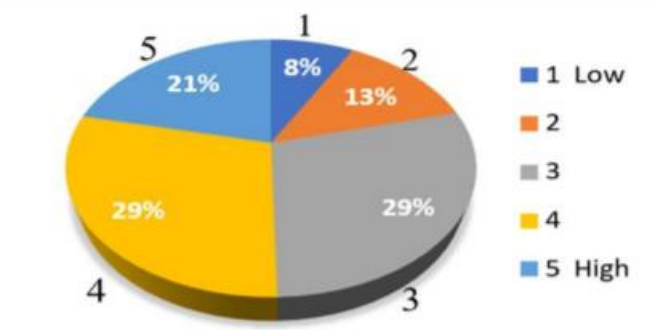


Figure 1 - Student's preference for online learning in the future

Figure 1 shows that while 21% of the students do not prefer online learning for the future half of the students prefer online learning in the future.

According to a study done in 2021 [11] on the effectiveness of online learning in India the authors have used a questionnaire to identify what motivates students to learn through online, their experiences, disturbances during online learning, he environment at home for online learning and devices used for online learning.

Figure 2 - Digital approaches that motivate students to learn

Figure 2 shows what motivates students to learn when using online learning. From the figure it is visible that 54.7% of the students which is the majority are motivated to learn using animations.

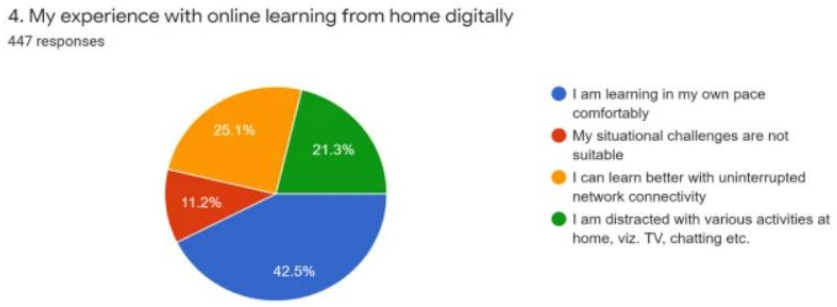


Figure 3 - The online learning experience of students

Figure 3 shows the learning experiences of students. 42.5% of the students have said that they are able to learn at their own pace comfortably through online learning.

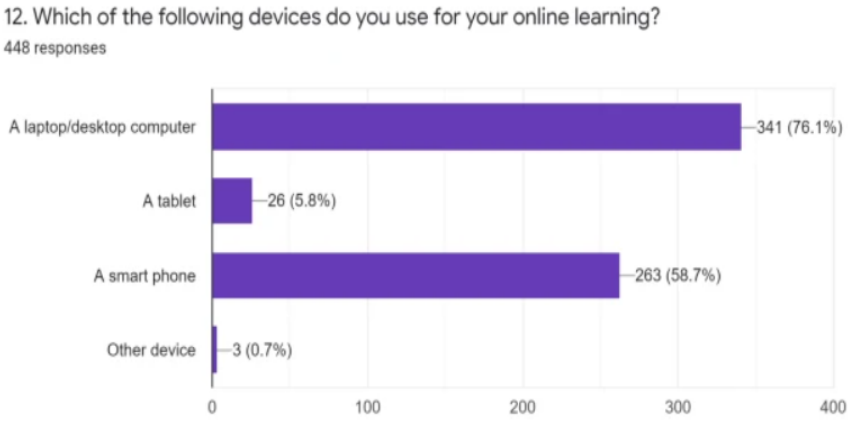


Figure 4 - Devices used for online learning

Figure 4 shows that 76.1% of the students use a laptop or a desktop for their online learning purposes.

These survey results suggest than online learning is a successful learning method, and it would not dissolve and would be used by majority of students even after the pandemic situation is over. It is safe to say that online education has a place in the society for the foreseeable future.

According to [12] HI face challenges such as limited access to tools to study and communication issues. Also, HI face accessibility issues when using online learning platforms which makes their learning harder.

In [12] it is mentioned that many studies done on this area suggests of an online learning platform for hearing impaired to learn interactively. Hence an online learning platform is the best solution to issues of HI.

2.2 Literature Survey

For the problems faced by HI many solutions have been proposed and has been implemented. Most of these solutions has been implemented to break the communication barrier that is between HI and normal hearing people. For instance, in [13] the authors have developed a mobile application which captures the signs performed and interpret in human readable language using computer vision and machine learning. This application is built to detect Sri Lankan sign language as the author has mentioned that many such applications has been developed for the use of American sign language.

EasyTalk [14] is another application that is developed based on Sri Lankan sign language. The authors gave mentioned that using this application users can convert verbal inputs to Sri Lankan sign language and vice versa. The users also mention Hand Gesture Detector uses pre-trained models to capture hand gestures. The detected hand signs are classified and translated by the Image Classifier. For detected hand signs, the Text and Voice Generator generates a text or an audio structured output. Finally, the Text to Sign Converter converts entered English text into animated graphics based on sign language. Many such research have been done on improving the accuracy and improving the ability to interpret sign language to text or speech.

In [15] the authors have developed an android based learning application for the hearing impaired. According to authors this application contains videos and materials posted by teachers on a variety of subjects. If necessary, it is possible to download it. It means that users can study whenever and wherever they want, without having to worry about time

constraints or internet availability. Quiz, set a schedule, event, chat, and a memory game are among the app's other features as well as additional tools to help hearing-impaired people get the most out of online learning. This system is a teacher-based teaching environment which enables the hearing-impaired students to chat with each other if necessary. This system does not address the issue that majority of the HI (deaf) do not know how to read written text. Many such research has been done and has developed learning platforms that can be used by HI but many of these do not address the issue that majority of HI are having trouble reading.

2.3 Research Gap

According to the literature survey done above the following issues were found as research gaps,

- Limited systems use SSL as the dialect of the language.
- Systems use text as caption and does not use sign language as caption which would make it easier and would make it accessible to HI who cannot read.
- Existing systems lack the analyzing of emotion which is essential to be integrated with the sign language.

So, this research is done to provide a solution to these identified gaps by developing a system with the ability to convert the content of a video to sign language along with the analyzed emotions integrated to the animated avatar.

When we consider existing implementations in this area:

- In Research A [4], the authors have presented a 3D virtual reality environment where HI can communicate with each other and to assist the learning and teaching process of the Brazilian sign language.

