INETRACTIVE, VISUAL LEARNING-BASED TOOL FOR HEARING IMPAIRED CHILDREN TO IMPROVE LANGUAGE SKILLS

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Dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Hons), Information Technology, Specialization in Software Engineering

Department of Computer Science and Software Engineering

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DECLARATION

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The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

Dr. Janaka Wijekoon

Signature of the supervisor Date

Abstract

According to the World Health Organization (WHO), approximately 466 million people worldwide have disabling hearing loss, which represents about 6.1% of the world population.[1] Among those people, most of the people with hearing impairments can hear after getting an implant or after starting to use a hearing aid. But those people still tend to use sign language for communication because they do not have an improved vocabulary. Vocabulary development is mostly affected in between the age of 3 to 6 years. [2] Which is why a customized tool for hearing impaired people who are recovering is needed.

The aim of this research is to develop a learning tool to provide the ability to use visual based materials from the surrounding environment to improve vocabulary in early ages. CEHIC (Centre for Education of Hearing-Impaired Children) worked in collaboration with us the entire period of the research and the tool is developed under their supervision. Furthermore, this tool has four main areas of development. It will initially discover the level of the student each day when they try to use the application. Then the student can explore what's around the child through the camera, which enables seamless and effective learning experience for the child to interact with his surrounding environment and learn based on them, after that it generate meaningful sentences and phrases from the objects that observed previously and the words they have learnt. Finally, lip reading training which basically involves with training lip movements for the alphabet and that gives visual feedback while monitoring the mouth movements of the

As the Initial Status Determination and Progress Monitoring (ISDPM) component, a quiz river which is dynamically updating is implemented to determine the initial status of the user and a progress map which will show the progress, or the downgrade of the user will be displayed with the intention of presenting the outcome in an interesting method.

Keywords – Visual Based, Learning Tool, WHO, Initial Status

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Table 1: List of Acronyms and Abbreviations

Abbreviation	**Description**
CEHIC	Centre for Education of Hearing-Impaired Children
WHO	World Health Organization
ISDPM	Initial Status Determination and Progress Monitoring
ML	Machine Learning
SVM	Support Vector Machine
dB	Decibel
SL	Sri Lanka
COVID-19	Corona Virus Disease 2019
KNN	K-Nearest Neighbors
SVM	Support Vector Machine
AI	Artificial intelligence

1 INTRODUCTION

1.1 Background & Literature Survey

According to the World Health Organization (WHO), approximately 466 million people worldwide have disabling hearing loss, which represents about 6.1% of the world population.[1] The prevalence of hearing impairment in Sri Lanka is estimated to be around 9.3% of the population.

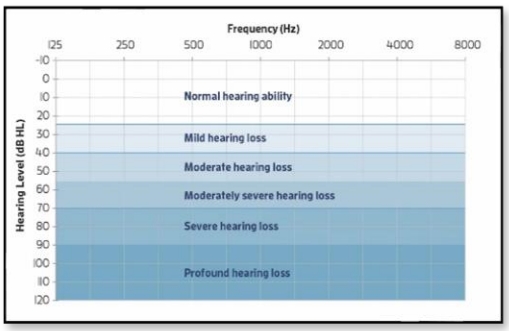


Figure 1 Hearing Loss Measure

A person with normal hearing has a hearing threshold of 0-20 dBs. Mild hearing loss ranges from 20-40 dB, moderate hearing loss ranges from 40-60 dB, severe hearing loss ranges from 60-80 dB, and profound hearing loss ranges from 80 dB or more. The above graph can be useful in understanding the severity of a person's hearing loss based on their audiogram, which is a chart that shows the results of a hearing test. It can also help in selecting appropriate hearing aids or other assistive listening devices for individuals with different levels of hearing loss.

Among the people who are hearing impaired, 91% of the people can hear after getting a cochlear implant or after starting to use a hearing aid.[2] But still 94% of hearing-impaired people still tend to use sign language for communication. Some of the reasons for this are, [3]

- Not having an improved vocabulary to start communicating by speaking. Vocabulary and language development is majorly done during the early ages from 3 to 6 years. If the child missed that period, then it can be difficult for them to start communicating after getting an implant or a hearing aid.

