HASTHA: ONLINE LEARNING PLATFORM FOR HEARING IMPAIRED

Project ID: 2022-059

Final Report

Maddugoda C.D – IT19153346

Bachelor of Science (Hons) Degree 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)

…………………………… ……………………….

Signature of the Co-supervisor Date

(Mr. Yashas Mallawarachchi)

ABSTRACT

Numerous game-based online systems are available for kids to learn and gain knowledge and with entertainment. Nevertheless, less attention is traced on game-based learning systems for hearing impaired children to learn Sri Lankan sign language (SSL). Few existing systems are only capable of displaying questions using an avatar in sign language and detecting the sign language answer given by the student. In such systems, users will not be able to know the correctness of the answer. Since sign languages are mostly involved with several gestures it is possible to have partially correct answers and systems developed for sign language do not display where the users got wrong in case of a partially correct answer as in most regular learning platforms. "*Hastha*" attempts to bridge this gap between regular learning platforms and sign language-based learning platforms and provides feedback on the correctness of the answer evaluating correctness of each gesture involved to represent a word in SSL using a comparison algorithm. It also displays the total correct percentage, expected answer and what must be corrected to make learning more effective for the users.

Keywords: Sri Lankan sign language, online learning platform

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LIST OF ABBREVIATIONS

SSL	Sri Lankan Sign Language
HI	Hearing Impaired
ASL	American Sign Language
UNICEF	United Nations Children's Fund
ISL	Indian Sign Language
BISINDO	Indonesian Sign Language
ArSL	Arabic Sign Language
API	Application Program Interfaces

LIST OF APPENDICES

1. INTRODUCTION

1.1 Overall Background

According to the ministry of health to [1], it was evidential that 9% of Sri Lankans suffer from some sort of a hearing disorder. Sign Language is the main and official medium of Communication of such hearing-impaired individuals in the world as mentioned in [2]. As per [3] Sign language varies significantly depending on the factors as country, region, and nation. Calling attention to the same reference [3], there exist several sign languages with slightly different regional accents even within the countries where one language is spoken. Similarly, several sign languages with minor variations can be found in Sri Lanka, as per the research[4]. Nevertheless, Sri Lankan Sign language (SSL) can be recognized as an elementary attempt to standardize island wise sign language.

As per the findings of [5] , solid foundation mother tongue helps in improving literacy skills and acquiring academic skills easier than in any other language. Application of this finding to sign language depicts the importance of helping Sri Lankan hearing impaired students to learn SSL. Hence, although there exist few learning systems for ASL and BSL, developing a learning system to learn SSL correctly from ground level lays the foundation to improve skills of Sri Lankan hearing impaired students immensely.

1.2 Importance of online learning in education

A vast number of game-based learning systems and applications are available for kids to learn and improve skills in addition to the knowledge gained from school as can be seen in [6]. Nevertheless, learning platforms available to learn sign language are comparatively limited although they are equally important. Development of learning platform for SSL is paid further less attention [7]. The system developed for one sign language cannot be used by the users who are using another sign language similar to the spoken languages as discussed in [7]. Hence developing a separate learning system for SSL with interactive features is essentially important. The limited number of available learning systems for SSL lacks interactivity as most systems are only capable of teaching and recognizing the gesture and are not able to provide any feedback on the correctness of the answer as can be seen in papers [7] [8] [9]. Mitigating these barriers, developing feedback enabled learning system for SSL would help children with hearing impairments learn sign language interestingly.

1.3 Real-time video capturing methods

Detecting sign language correctly is important in sign language-based learning platforms. Sign language detection can be implemented mainly in two methods

1. Using wearable Armband

2. Using Computer vision

Using wearable armband is a sensor-based approach and Kinect sensor [10] and leap motion controller [11] are being used in implementing sign language detection systems in a sensor-based approach. Image processing is used in computer vision-based approach. However, it is proven wearable armband is comparatively costly [12] as well as inconvenient [13]. Hence the computer vision-based image processing approach is comparatively cheaper and hence affordable. Despite the advantages, the computer vision approach is observed to produce weak results in tricky real-world backgrounds [13].

1.4 Component Overview

Considering the above-mentioned factors, developing an interactive online learning system for Hearing Impaired (HI) in SSL is focused as the end product of the research. Hence, teaching SSL syllabus for kids with hearing impairments as a game in levels and evaluating the child with questions at the end of each level is focused on this research component. The evaluation is conducted by detecting the answer given by the child using the normal camera in the device and comparing the correct answer against the given answer. In case of a partially correct answer, the correct percentage as well as what must be corrected to make the complete answer correct is provided to the user as feedback through a designed gif avatar. This encourages the user to learn SSL with interest and increases user engagement.

2. LITERATURE REVIEW

2.1 Background study

The pandemic situation raised with Covid 19 outbreak has now become new normal and with numerous challenges to daily routine, pandemic created a positive effect towards online education [14]. According to UNICEF [14], most learning systems gradually got transformed into the online mode. Figure 1 shows the statistics for implementation of digital and broadcast learning policies by educational level.