- In Research B [6], the authors have proposed a teaching environment for sign language which gives live gesture feedback for Irish sign language.

- In Research C [7], the authors have proposed a system for teaching Sri Lankan sign language which would be beneficial for primary school students to learn the basics without any help or guidance from their parents or teachers.

- In Research D [16], the authors have proposed an e-leaning platform for the HI where a lecturer uploads the lesson video, and the user can see the content of the video as caption along with the video. This system also facilitates communication between students and the teacher and teaching of sign language. This system has also proposed a video enhancing feature which would enhance low light videos uploaded by the lecturer without any third-party involvement to produce a clear enhanced lecturer video to the students. This system is based on American sign language.

Table 1 - Comparison between existing studies and the proposed system

Feature / **Research**	Based on SSL	Generating captions in the form of sign language	Analysing of emotion in each video	Conversion to sign language
Research A [4]	✗	✗	✗	✓
Research B [6]	✗	✗	✗	✓
Research C [7]	✓	✗	✗	✓
Research D [16]	✗	✓	✗	✓
Proposed system	✓	✓	✓	✓

2.4 Research Problem

A HI has limited access to videos and resources that they could refer when they need. A non-HI would be able to use search engines like google to search for any problem that they might get and get answers within seconds. Also, they can get knowledge using YouTube videos which the HI is not able to do unless the person who has uploaded the video has added accessibility for the HI or the video is specifically for the HI. In such cases these individuals face limitations when accessing these types of videos.

Therefore, to it is necessary to develop a feature where they would be able to search and refer a content of a certain video in sign language. This will enable a HI person to gain knowledge or clear doubts refereeing to videos even if they are unable to read which is the case in many situations.

A survey was carried out to identify what solutions can be provided to the Hearing-Impaired community of Sri Lanka that would benefit them. This survey was carried out at a deaf school in Sri Lanka and 27 responses were collected.

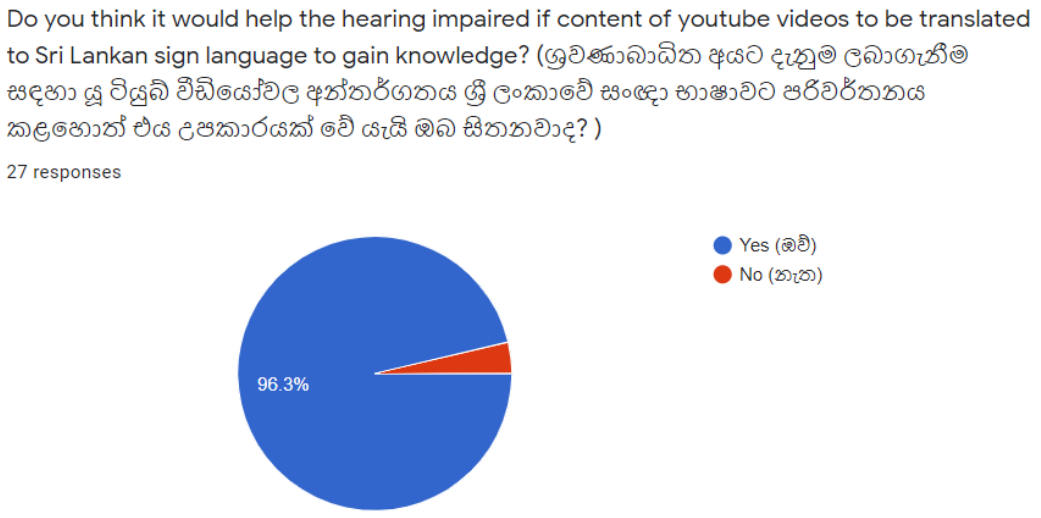


Figure 5 - Survey question

According to figure 2.3, 96.3% of the responses suggested that a feature where the content of a video captioned using sign language would benefit them.

In [16] The authors have proposed a platform that makes use of sign language to help students and tutors communicate more effectively while also providing sign language learning resources, practice opportunities, and Q&A sessions. The system includes a low-light enhancement module that enhances the videos submitted by the instructor, as well as a module that converts the uploaded lessons to American Sign Language and converts the sign language questions to the text. In the paper, the authors mention that for the uploaded lessons to be converted to sign language they have used the caption of the video as a text and a text to ASL conversion has been done. The author expects to provide a user with the ability to get the content of the uploaded lesson on ASL. In this system using text as a caption, the method is not the ideal method according to [17] where the author mentions that majority of HI does not read better than elementary level meaning that they have trouble reading long sentences. Also, the systems are based on ASL and do not include emotion analysis. Facial expressions are a crucial factor in sign language. According to [3] Facial expressions play a vital role in sign language and are used to express emotions when communicating. For example, if a person is happy the greeting “Good morning” would be said with a smiling face and if sad it would be said with a sad facial expression just like people who are able to speak greet with a happy tone when happy and with a sad tone when sad

3. OBJECTIVE

3.1 Main Objective

The main objective of this component is to give the opportunity for a HI to gain knowledge through referencing videos which will be captioned in SSL.

3.2 Specific Objective

The following sub objectives should be fulfilled to achieve the specified objective.

- **An algorithm to identify emotions using speech recognition, text analysis and Facial Expressions.**

  This objective aims on analyzing the extracted audio and video part by part to identify the emotion that is expressed. The identified emotions are used as facial expression for the output along with converted sign language. This will give the HI to understand the emotion of the video along with the content.

- **Extracting content of the video and converting to SSL**

  This objective aim on converting the content of the video into SSL so that the user will be able to understand what is being said in the video easily with the language that they are most familiar with.

- **An algorithm to map converted sign language and the identified emotions**.

  This objective aims on an algorithm to match to map the identified emotion and the converted signs so that it can be used to build the SSL signing avatar with facial expressions. This will be helpful for the HI in Sri Lanka to clearly understand the content of the video to gain knowledge from them.

4. METHODOLOGY

The main functionality of this component is to capture the content of a provided video and to convert the content to sign language to display as a caption while identifying and displaying the emotion along with it. HI can provide a YouTube video link and the system will take the link and will download the video. Then the system will extract the audio segment from the video and will split the audio file into chunks based on the silences. These audio chunks are used to identify the emotions using speech recognition as well as to identify the emotion after converting to text. Then the video is also broken into parts using the time stamps of the audio chunks to be used to identify the emotion using facial expressions if facial expressions are available in the video.