- Communication preferences: Some individuals with hearing impairments may prefer to communicate using sign language even if they are able to hear and understand spoken language with the help of a hearing aid or cochlear implant. Sign language may be their preferred method of communication, and they may feel more comfortable and confident using it. This also occurs depending on the 1st mentioned point.
- Social and cultural identity: For many individuals who are deaf or hard of hearing, sign language is an important part of their social and cultural identity. It may be the primary means of communication within their community, and they may feel a strong sense of connection to others who use sign language. Even if they can hear and understand spoken language with the help of a hearing aid or cochlear implant, they may still choose to use sign language to maintain this connection.
- Limitations of hearing devices: While hearing aids and cochlear implants can be effective in improving hearing and understanding spoken language, they are not perfect solutions. They may not work as well in noisy environments or with certain types of sounds or accents. In these situations, individuals with hearing impairments may find it easier and more effective to use sign language.
- Accessibility: Even with hearing aids or cochlear implants, some individuals with hearing impairments may still experience communication difficulties in certain situations. For example, they may not be able to use their hearing devices in a swimming pool or during sports activities. In these situations, sign language may be the most accessible and effective means of communication.

In contrast to this, most of the children who are considered as “hearing impaired” are not completely deaf. They have mild hearing. [8] And also most of the children who are deaf and the others with some hearing can be treated with hearing aids, cochlear implants, brainstem implants or bone-anchored hearing aids [8][7] By the time these treatments are taken the children are well behind vocabulary wise compared to children who were not having any hearing disability in their early age.[10]

The children who are having hearing impairment are getting used to using sign language as their communication method in this scenario and they get comfortable with it which makes it harder for them to start communicating using words when they get a hearing aid or an implant.

Language development is a key area of child development, and it starts with sounds and gestures at first and then words and sentences will be learnt. [7] Hearing impaired children who have recovered later has completely or partially lost this starting stage. So, the child's ability to communicate is very low and that affects [12]

- Ability to express feelings.
- Ability to understand other people.
- Ability to solve problems.
- Ability to initiate and maintain relationships.

This has a huge negative impact on the cognitive abilities of a child which are memory, reasoning, visualization, and perceptual functioning [19] Early exposure to language sets the foundation for cognitive ability, literacy, school readiness and, ultimately, educational achievements.

There are mainly 5 stages of a child learning language. [11] Those stages are

1. Pre-Production
2. Early Production
3. Speech Emergence
4. Intermediate Fluency
5. Advance Fluency

Pre-Production is the basic level and during that stage the child is mostly silent and listen to others. They are learning word by word and understanding the meanings. [11] In Early Production Stage, the child starts to use the words that they learnt in the preproduction stage. [11] Other stages come next with each stage with more usage of language.

As children who did not have any hearing ability in their early childhood and children who had slight hearing has lost these fundamental stages and they will need to learn new words and improve their vocabulary to develop their cognitive abilities and other related abilities discussed above.

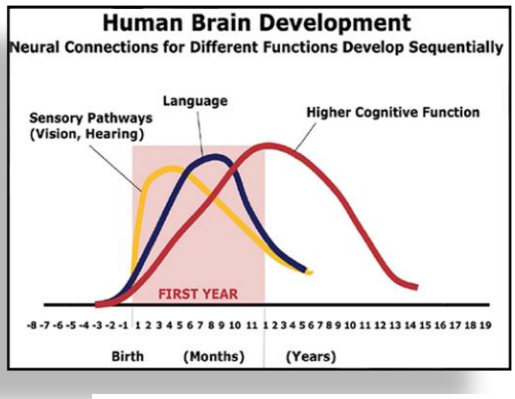


Figure 2 Human Brain Development

It is both the quality and quantity of words a baby hears that brings richness to the child's vocabulary and has a profound impact on his school performance, IQ and life trajectory.

As an example, even though it can be assumed that the children who are having a hearing loss might be having better reading skills as they have vision, that is proved not to be true. Overall, the results in [21] reports that young children who are deaf have inferior reading skills than children with normal hearing group. They were particularly slower and less precise while reading single words and phrases.