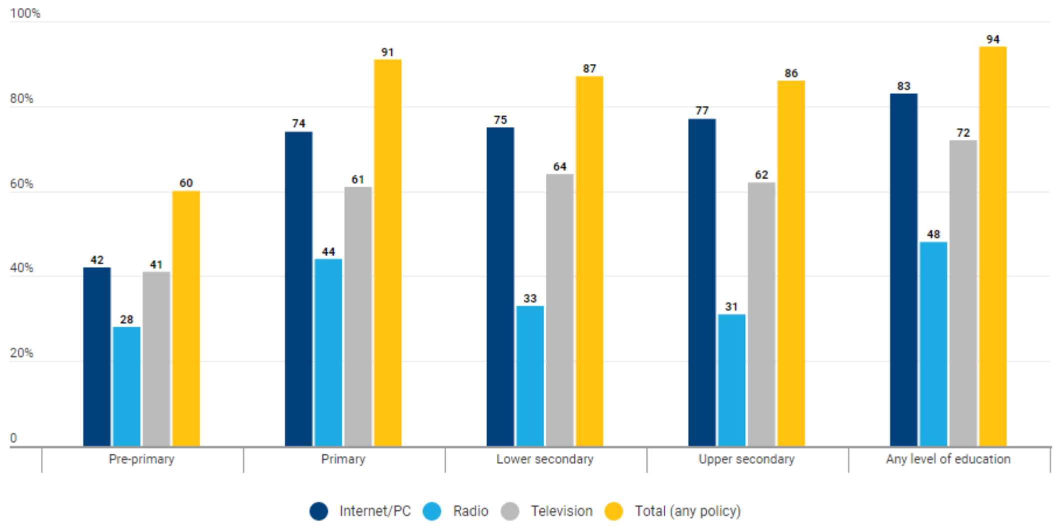

Figure 1 digital and broadcast remote learning policies

Sources: UNESCO-UNICEF-World Bank Survey on National Education Responses to COVID-19 School Closures (2020) and UNICEF country offices (2020).

As per the above statistics, it is evidential that the development of online learning system would not be a waste of effort and same applies for the sign language. The uncertainty of continuous need for online platforms in future can be answered with the survey research statistics conducted by [15] .

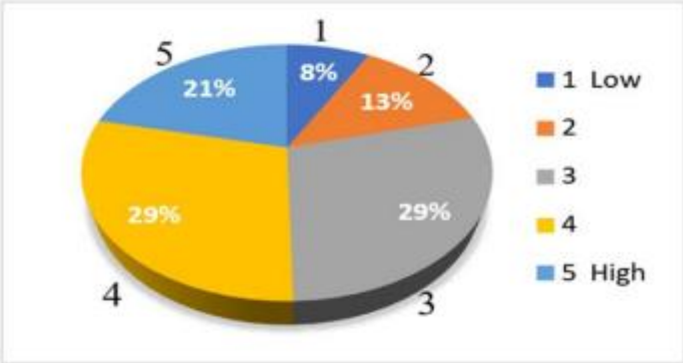

Figure 2 Student's preference for online learning in the future

As per the above survey results [15], students prefer proceeding with online learning for future studies and hence the commercial value for the e-learning system would not be degraded in future and would continue to provide benefits for Sri Lankan hearing impaired students.

In-line with the research results of [4], the game-based learning approach is more efficient in terms of motivation to learn compared to traditional learning mechanisms. Nevertheless, comparatively less focus is subjected to making learning interesting through game-based approach for Sri Lankan sign language. Despite the fact the language is being taught to the students in physical and online environments, less attention is drawn to game-based learning system for Sri Lankan sign language.

Interactivity is a key feature in game-based learning systems. Interactivity is found to boost the interest of the students in learning as per the study of [16]. Hence, encouraging user interaction in online learning system for Sri Lankan sign language is essentially important to uplift the learning interest of hearing-impaired children. System being able to detect if the answer is correct or wrong as well as providing the feedback on the answer if the answer is given by the user is incorrect or partially correct would assist the user interactions in learning Sri Lankan sign language specially since most words in SSL has multiple gestures to interpret a single word as can be found in [4]. This fact can be further clarified with the figures extracted from the source [17]

Figure 3 sign language representation 1

Figure 4 sign language representation 2

2.2 Literature Survey

Learning platform for hearing impaired kindergarten kids has been developed previously for Indonesian sign language with augmented reality in the research [9]. However, this application media was available only in offline mode and hence large RAM capacity and processor speed was required for fast video access. Mitigating this downside, an interactive online learning media for hearing impaired kindergarten children has been developed for Indonesian sign language [18]. Despite the speed access to the resources without requiring higher RAM capacity, this platform has only used flashcards for the teaching component, hence real-time user interaction is observed to be limited.

Static sign language detection mechanism has been implemented for SLSL based on conversational signs in an application called “Wadhan” [19]. In another work [8]Sign language is recognized with template matching technique. In this study gestures are captured by the camera as images and are subjected to feature extraction with analysis, background removal and image smoothing. Then the image is compared against the dataset and the respective sign alphabet symbol is displayed as the final result. Since the work is image based, interactivity in the system is observed to be limited.

An Augmented reality-based system for Arabic sign language focusing on literacy development of hard hearing children is proposed at the conference [20], anyhow the research is still marked as ongoing, hence real implementation of the proposed system is not found to be available online.

According to J.R. Liddell [21], sign language can be described as a combination of three components.

1. Shape of hand
2. Position of hand
3. Movement of hand

Therefore, analysis of the above three components must be conducted in order to provide accurate feedback to the user. Considering these three factors to provide feedback, an interactive system to teach Irish sign language has been developed according to the research paper [22], Signs are demonstrated to the user using a virtual teacher and real-time feedback on the sign is given to the user evaluating user performance using colored gloves. The system is available as software.

In [23], an online learning platform for HI in ASL is developed. The teaching component in this platform is based on uploaded videos for teaching, and the platform can capture low light videos and enhance them using low light enhancement strategies. This enhancement is approached by converting the video to grey scale from RGB.