4.1 System Architecture Diagram

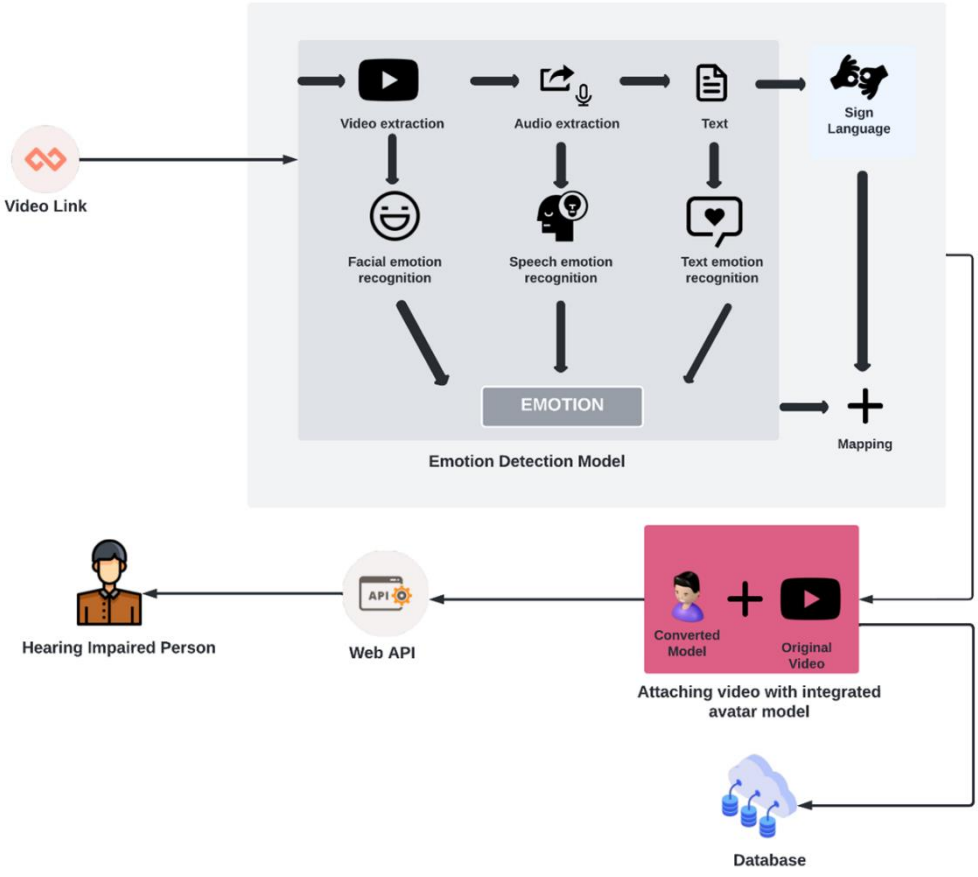


Figure 6 - Function Architecture Diagram

The above functional diagram shows the functionality of emotion identification and conversion of video content to SSL.

4.2 Audio extraction and splitting

4.2.1 Downloading video

The video is downloaded using the youtube dl library of python where the video link is provided by the user and the video will be downloaded in mp4 format.

```
# Downloading given youtube video for processing
def download_video(link):

    link_split = link.split('/')
    end = link_split[3]

    ydl_opts = {}
    with youtube_dl.YoutubeDL(ydl_opts) as ydl:
        ydl.download([link])
        info_dict = ydl.extract_info(link, download=False)
        video_title = info_dict.get('title', None)

    return video_title , end
```

Figure 7 - Download Video Code

4.2.2 Audio extraction

After the video is downloaded this will be used to extract the audio to be used for emotion identification using SER and also to extract the text to convert content to sign language. This is done using ffmpeg and the subprocess module of python which is a module that allows you to spawn processes, connect to their input/output/error pipes, and obtain their return codes. The extracted audio is saved as a wav file.

```python
def convert_video_to_audio_ffmpeg(video_file, output_ext="wav"):

    """Converts video to audio directly using `ffmpeg` command
    with the help of subprocess module"""
    filename, ext = os.path.splitext(video_file)
    subprocess.call(["ffmpeg", "-y", "-i", video_file, f"{filename}.{output_ext}"],
                    stdout=subprocess.DEVNULL,
                    stderr=subprocess.STDOUT)
```

Figure 8 - Audio Extraction Code

4.2.3 Audio and Video splitting by silences

Since it is necessary to analyze the emotion sentence by sentence it is essential that we split the video and the audio by sentences as well. This is accomplished using the pydub python library for audio splitting and using ffmpeg tools for the video.

The audio is first split based on the silences where if there is no audio for 5 seconds the system will consider this to be an end of the sentence and will split the audio accordingly. A silent threshold is defined as -16 dBFS to let the system identify beyond what amplitude level is to be considered as silence.

```python
# Function which splits given audio in to chunks by sentences
def break_chunks(path):

    # open the audio file using pydub
    sound = AudioSegment.from_wav(path)

    # split audio sound where silence is 500 miliseconds or more and get chunks
    chunks = split_on_silence(sound,
        min_silence_len = 500,
        silence_thresh = sound.dBFS-14,
        keep_silence=500,
    )

    # create a directory to store the audio chunks
    folder_name = "audio-chunks"

    if not os.path.isdir(folder_name):
        os.mkdir(folder_name)

    # process each chunk
    # export audio chunk and save it in
    # the `folder_name` directory.
    for i, audio_chunk in enumerate(chunks, start=1):
        chunk_filename = os.path.join(folder_name, f"chunk{i}.wav")
        audio_chunk.export(chunk_filename, format="wav")

    return chunks
```

Figure 9 - Splitting Audio Code

After audio is broken into parts based on the timestamps of the audio segments the video is also broken into parts with ffmpeg tools.

```python
def break_video(video):
    #Convert wav to audio_segment
    audio_segment = AudioSegment.from_wav("path.wav")

    #normalize audio_segment to -20dBFS
    normalized_sound = match_target_amplitude(audio_segment, -20.0)
    print("length of audio_segment={} seconds".format(len(normalized_sound)/1000))

    #Print detected non-silent chunks, which in our case would be spoken words.
    nonsilent_data = detect_nonsilent(normalized_sound, min_silence_len=500, silence_thresh=normalized_sound.dBFS-14, seek_step=1)

    times = []
    #convert ms to seconds
    print("start,Stop")
    for chunks in nonsilent_data:
        print( [chunk/1000 for chunk in chunks])
        times.append([chunk/1000 for chunk in chunks])

    required_video_file = video

    for time in times:
        starttime = time[0]
        endtime = time[1]
        ffmpeg_extract_subclip(required_video_file, starttime, endtime, targetname="video/"+str(times.index(time)+1)+".mp4")
```

Figure 10 - Splitting Video Code

The process of the captioning module contains 4 sub parts.