Figure 3 Centre for Education of Hearing Impaired Children

CEHIC is an education center which gives primary education to children who used to be hearing impaired and now recovering after using a hearing aid or getting a cochlear implant. It is situated in Dalugama, Kelaniya. This institute mainly focuses on language development of children. This organization was founded by Rev. Sr. Greta Nalawatta. These are the objectives of CEHIC,

2. Early identification of hearing impairments
3. The auditory – verbal method
4. Provide preschool education.
5. Integration of students with mainstream educational system
6. Providing holistic education
7. Involve parents in the training process.
8. Research and development of training materials

Currently all the training sessions are done in CEHIC physically. The parents of the children have to take their child to CEHIC and there they have daily sessions to educate the child. This has been an issue due to many reasons. Some of them are,

- Transportation: One of the biggest challenges of attending classes physically is transportation. Students must commute long distances as students come here from all over the island. They deal with traffic congestion or rely on public transportation that may be unreliable or inaccessible.

- Time constraints: Physical attendance requires students and parents to adjust their schedules to accommodate class times. This has become an issue for parents with other children to take care of and working on jobs.

- Health and safety concerns: In the wake of the COVID-19 pandemic, health and safety concerns have become an increasingly important issue for individuals attending classes physically. It applies to all other diseases which can spread among children and parents.

- Accessibility: Physical attendance is challenging for individuals with disabilities or mobility issues, if they suffer from any other disabilities other than being hearing-impaired.

- Cost: Attending classes physically is more expensive than online learning, particularly if students and parents must pay for transportation, parking, or even housing.

- Distractions: Physical attendance can be distracting, particularly as there are hundreds of students and the classroom environment is noisy or disruptive.

Online learning, also known as e-learning or distance learning, is a form of education where students can access learning materials, participate in virtual discussions, and complete assignments remotely using digital technologies, such as the internet, computers, and mobile devices.

Studies show that 77% of academic leaders believed that online education offerings were just as good, if not better, than classroom-based educational offerings. [16] Recent COVID-19 pandemic also pushed many traditional teaching and learning practices to divert into online learning. [11]

Figure 4 Growth of People using Online Learning Tools

So, the research team of us proposed CEHIC to collaborate with them in research and development of an online tool for the language and vocabulary development of children who require this training.

This proposed tool comes to use in solving all these issues mentioned above. The aim is to improve the vocabulary of the child in their normal surrounding environment while monitoring the child's progress including pronunciation and lip movement. The implemented solution should be a gamified one. Internet computer games are proven to be more attractive in the context of technology enhanced learning, as the attraction of a child can be appealed into a game and if they can also gain rewards that will be more interesting and addictive as well. [4][17] Playfulness is orthogonal to learning theory and the child will be unknowingly adding a lot of words into their vocabulary using the application.

Gamification based approach is used in this. Gamification is the process of incorporating game elements into non-game contexts to enhance user engagement and motivation. It involves using game design principles, mechanics, and concepts to create interactive and immersive experiences in various domains, such as education, health, marketing, and workplace training.

Gamification typically includes features such as points, badges, leaderboards, challenges, and rewards to encourage participation, competition, and progress. By making tasks or activities more interactive, enjoyable, and rewarding, gamification aims to motivate users to achieve their goals and improve their performance.

There are many benefits of using gamification in e-learning such as,

- Increased sales effectiveness
- Product Training
- Increased learner engagement
- Increased learner retention
- Provides instant feedback
- Allows to fail and learn