Background removal and feature extraction methodologies have been followed in order to achieve the best results in capturing. The system is objected to teach basics of ASL such as ASL alphabet. Upon completion of each lesson, the user is asked to repeat the lesson as displayed in the tutorial and depending on the correctness of the answer, the user will be asked to repeat the task or will be given a new task. However, the user will not be given any feedback on the fault part in the answer in this approach.

3. RESEARCH GAP

As per the above literature survey, it can be observed that most learning platforms developed for sign language are not based on SLSL. Although comprehensive research studies have been conducted in research [10] [18] [20] [23] , they were not based on SSL. As discussed in the background study, sign languages are different from one language to another like spoken languages. Hence SSL is different from ASL, ISL, ArSL, BISINDO and other sign languages and there exists a gap in implementing the advanced features in learning platforms for SSL.

Although the application “Wadhan” in the research [19] is based on SLSL, the system is limited to static sign language detection based on images. Since interactivity is a key feature in teaching sign language as discussed above, implementation of dynamic capturing is important.

In the study [23], an online learning system with dynamic capturing through visual computing is implemented. However, this application has been developed for ASL and although there exists a teaching component, knowledge evaluation to check if the user has learnt properly is not implemented in this system.

In the work of [22] , feedback enabled learning system is implemented for Irish Sign language as discussed in the literature review. Anyhow, the system requires additional colored gloves to be worn in order to detect the symbol. Further, it is not capable of providing feedback on the answer and is only capable of detecting if the answer is correct or wrong. In the case of a partially correct answer, the user will not be educated on where they got wrong and what part of their answer is correct or wrong. Hence correcting the mistake from the user’s side is tedious.

All the above systems are not tallied SSL syllabus. Since the teaching component is mainly based on primary sign language teaching for hearing impaired kids, teaching content properly is important.

Table 1 :Difference between existing studies and the proposed system

Feature / Research	Based on SLSL	dynamic detection of sign language enabled	Detect if the answer given is correct	Provides feedback on the answer	Available online	Exists an avatar with expressive emotions
Research A [7]	✓	✓	✗	✗	✓	✗
Research B [18]	✗	✓	✗	✗	✓	✗
Research C [19]	✓	✗	✗	✗	✓	✗
Research D [22]	✗	✓	✓	✗	✗	✗
Research E [23]	✗	✓	✗	✗	✓	✗
Proposed system	✓	✓	✓	✓	✓	✓

4. RESEARCH PROBLEM

Plenty of online resources including learning platforms are available for kids to learn spoken languages. However, availability of online resources for sign language, specifically SSL, is limited as discussed above. Correcting mistakes is a key area in learning [24]. Unfortunately, out of the limited number of available learning platforms for SSL, none provides the user with the opportunity of knowing the mistakes in their answers in sign language as justified in the literature survey. Further, it is possible to have partially correct answers in SSL as it requires a series of gestures to represent one word as explained. Hence in case of the answer being partially correct, the user should be able to know what part of their answer is correct, where they got wrong and what to improve. Considering these factors, developing feedback enabled learning system for SSL starting from basic signs for hearing impaired children is crucial. The survey results as per the survey conducted by the research team confirm this request, as can be seen in figure 5.

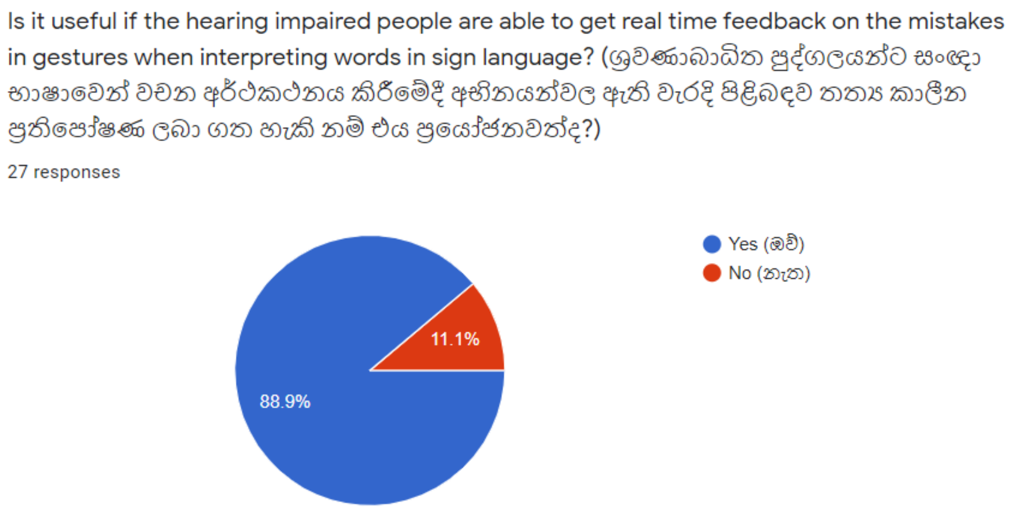

Figure 5 Response-real-time feedback on mistakes

As per the above survey results, more than 89% have stated that it is useful if the hearing-impaired people are able to receive real time feedback on their mistakes in the gestures when interpreting words in sign language. Hence this requirement will be addressed through research.