- Converting to sign language.
- Identifying emotion using speech recognition.
- Identifying emotion using text analysis.
- Identifying emotions using the facial expression in the video if there are any.

4.3 Converting to sign language

Through this component, the extracted text is converted into sign language. First, the text goes through a tokenization process where the sentences are broken into words choosing only the words that are necessary for conversion. Then the stop words are removed which eliminates common words like articles, prepositions, models, conjunctions, etc. Then the words are stemmed to their root. After this process is completed, the remaining words are taken, and the respective sign related to the word will be used to display the output.

4.4 Identifying emotion using speech recognition.

This component is focused on identifying the emotion based on the extracted audio from the provided video. Here the emotions are segmented into three basic parts negative, positive, and neutral.

4.4.1 Feature Extraction

For the process of emotion detection, three key parameters are used from the audio signal \cite{b13}.

- Mel Frequency Cepstral Coefficients (MFCC) - The Mel scale is used to compare the perceived frequency of a tone to the actual measured frequency. It scales the

frequency to match what the human ear can hear more closely. The envelope of the voice signal's temporal power spectrum depicts the vocal tract, and MFCC accurately represents this envelope.

- Mel Spectrogram - Mel spectrogram plots amplitude on frequency vs time graph on a “Mel” scale. The spectrogram is created by doing a Fast Fourier Transform on overlapping windowed portions of the signal. This is simply a spectrogram that represents amplitude on a Mel scale.

- Chroma - In a normal chromatic scale, a Chroma vector is a 12-element feature vector that indicates how much energy of each pitch class is present in the signal

```
#Extract features (mfcc, chroma, mel) from a sound file
def extract_feature(file_name, mfcc, chroma, mel):
    with soundfile.SoundFile(file_name) as sound_file:
        X = sound_file.read(dtype="float32")
        sample_rate=sound_file.samplerate
        if chroma:
            stft=np.abs(librosa.stft(X))
        result=np.array([])
        if mfcc:
            mfccs=np.mean(librosa.feature.mfcc(y=X, sr=sample_rate, n_mfcc=40).T, axis=0)
            result=np.hstack((result, mfccs))
        if chroma:
            chroma=np.mean(librosa.feature.chroma_stft(S=stft, sr=sample_rate).T,axis=0)
            result=np.hstack((result, chroma))
        if mel:
            mel=np.mean(librosa.feature.melspectrogram(X, sr=sample_rate).T,axis=0)
            result=np.hstack((result, mel))
    return result
```

Figure 11 - MFCC Feature Extraction Code

4.4.2 Model Training

After the features are extracted, a model was trained using the Multi-layer Perceptron classifier (MLPC) to detect the emotions for a given audio signal. The required parameters for the model were identified using hyper parameter tuning.

```
#Initializing the Multi Layer Perceptron Classifier
model=MLPClassifier(alpha=0.05, batch_size=256, epsilon=1e-08, hidden_layer_sizes=(500,),
                    learning_rate='constant', max_iter=700 , solver="adam" , activation= 'tanh')
```

Figure 12 - Model Training Code - SER

4.5 Identifying emotion using text analysis.

This component is focused on identifying the emotion based on the extracted text from the provided video. Here the emotions are segmented into three basic parts negative, positive, and neutral.

The dataset is initially cleaned to remove any characters and punctuations.

```
def cleantext(data):
    data = re.sub(r'@[A-Za-z0-9]+', '', data) # remove @mentions
    data = re.sub(r'#', '', data)# remove # tag
    data = re.sub(r'RT[\s]+', '', data) # remove the RT
    data = re.sub(r'https?:\/\/\S+', '', data) # remove links
    data = re.sub('(\\\\u([a-z]|[0-9])+)', ' ', data) # remove unicode characters
    data = re.sub(r'"', '', data)
    data = re.sub(r':', '', data)
    data = re.sub(r'=', '', data)
    data = re.sub(r'`', '', data)


    return data
```

Figure 13 - Text Preprocessing Code

Next, the text is lemmatized and stemmed for classification.

```
def pre_process(text):
    text_1 = text.split()

    lemmatizer = WordNetLemmatizer()
    ps = PorterStemmer()
    lemmatized_words=[]
    for w in t:
        w = ps.stem(w)
        lemmatized_words.append(lemmatizer.lemmatize(w))
```

Figure 14 - Lemmatization and Stemming Code

The words were sorted and finally were taken through the process of removing stop words.

```
vectorizer = CountVectorizer(max_features=1500, min_df=5, max_df=0.7, stop_words=stopwords.words('english'))
X = vectorizer.fit_transform(data['Text']).toarray()
tfidfconverter = TfidfTransformer()
X = tfidfconverter.fit_transform(X).toarray()
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
```

Figure 15 - Stop Word Removal Code

Finally, the text was classified using the model.

```
from sklearn.ensemble import RandomForestClassifier
classifier = RandomForestClassifier(n_estimators=100, random_state=0)
classifier.fit(X_train, y_train)
```

Figure 16 - Text Analysis Model 1

```
lr=LogisticRegression(max_iter=1000, multi_class='multinomial')
lem=lr.fit(X_train, y_train)
```

Figure 17 - Text Analysis Model 2

```
from vaderSentiment.vaderSentiment import SentimentIntensityAnalyzer
analyser=SentimentIntensityAnalyzer()
```