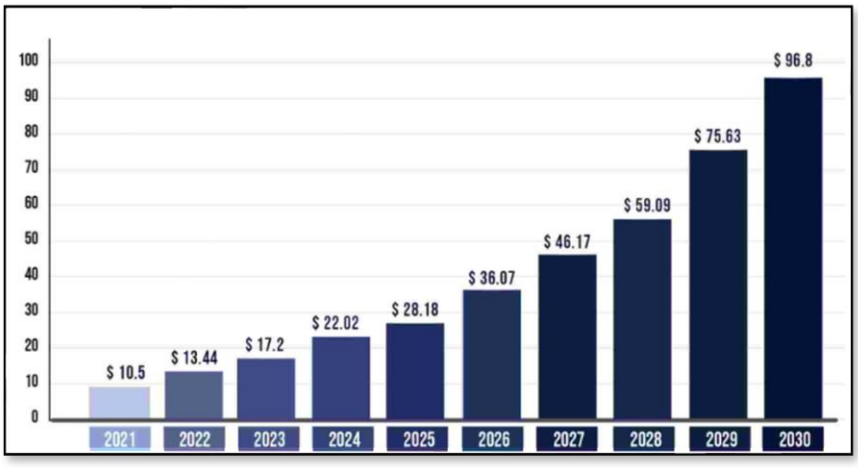


Figure 5 Gamification Market Size -2021 (USD Billion)

As an important step of the is beneficial to detect the progress of the child and reward them according to their performance. This increases motivation because by receiving regular feedback and rewards for their progress, children are more likely to be motivated to continue working towards their goals. And it improves self-esteem because positive reinforcement can help children develop a sense of accomplishment and improve their self-esteem. This can be particularly important for children who may struggle with low self-confidence or self-doubt. In addition to those, it provides greater engagement by providing regular feedback and rewards and this will make children more likely to remain engaged and invested in learning through the tool. This also helps parents to get to know whether their child is making any progress or not. [20]

1.2 Research Gap

When the child opens the application first, the system will figure out the daily initial status of the child. And then the status will be updated according to the usage of the tool and the responses taken by the system in learning procedures.

Research A states a system where reinforcement learning will be used to develop an adaptive learning system which has initial state determination based on static and dynamic factors and then recommending a learning material or path. Then a reward for the action of the user will be given. This is not taken analyzing any factor and it just directly takes a satisfaction level from the user.[2]

Research B states a solution where a student's progress being determined using the accuracy rate of the answers given by a student.[20] Gamification and Reward Mechanism are used in here. This is mainly a solution proposed to communicate the progress of the child with their parent or any guardian and. This works as a Daily Behavior Report Card (DBRC). Individualized Education Program is suggested, and the progress of the student will be updated by rewarding positive values and negative values.[22]

As reference applications, "Hopster", "Early Learn" and "ABC Kids" were studied. "Hopster" is a British media service provider aiming preschool aged children. It is available for both Android and iOS users. It works on improving the vocabulary of children and it does not have any reward mechanism. "Early Learn" is an app designed for preschool kids and kindergarten kids. Students can learn alphabet, rhymes, numbers and fruit names using this. The third application referenced was "ABC Kids". This app provides a simple app focusing on teaching the alphabet to children. This plays an audio pronouncing the letter, but it does not have any mechanism to detect the child's pronouncing. Basically, all these does not have any personalized filtering and mainly focused on teaching alphabet and introducing new words to children.

Table 2 Research Gap

Reference	Initial Status Determination	Daily Progress Monitoring	Analyzing Answer Accuracy	Analyzing Difficulty Levels specially for hearing impaired children	Analyze Time Spent for a Quiz
Research A	Yes	No	Yes	No	Yes
Research B	No	Yes	No	No	No
Existing Learning Tools	Yes	Yes	Yes	No	No
Implemented System	Yes	Yes	Yes	Yes	Yes

The implemented system component for initial status determination and progress monitoring (ISDPM) has initial status determination, daily progress monitoring, analyzing difficulty levels of the questions specially under constraints for hearing impaired children who are recovering, analyzing answer accuracy, and analyzing time spent for the quiz. Since there are no tools or enough research done on this same area of study, it can be found beneficial for both research purposes and commercialization purposes as well. CEHIC has collaborated for support and guidance throughout the project to help improve the application and make it unique and advantageous for hearing impaired children who are recovering by trying to expand their vocabulary.