In line with the survey results, it is evidential that most hearing-impaired people expect to state what percentage of their answer is correct or wrong along with the mistake they have done and the correct answer, since more than 77% of the responses have voted for that option. This can be seen in figure 6

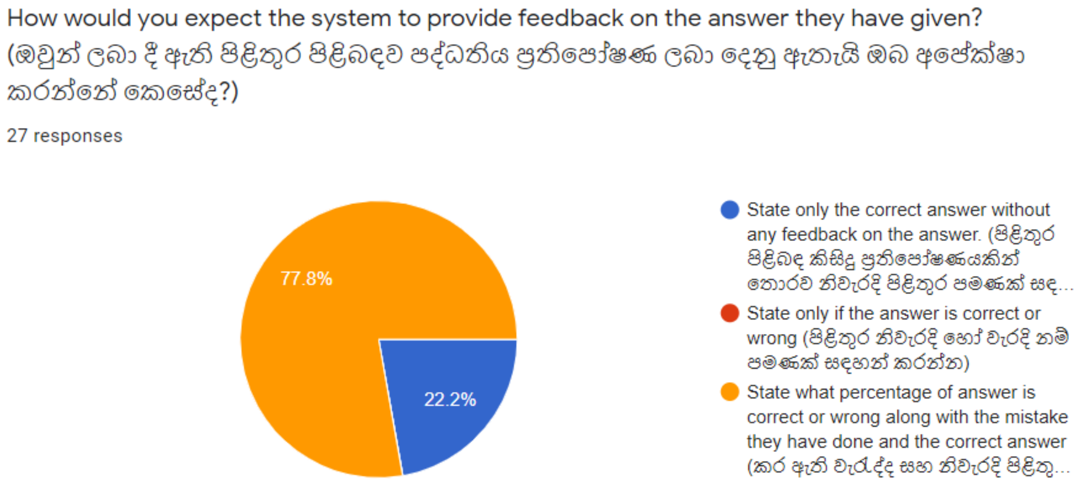

Figure 6 Response-feedback on the answer

Moreover, it is difficult for the teacher to pay individual attention to each student in the physical classroom. Feedback enabled learning systems bring individual attention to each child and hence provide a guaranteed quality education. However, Children learning SSL lacks this opportunity as learning systems with proper feedback is not available for SSL.

5. OBJECTIVES

5.1 Main Objective

The main objective of the research is to develop an interactive learning platform to help learning SSL for hearing impaired children and to guide learning ASL for users who already know SSL in Sri Lanka. The system is expected to provide additional learning recommendations that will be provided to outside videos by converting them into SSL as well as to clear user doubts with an interactive Chabot.

5.2 Specific Objective

The objective of teaching SSL and evaluation is to provide a game-based teaching component with evaluations at each level to check if the user has grabbed the content as expected.

The sub objectives below are accomplished in achieving the specified objective.

- **Clearly Teach sign language**

  One objective is to teach SSL to children with hearing impairments in an interesting way as a level-based game, using the gif avatar model. The content in the game is tallied to SSL syllabus and hence the HI kids get a chance to learn the SSL content interestingly

- **Identify sign language Answer to the quiz question**

  The level-based game consists of a quiz where at the end of each level knowledge evaluation is conducted. One of the objectives is to detect the answer given by the user/ child with higher accuracy in order to provide effective feedback on the answer. This objective is accomplished using the TensorFlow MediaPipe holistic by detecting the correct gesture using the LSTM -trained model.

- **Provide Feedback on the answer**

  One of the important objectives is to compare the answer given by the user/child with the actual answer and provide feedback on what percentage of their answer is correct and what must be improved in order to make the answer completely correct. A comparison algorithm to check the similarity between the given answer and expected answer is built in order to achieve this objective. Attached to this objective, the system encourages children/users to provide completely correct answers by using the gif avatar

6. METHODOLOGY

6.1 Methodology

This component is objected to help HI (specifically hearing-impaired children) in learning SSL. As discussed above this is achieved as a level base game where customized evaluation is carried at the end of each level. The SSL content is taught using the designed avatar. The tedious task here is to provide feedback on the performance of the child against the questions being asked by the avatar at the end of each level in the game. Each answer given is compared with the available answer in the database and the correct percentage is displayed. In case of a partially correct answer, the mismatched section should be conveyed to the user, using the avatar.