Figure 18 - Text Analysis Model 3

4.6 Identifying emotions using the facial expression

This component focuses on detecting any facial expressions that are in the video and if any. Facial expressions are detected by the system will capture this frame using OpenCV.

```
# Function to extract frames
def FrameCapture(path , i):

    cap = cv2.VideoCapture(path)
    count = 0

    paths = 'images/'+str(i)
    # Check whether the specified path exists or not
    isExist = os.path.exists(paths)

    if not isExist:
    # Create a new directory because it does not exist
        os.makedirs(paths)

    while cap.isOpened():
        ret, frame = cap.read()
        if ret:
            # Convert into grayscale
            gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)

            face_cascade = cv2.CascadeClassifier(cv2.data.haarcascades + "haarcascade_frontalface_default.xml")
            # Detect faces
            faces = face_cascade.detectMultiScale(gray, 1.1, 4)
            for (x, y, w, h) in faces:
                cv2.rectangle(frame, (x, y), (x+w, y+h),
                        (0, 0, 255), 2)

                faces = frame[y:y + h, x:x + w]
                cv2.imwrite('images/'+str(i)+'/frame{:d}.jpg'.format(count), faces)

            count += 30 # i.e. at 30 fps, this advances one second
            cap.set(1, count)
        else:
            cap.release()
            break
```

Figure 19 - Facial Emotion Identification Code

After facial expressions are detected and frames are captured these frames will go through a process where the images are cropped and enhanced.

```
def trim():
    x = 0
    paths = 'images/'+str(x)

    # Check whether the specified path exists or not
    isExist = os.path.exists(paths)

    if not isExist:
    # Create a new directory because it does not exist
        os.makedirs(paths)
    for i in range(0,1000):
        # Read the input image
        img = cv2.imread('images/frame'+str(x)+'.jpg')

        # Convert into grayscale
        gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

        face_cascade = cv2.CascadeClassifier(cv2.data.haarcascades + "haarcascade_frontalface_default.xml")

        # Detect faces
        faces = face_cascade.detectMultiScale(gray, 1.1, 4)
        for (x, y, w, h) in faces:
            cv2.rectangle(img, (x, y), (x+w, y+h),
                          (0, 0, 255), 2)

            faces = img[y:y + h, x:x + w]
            cv2.imshow("face",faces)
            cv2.imwrite('faces/face'+str(x)+'.jpg', faces)

        cv2.imshow('img', img)
        cv2.waitKey()
```

Figure 20 - Frame Trimming Code

Finally, the facial emotion along with its percentage will be identified using the DeepFace library in python.

```
def detect_emotion(img):
    img1 = cv2.imread(img)
    result = DeepFace.analyze(img1 , actions = ['emotion'] , enforce_detection=False)
    # happy = result["happy"]
    # sad = result["sad"]
    # neutral = result["neutral"]

    return result
```

Figure 21 - Facial Emotion Detection Model

According to [18], emotion cannot only be detected using audio speech recognition since the accuracy is comparatively less. The author has discussed that a combination of speech emotion recognition and text analysis along with facial expression analysis helps us to better understand how people feel. Hence a scoring system is introduced in this function to identify the emotions using a combination speech, text and facial expressions.

According to [18] speech emotion recognition (SER) is not the best for emotion recognition alone as the audio tone of a person might not reflect what the person is feeling. Hence a low weightage is given for the emotions identified through speech while a high weightage is given to emotions identified using text. When comparing text and facial expressions more weightage is given to text once again just like with speech the facial expressions may not reflect the real emotion of a person and in addition, some videos might not have a person presenting and, in such instances, facial expressions will not be considered. 70% of the weightage is given to text and 20% and 10% weightage is given to facial expressions and speech respectively. The scoring equation is as follows.

Table 2 - Scoring Equation Guide

Emotion	**Detection Type**		
	SER	**Facial Expression**	**Text Analysis**
Positive	Ps	Pf	Pt
Neutral	Nes	Nef	Net
Negative	Ns	Nf	Nt

$$Positive\ Score = Ps * 0.1 + Pf * 0.2 + Pt * 0.7$$

$$Neutral\ Score = Nes * 0.1 + Nef * 0.2\ Net * 0.7$$

$$Negative\ Score = Ns * 0.1 + Nf * 0.2\ Nt * 0.7$$

```
final_emotion = list()
for i in range(1,len(audio_chunks)+1):
    index = i-1
    pos_aud = 0
    neg_aud = 0
    neu_aud = 0
    if audio_emotions[index] == "positive":
        pos_aud = 0.1
    elif audio_emotions[index] == "negative":
        neg_aud = 0.1
    else:
        neu_aud = 0.1

    positive = (facial_emotions[str(i)][0] * 0.2) + pos_aud + (text_emotions[index][0] * 70)
    negative = (facial_emotions[str(i)][1] * 0.2) + neg_aud + (text_emotions[index][1] * 70)
    neutral = (facial_emotions[str(i)][2] * 0.2) + neu_aud + (text_emotions[index][2] * 70)

    final_emotion.append([positive , negative , neutral])
```

Figure 22 - Final Score Calculation Code

Finally, the emotion with the highest score will be considered as the emotion for the given input.

4.7 Tools and Technologies

Python was mainly used for the development of this system since python provides a variety of libraries which is helpful to achieve the set target.

Libraries used:

- NLTK - NLTK or Natural Language Toolkit provides various libraries that can be used for data preprocessing.

- Scikit-learn - It is an open-source library used for data analysis and is used in most machine learning components for definition of predictive models and modeling to fit the data.

- NumPy - It is an open-source library used for data analysis and is used in most machine learning components for definition of predictive models and modeling to fit the data.

- VADER Sentiment - Valence Aware Dictionary and sEntiment Reasoner or simply VADER is a lexicon and rule-based feeling analysis instrument that is explicitly sensitive to suppositions communicated in web-based media.

- OpenCV - OpenCV is a library of programming functions mainly aimed at real-time computer vision.

- DeepFace - DeepFace is a deep learning facial recognition system created by a research group at Facebook. It identifies human faces in digital images.

- PyDub - PyDub is a Python library to work with only . wav files. By using this library we can play, split, merge, edit our . wav audio files.

- MoviePy - MoviePy is a Python module for video editing, which can be used for basic operations (like cuts, concatenations, title insertions), video compositing (a.k.a. non-linear editing), video processing, or to create advanced effects.

- SpeechRecognition - Library for performing speech recognition, with support for several engines and APIs, online and offline.

4.8 Testing

Testing was mainly conducted in two phases.

1. Testing of sign language conversion
2. Emotion identification

1. Testing of sign language conversion

   After implementation of the text to SSL conversion algorithm it is necessary to check the algorithm for accuracy using various test cases. Below are some text cases conducted to check the accuracy of the text to SSL conversion module of the component.