2 RESEARCH PROBLEM

According to the studies reported in [6], [7], [9] a child's language literacy and vocabulary are mostly impacted at their early age. For the children who has weak hearing and children who had to go for cochlear implants and hearing aids must be treated with speech therapy constantly for them to increase their language proficiency and vocabulary to be aligned with children who did not have any hearing disabilities in their early ages. Improving language proficiency not only helps in speaking, reading, and writing, but also helps develop cognitive functionalities as well. [19]

A child's vocabulary and language proficiency depend on many other factors too. Some of them are,

- Age
- Learning Environment
- Relationships with friends and family
- Motivation
- Social and Cultural Factors

Due to all these above factors a child's level of vocabulary can be different even when they are of the same age. That is why a level determination and progress monitoring method need to be there for every child without assuming their vocabulary level to be same depending just on their age.

Determining the initial status (ISD) of a child is important to track the progress of them. And considering as many factors as possible to determine that status can benefit significantly to the accuracy of the identified level. When the quiz is concerned, the quiz should be implemented not as a regular quiz, but a gamified one which grabs attention of little children.[17] This is the first impression of the user about the system and the initial point as everything that will be done after this in the learning process will be using this level to track the progress. The quiz needs to have content that is used in determining the level of a hearing-impaired child rather than it being for normal children who did not grow up with any hearing disability.

The level needs to be determined based on three key factors from identified methodology used in CEHIC and Audiology Centers. Those factors are,

- Difficulty level of the question – this is specific for children studying at CEHIC.
- Answer Accuracy
- Time spent to complete the quiz

Progress monitoring (PM) is where the progression of the user is determined and shown to the user using a reward mechanism. Furthermore, because the user in this scenario is a child, it would be efficient if the progress is shown to the user in a gamified way.[13] This can benefit the whole system as the user begins to be enthusiastic towards using the system with the intention of seeing their progress being shown in the progress map. Different progress levels need to be identified in this by research and shown to the user according to their performance.

There are no reports of a learning tool which determines the level and progress of a child increasing their vocabulary considering all following factors which are mentioned above. Existing tools tend to use answer accuracy using pre-defined materials for every user.

3 OBJECTIVES

The main objective of this solution is to develop a system to help children who are identified as hearing impaired and has a little chance of functioning as normal and children who can hear after adapting hearing aids and implants. The main components include providing the ability to capture objects in the child's surrounding environment and explore them, analyzing lip movement and pronunciation of the child to detect the accuracy, generate meaningful sentences and phrases with the reference of the words learnt by the child and determining the initial status of the student at the beginning and monitor and display the progress of the user with reference to the user interactivity factors.

3.1. Main Objective

The main objective of the ISDPM component is to first determine the initial status of the child when they first visit the application daily. This uses a gamified quiz. After that the system monitors the progress of the child with the previous attempt. After that, it displays the progress of the child using a progress map.

3.2. Specific Objectives

There are four specific sub-objectives that must be reached in order to achieve the overall objective described above.

Implementing a dynamic quiz river

• As the user logs in to the system, a quiz river will be displayed to them in a gamified environment. The quiz will initially have sounds and it will change 3 letter words, 4 letter words, 5 letter words and complex words through the quiz. The students will be provided if their answer is correct or wrong on the spot so they can learn there itself. The pronunciation of the word will be played in the background, and they can also listen to it by replaying.

Determine the Initial Status

• This analyzes the accuracy rate of the answers given by the user in the quiz, the time taken by the user to answer the quiz and the difficulty level of the quiz to determine the initial status of the user.

Detect the Progress of the Learner

• The user's progress will be evaluated based on the performance of the user in the quiz. Each time the quiz is done by the child a level needs to be determined and that level is compared with their previous attempt and the progress is determined by that.

Display the Progress of the User

• A reward mechanism will be used here, and the child's progress will be displayed in an attractive way which will reward starts along the way in a map. The main motive of this part is to encourage the child to gain more stars, which will unknowingly encourage them to learn more words.