6.1.1 System Architecture Diagram

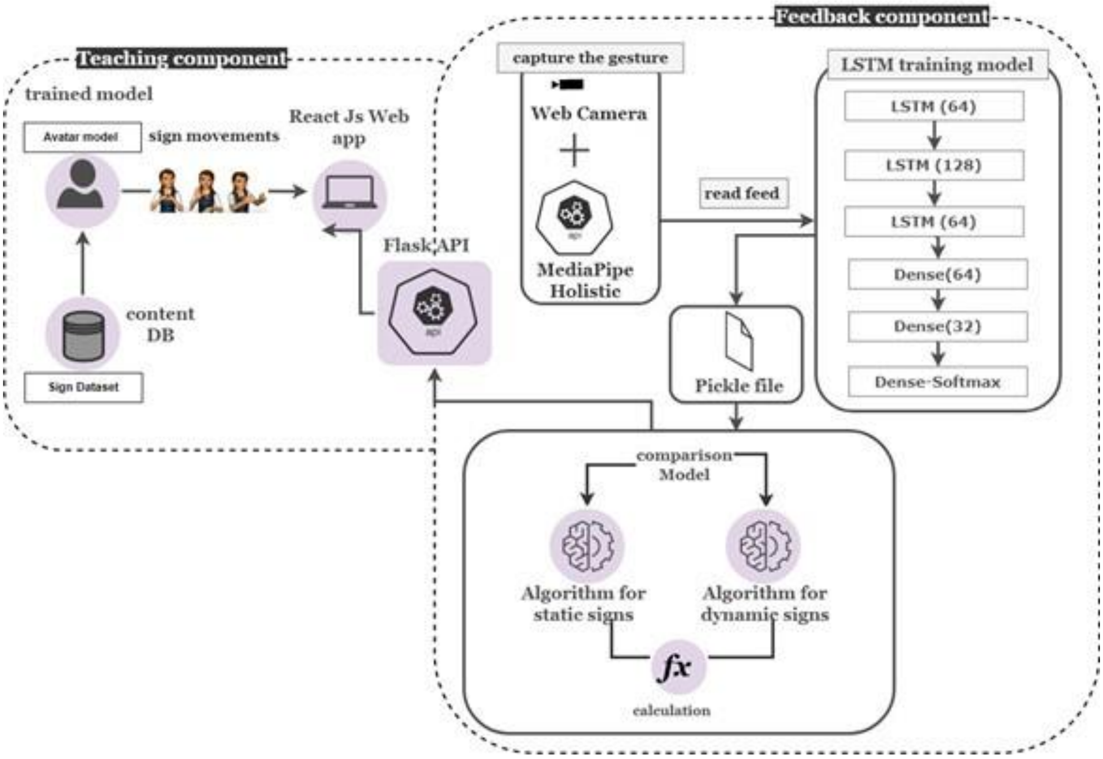

Figure 7 architecture diagram

As demonstrated in the architecture diagram in figure 7, the content stored in the database is taught using gif avatar model. Upon completion of learning users can take quizzes to check their knowledge in SSL. Answers for each question in the quiz are captured using web cam and MediaPipe holistic. The feed is then inserted into the LSTM training model where the model gets trained using 3 LSTM layers and 3 dense layers. The trained model is saved to a pickle file for future reference. Once the answer is detected, it is checked with respect to saved content in pickle file and correctness of the answer is checked using a comparison algorithm. Then the obtained result with evaluation is passed to the frontend through Flask API for the display to the user.

6.1.2 Sign Language Answer Detection

6.1.2.1 Importing Libraries

The following libraries are imported for the below mentioned functionalities.

Tenserflow,opencv	-Access the webcam
Mediapipe holistic	-Extract KeyPoint
NumPy	-To structure the arrays
Sklearn	-For evaluation matrix
Matplotlib	-To make visualization easier

6.1.2.2 Importing Models

The following models in Keras library are imported for the training.

Sequential	-To Build the sequential neural network
LSTM, Dense	- For action detection
Tensor board	-To monitor and trace model

6.1.2.3 Dataset Preparation

The detections are captured using OpenCV library and feed is read as frames. The stacked frames are equivalent to a video feed. Then the holistic model and drawing utilities are defined to make the detections and draw the key points so that the user can observe the detected key points. Landmarks are detected using the drawn key points. Landmarks are represented in terms of below visibility values

1. x: X axis position
2. y: Y axis position
3. z: Relative distance to the camera

flattened array of these x,y,z visibility values are used for KeyPoint extraction.

6.1.2.4 Color Format

The original capture from the camera is in the form of BGR but for mediaPipe holistic the color format of RGB is required hence the color format is converted from BGR to RGB using cvtColor function in OpenCV. After detection, colors are converted back to BGR for display.

6.1.2.5 Landmark Visualization

Landmarks and connections are formatted defining color, thickness, and circle radius for better display of landmarks.

6.1.2.6 Training

Sign Language input is captured using a Media Pipe Holistic and Tenser-flow object detection model. The necessary key points, pose landmarks, and hand landmarks are detected and marked using the media pipe holistic method. Then the detected landmarks are extracted, concatenated, and saved to a NumPy array.

The training of the model is separated into two selections based on below Category.

1. Category 1: SSL words that can be represented using one/few gestures (static and simple dynamic signs)
2. Category 2: SSL words that involve a series of gestures (dynamic signs with multiple gestures)

Category 1:

A group of words in the SSL syllabus are arranged into a single NumPy array, and 40 sequences each of which is 30 frames in length are trained for each word in the array and saved into a NumPy array within a folder. A collection of such folders containing NumPy arrays with frames are saved to another folder. A collection of such sequence folders is saved into another folder (one folder for each word/gesture).

Folder structure used is given below figure 8.

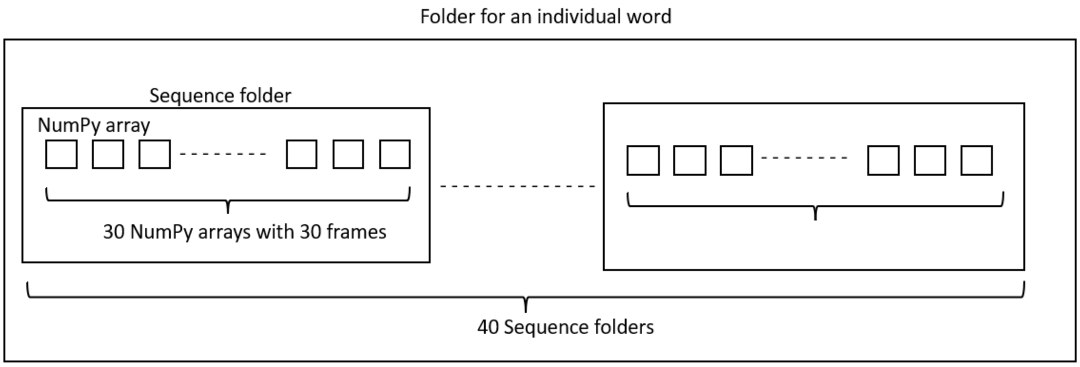

Figure 8 folder structure

Category 2:

Training steps are similar to Criteria 1. However, the NumPy array in these criteria consists of words each of which is involved with several gestures. Hence each word is saved in separate NumPy arrays. The array size is limited to several gestures.