Table 3 - SSL Conversion Test Case 1

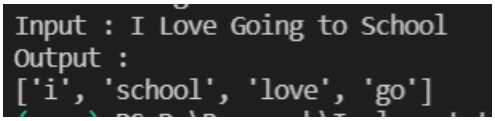
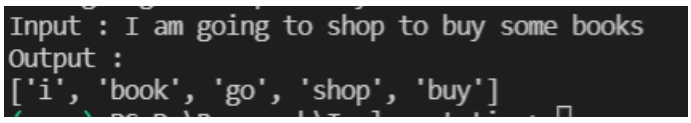
Test Case No	01
Description	Testing text to SSL conversion
Input	I Love Going to School
Expected Output	I school love go
Actual Output	
Result	Pass

Table 4 - SSL Conversion Test Case 2

Test Case No	02
Description	Testing text to SSL conversion
Input	I am going to shop to buy some books
Expected Output	I book go shop buy
Actual Output	
Result	Pass

2. Emotion identification

Table 5 - Emotion Identification Test Case 1

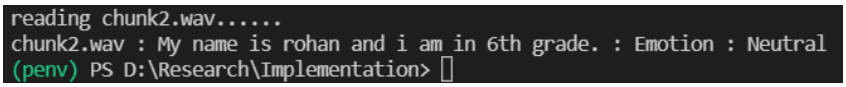
Test Case No	01
Description	Testing Speech emotion recognition
Input	Audio file
Expected Output	Neutral
Actual Output	
Result	Pass

Table 6 - Emotion Identification Test Case 2

Test Case No	02
Description	Testing emotion identification using text
Input	Today i would like to talk about my school.
Expected Output	Positive

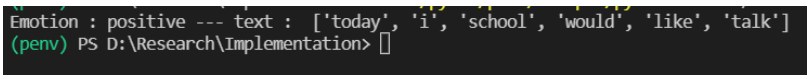
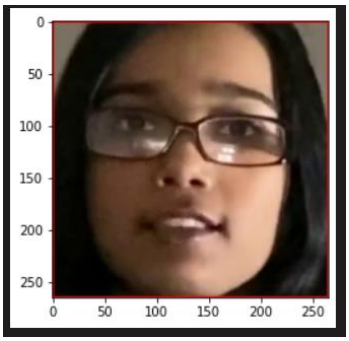
Actual Output	
Result	Pass

Table 7 - Emotion Identification Test Case 3

Test Case No	03
Description	Testing emotion identification using facial expression
Input	
Expected Output	Negative / Sad
Actual Output	{'emotion': {'angry': 12.567758560180664, 'disgust': 0.006765806756448001, 'fear': 4.10250648856163, 'happy': 0.0017589287381269 97, 'sad': 65.91660380363464, 'surprise': 0.008646050264360383, 'neutral': 17.395958304405212}, 'dominant_emotion': 'sad', 'region': {'x': 82, 'y': 44, 'w': 85, 'h': 85}}
Result	Pass

Table 8 - Emotion Identification Test Case 4

Test Case No	04
Description	Testing emotion identification using facial expression
Input	
Expected Output	Neutral
Actual Output	{'emotion': {'angry': 0.00010079641615975008, 'disgust': 1.987996474569762e-11, 'fear': 1.7004362389705323, 'happy': 0.004079599118413724, 'sad': 0.07617791870179288, 'surprise': 1.479451912161822, 'neutral': 96.73975090621417}, 'dominant_emotion': 'neutral', 'region': {'x': 16, 'y': 18, 'w': 235, 'h': 235}}
Result	Pass

4.9 Commercialization

The main reason to implement an online learning platform is to give the hearing-impaired community of Sri Lanka the ability to learn online and experience the advantages of learning online compared to on premise learning. This also gives makes the HI from feeling left out in the society as they also have the opportunity to learn using a learning platform.

The implemented system is a reliable, user friendly and a interactive system with a game based learning feature which attracts the target audience and keeps them interested throughout the learning process. Lack of such systems for the hearing-impaired community of Sri Lanka will influence in making this system a high demand system among the HI. This system will help HI who is fluent in SSL to learn ASL using SSL. This will make this system to target users of any age categories from children to adults irrelevant of their level of knowledge of SSL.

The two premium features of the system being the search module and the SSL captioning module will be of high demand as this will let the HI community to search, enjoy and gain knowledge from videos in SSL without having the need to be relied upon a 3rd party. Also, these two features have the potential to be integrated with other LMS systems that are used by universities and educational institutions on a subscription basis where it would expand their educational services to HI as well.

5. RESULTS AND DISCUSSION

The main idea of this system is to solve the problems faced by HI community in Sri Lanka who doesn't know other dialects of sign language hence have trouble using already implemented systems. This chapter will discuss the results / output for sign language captioning module with the code segment and the output.

5.1 Results

5.1.1 Speech emotion recognition

To identify the emotion using speech four models were tested for accuracy to select the most suitable classification model. These model takes an audio file as input an analyzes the audio file to identify the emotion. The following table shows the different models used and the results of each model.

Table 9 - SER Results

Model	Accuracy	F1 score	Precision	Recall
MLPC	79.03%	0.79	0.80	0.80
Random Forest	68.55%	0.69	0.70	0.70
Decision Tree	70.83%	0.68	0.69	0.69
Logistic Regression	61.8%	0.61	0.61	0.61

The accuracy of the build model was tested using a test set of data and the achieved accuracy was 79.55% with an F1 score of 0.79. Multi-Layer Perceptron Classifier (MLPC) was used for the classification since MLPC had the highest accuracy of the used models.

5.1.2 Text Emotion Analysis

To identify the emotion using text four models were tested for accuracy to select the most suitable classification model. These model takes text as input and preprocess the text and analyzes the to identify the emotion. The following table shows the different models used and the results of each model.

Table 10 - Text Emotion Analysis Results

Model	Accuracy	F1 score
VADER Sentiment	84%	0.84
Random Forest	76.84%	0.73
Multinomial Naïve Bayes	66.33%	0.66
Logistic Regression	70.5%	0.69

The used technology for sentiment analysis was able to predict the emotion with an accuracy of 84% with a F1 score of 0.84. This was higher than the other predicted models hence were selected as the model for text emotion prediction.

5.1.3 Facial expression detection

A deep face library was used for the detection of emotion in facial expressions as this has an accuracy of 97% for the detection of a face and an accuracy of 80% for emotion detection.