4 METHODOLOGY

4.1 Material and Methods

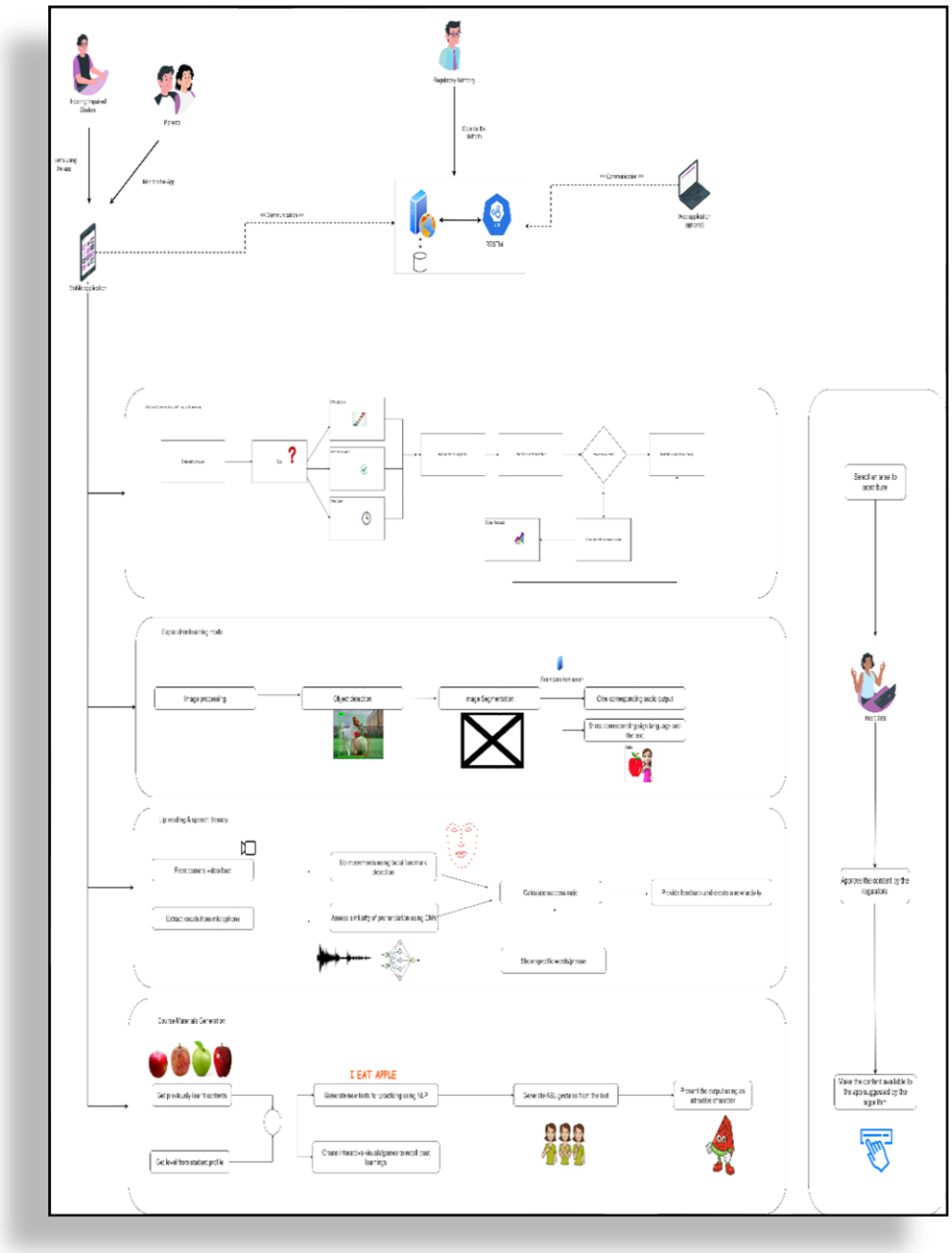


Figure 6 Overall System Diagram

(For a clear overall system diagram: Link)

Figure 6 illustrates the overall system diagram of the proposed solution which was intended to come up with a mobile application for recovering hearing-impaired children to help improve their vocabulary faster. The stakeholders of this system are

children, parents, and supervisors. As shown in the diagram there are four main components of this system.

- Initial Status Determination and Progress Monitoring
- Object Detection and Explorative Learning
- Contextually Similar Word Generation and Content Filtering
- Lip Movement and Voice assisted Feedback Mechanism

Initial Status Determination and Progress Monitoring will determine a level for the user every day when they log into the application and detect the progress of the user. Object Detection and Explorative Learning allows children to explore their surrounding environment using the camera and uses those detected images to teach the child. Contextually Similar Word generation works in generating content like the objects explored by the child and widening the vocabulary. Content Filtration filters and takes only child friendly words. Lip movement and voice-based feedback mechanism works in determining the accuracy of the pronunciation of the word by child using the lip movements and voice.