6.1.3. Feedback Generation

Feedback is generated through a comparison algorithm. Once the series of gestures are detected, they get saved to a list in a pickle file for comparison with the expected answer. The saved model with the expected answer is compared with the detected answer saved in the pickle file. The algorithm is designed to vary according to the above-mentioned categories. For category 1, the answers in the two lists are compared element wise and different score counts are given for providing correct answers with a different number of attempts. If the attempts exceed 3, the answer for that specific word is marked as incorrect and the loop is set to break.

The algorithm built for comparison category 2 is designed to evaluate each gesture in one word. Therefore, a score value is not calculated for each element in the array since one element corresponds to a gesture. Nevertheless, each gesture is evaluated separately, and the correctness of the gesture is marked for each word. In the case of a partially correct answer, the sequence of gestures is marked as correct and wrong individually hence the user is able to know which gesture is correct, and which gesture is wrong. Elements in the two arrays are compared using the zip function and if both elements are found to be correct, the gesture gets marked as correct.

The algorithm developed for comparison is shown in figure 9 below.

```
i=[]
j=[]
def arrays_equal(a, b, c):
    for ai, bi in zip(a, b):
        if len(j)>=len(b) or len(i)>=len(a) or c==1:
            print('breaking')
            break

        if a[len(i)]==b[len(j)]:
            print('correct')
            ans.append('correct')
            i.append(1)
            j.append(1)

        else:
            j.append(1)
            print('Try Agian')
            trial=[]
            while a[len(i)]!=b[len(j)]:
                if len(trial)>1:
                    print('Incorrect')
                    ans.append('Incorrect')
                    break
                else:
                    print('Try Agian')
                    trial.append(1)
                    j.append(1)
                    print(a[len(i)],b[len(j)])

            if len(trial)>1:
                if a[len(i)]==b[len(j)]:
                    print('correct')
                    ans.append('correct')
                    i.append(1)
                    j.append(1)
                if len(j)==len(b):
                    c=c+1
                    break
                else:
                    i.append(1)
                    j.append(1)
                    continue

            else:
                if a[len(i)]==b[len(j)]:
                    print('correct')
                    ans.append('correct')
                    i.append(1)
                    j.append(1)

                    if len(j)>=len(b) or len(i)>=len(a):
                        break

    return ans
```

Figure 9 Comparison Algorithm

Correctness of the answer is checked as shown in figure 10.

```python
res=[]
count=0
for i in range(0,len(ans)):
    if ans[i]=='correct':
        count=count+1
        res.append("https://www.antrag-elternzeit.de/wp-content/uploads/cropped-ok-icon-3099.png")
    else:

        res.append("https://th.bing.com/th/id/R.843347e07aa0722c4df7f01fdf031633?rik=qGrd22VbxPIxcw&riu=http%3a%2f%2fpluspng.com%2fimg-png%2fpng

percentage=round((count/len(ans)*100),2)
score=count*5
```

Figure 10 Checking correctness

The respective result is returned to the frontend as shown in figure 11.

```javascript
function Advanced(){

    const [answers, setAnswers] = useState([])

    useEffect(() => {
      const fetchData = async () => {
        const result = await fetch('http://127.0.0.1:5000/advanced')
        const jsonResult = await result.json()

        //setAnswers(jsonResult)
        setAnswers(jsonResult)
      }

      fetchData()
    }, [])
```

Figure 11 Fetch result to the frontend

6.1.4 Tools and Technologies

Technology stack:

- For Object detection -Tensor flow
- For Video processing -OpenCV
- For Version controlling-GIT
- Frontend-HTML, CSS
- API-Flask

Programming Languages:

- Python –libraries: NumPy, sklearn, matplotlib, TensorFlow, cv2

Tools:

- Google Colab
- Cuda Toolkit
- Media pipe

6.2 Commercialization

Online learning platforms for kids are popular around the world for its ability to make learning interesting. Few such popular game-based learning systems are Encarta kids, PBS kids and national geography kids. Despite the high demand, minimal attention is drawn towards game-based learning systems for SSL. Hence our system will be on demand. Even though the child might learn sign language at school, the teacher might not be able to pay attention to the child individually. Therefore, there might be some doubts or misunderstandings in learning. Since *Hastha* monitors each child individually and provides customized feedback, *Hastha* is a particularly useful platform in learning SSL and adding a comprehensive commercial value.

Further, System will be promoted through welfare organizations as feedback enabled learning system is still not available. Despite the unavailability, the system will be useful in learning SSL from the beginning.

7. Testing and Implementation

7.1 Implementation

The model is separated into training and testing sets and looped through each frame in sequence folder and then 40 sequence folders to train each individual word/gesture in the category. Folder structure shown in figure 6.2 is used for this looping. The words/gestures available in the array are mapped to numerical values in order to loop through each word/gesture in the array when training.

Eg:{‘Gesture 1’, ‘Gesture 2’, ‘Gesture 3’}

Gesture 1 → 0

Gesture 2 → 1

Gesture 3 → 2

to_categorical function available in the keras utils is used to convert the initial labels defined by numerical values to a series of numbers into one representation.