The combination of all was tested with a set of video files manually and has an accuracy of 78.9%.

5.2 Research Findings

According to tests done and results achieved it was identified that MLPC was the best model to identify emotion using speech when compared with other machine learning models such as Random Forest and Decision tree. Also, when considering text emotion analysis VADER sentiment proved to be the best solution as it had a high accuracy considering other models. The output of VADER sentiment gave percentage for each emotion which was ideal for this functionality. DeepFace was used for facial emotion detection as it has a accuracy of 80% for emotion detection and 90% accuracy of a face detection. Since all videos does not have faces, this was ideal as if a face was present, it would detect the face and capture the frame using OpenCV. The primary objective of this was to convert content of videos to SSL and caption using SSL along with the identified emotion and this target was achieved successfully.

5.3 Discussion

At the initial stages of development, it was noticed that emotion couldn't be identified only using speech as it was planned. This was mainly since the person who is speaking may have a monotonous tone and hence the content may be positive, but the tone of the voice will get classified as negative due to this. Therefore, after further research it was decided to use a combination of speech, text, and facial expressions for emotion detection.

When comparing with other learning platforms that are developed for HI it was proved that there was no system exists with this functionality and focused on SSL. Therefore, this the accuracies achieved through functionality can be determined to be the best success rate.

5.4 Future Work

Even though we find this research completed, there are expectations and updates for the system. At the moment this system works around English as primary language and in the future the system could be enhanced and updated to work with Sinhala and Tamil as well. Also, currently this system focuses on Sri Lankan HI community hence focused on SSL bit the system has the potential to reach a global audience with addition to chose primary sign language for the user to select.

6. CONCLUSION

The research is objected to address the issues faced by HI in Sri Lanka with respect to learning SSL including limited learning systems for SSL. The research result is the implementation of Learning Platform providing an effective learning experience to learn SSL for the kids/adults with hearing impairments in Sri Lanka. The system is consisted of level-based games and comprehensive evaluation at the end of each level guaranteeing effective learning experience for HI kids. Further, the system is comprised of a sign language capturing module and chat-bot feature to search gain additional knowledge in SSL for HI adults. The system further facilitates SSL to ASL translation filling the gap in learning ASL for the HI in Sri Lanka. It is expected to gain more exposure to Online learning systems and better learning experience by the HI in Sri Lanka with the implementation of this system.

Sign Language capturing module can translate a YouTube video input to SSL, addressing the learning limitations faced by HI in Sri Lanka due to less learning resources. It is also capable of emotion analysis of the video feed. This specific component successfully translates the content of the video to SSL alongside emotion detection to provide the user with a complete experience in sign language.

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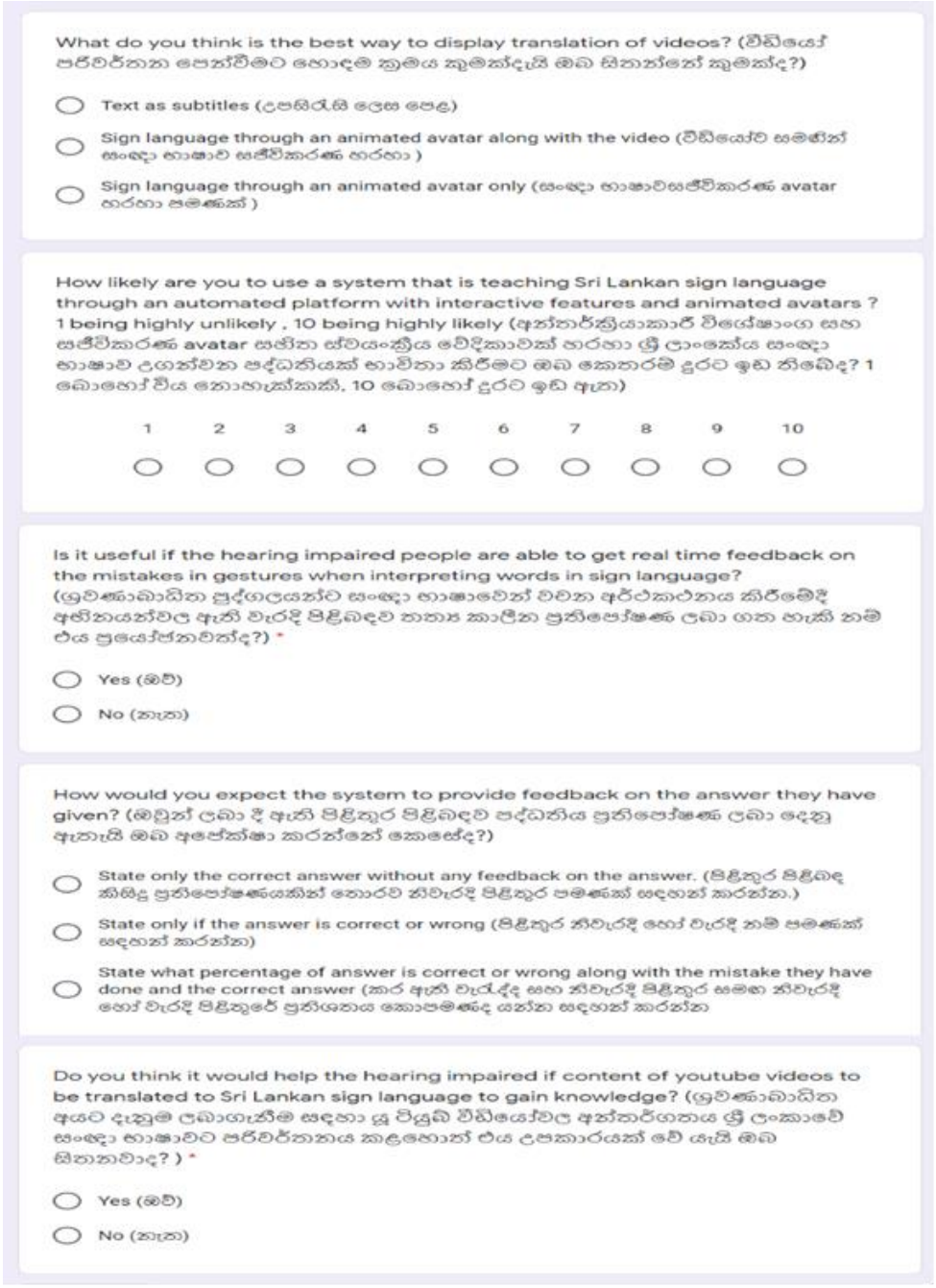
APPENDICES

Appendix A: Survey Questionnaire



What do you think is the best way to display translation of videos? (වීඩියෝ පරිවර්තනය පෙන්වීමට හොඳම ක්‍රමය කුමක්දැයි ඔබ සිතන්නේ කුමක්ද?)