Eg:

Array ([[1,0,0], → Gesture 1

[0,1,0], → Gesture 2

[0,0,1]]) → Gesture 3

7.2 Testing

Table 2 :Test Case 1

Test Case No 1		
Description	Check if the testing results are highly accurate as the accuracy score	
Input	Input 1	poses[np.argmax(res[1])] & poses[np.argmax(y_test[1])]
	Input 2	poses[np.argmax(res[1])] & poses[np.argmax(y_test[1])]
	Input 3	poses[np.argmax(res[1])] & poses[np.argmax(y_test[1])]
Expected output	Results should be equal for most cases	
Actual output	Result 1	Twelve & Twelve
	Result 2	Sixteen & Sixteen
	Result 3	Nineteen & Nineteen
Status	Pass	

Table 3 Test Case 2

Test Case No 2	
Description	Check if the input is detected as expected
Input	Spider, Tusker, Crab, Spider, Dog, Crab, Tortice, Fox
Expected output	Spider, Tusker, Crab, Spider, Dog, Crab, Tortice, Fox
Actual Output	PS C:\Users\HP\Documents\Final Year\2022-059> & C:/Users/HP/AppData inal Year/2022-059/frontend/sign-language-learning/src/AnimalAnswer ['spider', 'Tusker', 'crab', 'spider', 'dog', 'crab', 'Tortise', 'f [1, 1, 1, 2, 3, 3]
Status	Pass

Table 4 Test Case 3

Test Case No 3		
Description	Check if the Number of attempts in comparison algorithm is correct	
Input	Spider, Tusker, Crab, Spider, Dog, Crab, Tortice, Fox	
Expected output	Spider	Attempt 1
	Tusker	Attempt 1
	Crab	Attempt 1
	Dog	Attempt 2
	Tortoise	Attempt 3
	Fox	Attempt 3
Actual Output	Use a production WSGI server instead. * Debug mode: on * Running on http://127.0.0.1:5000 (Press CTRL+C to quit) * Restarting with stat ['spider', 'Tusker', 'crab', 'spider', 'dog', 'crab', 'Tortise', 'fox'] [1, 1, 1, 2, 3, 3] * Debugger is active! * Debugger PIN: 293-912-727	
Status	Pass	

Table 5 : Test Case 4

<table>
<tr><td colspan="2">Test Case No 4</td></tr>
<tr><td>Description</td><td>Check if the result is fetched to the API correctly</td></tr>
<tr><td>Input</td><td>Spider, Tusker, Crab, Spider, Dog, Crab, Tortice, Fox</td></tr>
<tr><td>Expected output</td><td>Jason array fetched to the API with correct/wrong indication symbol, answers, attempts and scores</td></tr>
<tr><td>Actual Output</td><td>{
"ans1": "https://www.antrag-elternzeit.de/wp-content/uploads/cropped-ok-ico
"ans2": "https://www.antrag-elternzeit.de/wp-content/uploads/cropped-ok-ico
"ans3": "https://www.antrag-elternzeit.de/wp-content/uploads/cropped-ok-ico
"ans4": "https://www.antrag-elternzeit.de/wp-content/uploads/cropped-ok-ico
"ans5": "https://www.antrag-elternzeit.de/wp-content/uploads/cropped-ok-ico
"ans6": "https://www.antrag-elternzeit.de/wp-content/uploads/cropped-ok-ico
"answers": [
"spider",
"Tusker",
"crab",
"spider",
"dog",
"crab",
"Tortise",
"fox"
],
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"attemp2": 1,
"attemp3": 1,
"attemp4": 2,
"attemp5": 3,
"attemp6": 3,
"score1": 5,
"score2": 5,
"score3": 5,
"score4": 3,
"score5": 1,
"score6": 1,
"totalscore": 6
}</td></tr>
<tr><td>Status</td><td>Pass</td></tr>
</table>

8. RESULTS AND DISCUSSIONS

8.1 Results

Category 1:

The results are captured using the Tensor flow media pipe model. The multi-class classification models are defined level wise and number of words for each level is varied. Accuracy of each model is based on number of input features(classes) and overlap /uniqueness of gestures. The system identifies the gestures with higher testing accuracy if the number of classes/input features are lower and distinguishable.

Category 2:

Each dynamic sign is with involved several numbers of gestures. Hence unlike in category 1, one specific sign is identified as a series of gestures. This is a key consideration when developing the comparison algorithm for evaluation of each gesture involved for a specific sign.

Different Accuracy obtained for Trained models in Category 1 and Category 2 are listed in the below table 6.

Table 6 :Comparison of Accuracies from Category 1 and Category 2

Category	Level	Number of Input Features	Accuracy	F1 Score
1	Animals	6	91.67%	0.9111
	Colours	9	94.44%	0.9404
	Numbers	10	100%	1.0
2	Light Colours	11	95.45%	0.96190
	Dark Colours	11	95.45%	0.96190
	Family Members	3	100	1.0

8.2 Research Findings

According to the Models trained for the SSL game development, it is found that the model accuracies can be increased by the combination of MediaPipe Holistic followed by LTSM layers. Further, higher accuracies can be obtained for with lesser input features hence having higher number of game levels with a smaller number of words per level is the most effective way to follow for any game development using computer vision and model training. The Comparison algorithm developed can be used in similar applications in future.

8.3 Discussion

Keras in TensorFlow is used to build a sequential neural network. The model is trained using 3 sets of LSTM layers followed by 2 dense layers. Relu activation function is used for the training of LSTM layers and first two dense layers and Softmax activation function is used for the training of last dense layer as can be seen in the figure 12.

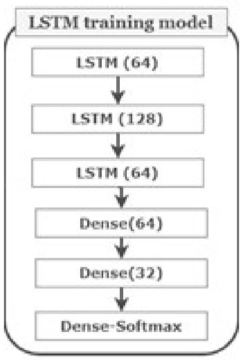

Figure 12 LSTM training model

All the models are trained with satisfactory accuracies as can be seen in table 2. All accuracies obtained are greater than the expected accuracy of 80%. Limiting the number of input variables for each model is the key for obtaining such high accuracies.

Animals (Category 1)

Model for ColorSign is trained with 300 epochs and with a categorical_crossentropy loss of 0.5222 and categorical accuracy of 0.8465.

Layer (type)	Output Shape	Param #
lstm (LSTM)	(None, 30, 64)	82688
lstm_1 (LSTM)	(None, 30, 128)	98816
lstm_2 (LSTM)	(None, 64)	49408
dense (Dense)	(None, 64)	4160
dense_1 (Dense)	(None, 32)	2080
dense_2 (Dense)	(None, 6)	198

Total params: 237,350
Trainable params: 237,350
Non-trainable params: 0

Numbers 1 to 10 (Category 1)

Model for ColorSign is trained with 400 epochs and with a categorical_crossentropy loss of 0.0024 and categorical accuracy of 1.000.

Layer (type)	Output Shape	Param #
lstm (LSTM)	(None, 30, 64)	82688
lstm_1 (LSTM)	(None, 30, 128)	98816
lstm_2 (LSTM)	(None, 64)	49408
dense (Dense)	(None, 64)	4160
dense_1 (Dense)	(None, 32)	2080
dense_2 (Dense)	(None, 10)	330

Total params: 237,482
Trainable params: 237,482
Non-trainable params: 0

Numbers 11 to 20 (Category 1)

Model for ColorSign is trained with 400 epochs and with a categorical_crossentropy loss of 0.0024 and categorical accuracy of 1.000.

Layer (type)	Output Shape	Param #
lstm_3 (LSTM)	(None, 30, 64)	82688
lstm_4 (LSTM)	(None, 30, 128)	98816
lstm_5 (LSTM)	(None, 64)	49408
dense_3 (Dense)	(None, 64)	4160
dense_4 (Dense)	(None, 32)	2080
dense_5 (Dense)	(None, 10)	330

Total params: 237,482

Trainable params: 237,482

Non-trainable params: 0

Simple Color Detection (Category 1)

Model for ColorSign is trained with 500 epochs and with a categorical_crossentropy loss of 0.3808 and categorical accuracy of 0.8626.

Layer (type)	Output Shape	Param #
lstm (LSTM)	(None, 30, 64)	82688
lstm_1 (LSTM)	(None, 30, 128)	98816
lstm_2 (LSTM)	(None, 64)	49408
dense (Dense)	(None, 64)	4160
dense_1 (Dense)	(None, 32)	2080

dense_2 (Dense)	(None, 9)	297

===
Total params: 237,449
Trainable params: 237,449
Non-trainable params: 0

Light and Dark Colour Detection (Category 2)

Model for ColorSign is trained with 400 epochs and with a categorical_crossentropy loss of 0.0153 and categorical accuracy of 0.9952.

Layer (type)	Output Shape	Param #
lstm (LSTM)	(None, 30, 64)	82688
lstm_1 (LSTM)	(None, 30, 128)	98816
lstm_2 (LSTM)	(None, 64)	49408
dense (Dense)	(None, 64)	4160
dense_1 (Dense)	(None, 32)	2080
dense_2 (Dense)	(None, 11)	363

===
Total params: 237,515
Trainable params: 237,515
Non-trainable params: 0

Family Members (Category 2)

Model for Family members is trained with 500 epochs and with a categorical_crossentropy loss of 0.3808 and categorical accuracy of 0.8626.

Layer (type)	Output Shape	Param #
lstm (LSTM)	(None, 30, 64)	82688
lstm_1 (LSTM)	(None, 30, 128)	98816
lstm_2 (LSTM)	(None, 64)	49408
dense (Dense)	(None, 64)	4160
dense_1 (Dense)	(None, 32)	2080
dense_2 (Dense)	(None, 3)	99

Total params: 237,251
Trainable params: 237,251
Non-trainable params: 0

9. 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 solution for the identified issues is implemented through the learning platform "*Hastha*", providing an effective learning experience to learn SSL for the kids/adults with hearing impairments in Sri Lanka. The System consists of a level-based game to learn SSL where the SSL syllabus content is taught effectively using a gif avatar model and content knowledge is checked with quizzes in distinct levels. User's answer for each quiz is detected using computer vision and evaluated using a comparison algorithm. The evaluation is comprised of correctness of each gesture involved in the answer, expected answer and relevant scores for each answer in each level. 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 "*Hastha*".

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LIST OF APPENDICES

Appendix A : Survey Questions

What do you think is the best way to display translation of videos? (වීඩියෝ පරිවර්තන 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 සජීවිකරණ හරහා)
- ◯ Sign language through an animated avatar only (සංඥා භාෂාව සජීවිකරණ 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 සජීවිකරණ avatar සහිත ස්වයංක්‍රීය වේදිකාවක් හරහා ශ්‍රී ලාංකේය සංඥා භාෂාව උගන්වන පද්ධතියක් භාවිතා කිරීමට ඔබ කෙතරම් දුරට ඉඩ තිබේද? 1 බොහෝ විය නොහැක්කකි, 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 තත්‍ය 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)