- ◯ Text as subtitles (උපසිරැසි ලෙස පෙළ)
- ◯ Sign language through an animated avatar along with the video (වීඩියෝව සමඟින් සංඥා භාෂාව සජීවීකරණ හරහා)
- ◯ Sign language through an animated avatar only (සංඥා භාෂාවසජීවීකරණ avatar හරහා පමණක්)

How likely are you to use a system that is teaching Sri Lankan sign language through an automated platform with interactive features and animated avatars ? 1 being highly unlikely , 10 being highly likely (අන්තර්ක්‍රියාකාරී විශේෂාංග සහ සජීවීකරණ avatar සහිත ස්වයංක්‍රීය වේදිකාවක් හරහා ශ්‍රී ලාංකේය සංඥා භාෂාව උගන්වන පද්ධතියක් භාවිතා කිරීමට ඔබ කෙතරම් දුරට ඉඩ තිබේද? 1 බොහෝ විය නොහැක්කක්, 10 බොහෝ දුරට ඉඩ ඇත)

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Is it useful if the hearing impaired people are able to get real time feedback on the mistakes in gestures when interpreting words in sign language? (ශ්‍රවණාබාධිත පුද්ගලයන්ට සංඥා භාෂාවෙන් වචන අර්ථකථනය කිරීමේදී අභිනයන්වල ඇති වැරදි පිළිබඳව තාත්‍ය කාලීන ප්‍රතිපෝෂණ ලබා ගත හැකි නම් එය ප්‍රයෝජනවත්ද?) *

- ◯ Yes (ඔව්)
- ◯ No (නැත)

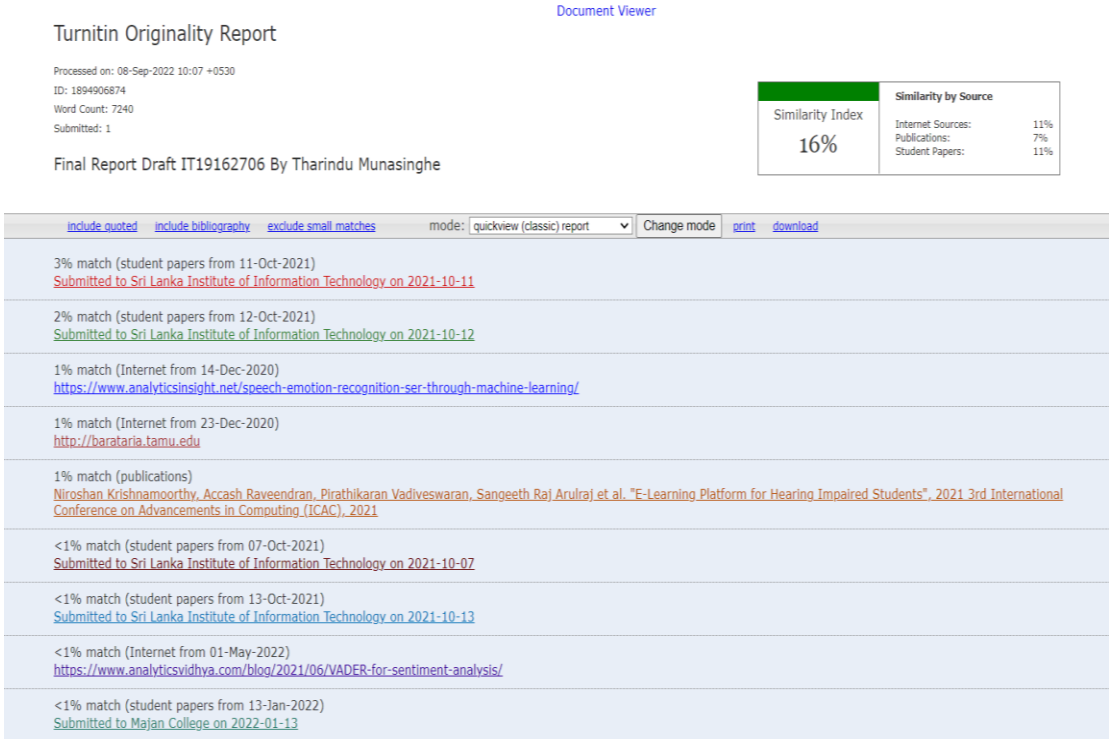
How would you expect the system to provide feedback on the answer they have given? (ඔවුන් ලබා දී ඇති පිළිතුර පිළිබඳව පද්ධතිය ප්‍රතිපෝෂණ ලබා දෙනු ඇතැයි ඔබ අපේක්ෂා කරන්නේ කෙසේද?)

- ◯ State only the correct answer without any feedback on the answer. (පිළිතුර පිළිබඳ කිසිදු ප්‍රතිපෝෂණයකින් තොරව නිවැරදි පිළිතුර පමණක් සඳහන් කරන්න.)
- ◯ State only if the answer is correct or wrong (පිළිතුර නිවැරදි හෝ වැරදි නම් පමණක් සඳහන් කරන්න)
- ◯ State what percentage of answer is correct or wrong along with the mistake they have done and the correct answer (කර ඇති වැරැද්ද සහ නිවැරදි පිළිතුර සමඟ නිවැරදි හෝ වැරදි පිළිතුරේ ප්‍රතිශතය කොපමණද යන්න සඳහන් කරන්න

Do you think it would help the hearing impaired if content of youtube videos to be translated to Sri Lankan sign language to gain knowledge? (ශ්‍රවණාබාධිත අයට දැනුම ලබාගැනීම සඳහා යූ ටියුබ් වීඩියෝවල අන්තර්ගතය ශ්‍රී ලංකාවේ සංඥා භාෂාවට පරිවර්තනය කළහොත් එය උපකාරයක් වේ යැයි ඔබ සිතනවාද?) *

- ◯ Yes (ඔව්)
- ◯ No (නැත)

Appendix B: Plagiarism Report



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