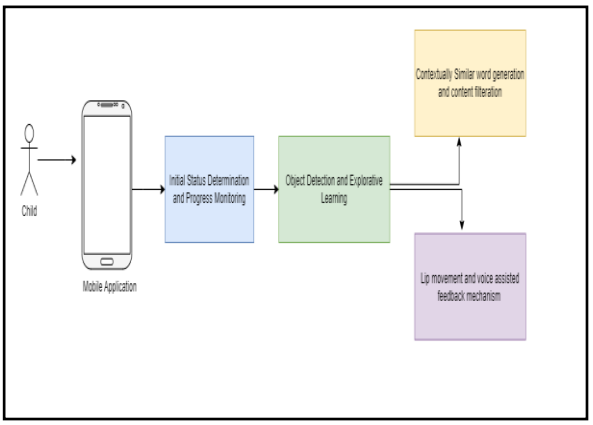


Figure 7 Component Structure

4.1.1 Problem Statement

This research component has two main sub-components. The first one is to implement a quiz river. The quiz river must have content was researched from CEHIC and audiology center. The content should be what is used to evaluate the hearing-impaired children who are recovering during their vocabulary increasing journey. The solution has to be a gamified one as this is used by children between 3 to 6 years.

In addition to that, the quiz river has to play the pronunciation of each word as this is what comes out most beneficial for hearing impaired children. The child should be able to learn on the spot by the quiz for more effective learning. This could be achieved by a quick feedback mechanism. The performance at the quiz should be evaluated based on major factors and the level of the user should be determined using those factors.

As the second part, the user's progress must be evaluated and displayed according to their performance. This has to compare the previous level of the user with the current level. Here too a gamified and attractive user interfaces should be used because this should work as a persuasion for the user to keep using the tool for their vocabulary development.

4.1.2 Component System Architecture

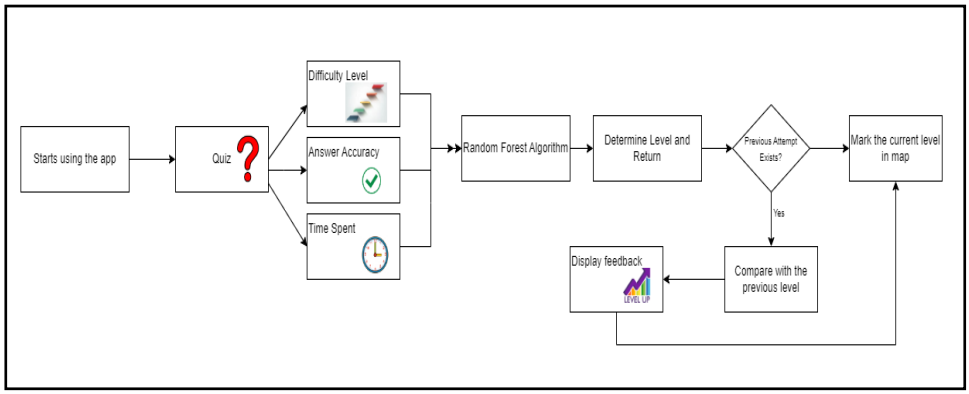


Figure 8 Component Architecture

Figure 8 illustrates the component architecture of the implemented component in simple manner. Initially, the user has to answer a quiz and that quiz will have questions from various difficulty levels identified for these aimed set of children. After the quiz ends the application will take the,

1. Answer Accuracy
2. Difficulty Level
3. Time Spent

And those data will be used in determining the level of the user by the random forest algorithm developed. It is trained using thousands of a dataset and it has to take these 3 inputs and output the level of the user.

After that, the system checks whether there were any previous attempts in this quiz and if there are, then it will be compared with the new level and a comment based on the performance of the user is displayed. After that the current level of the user is updated and displayed in the progress map. If there were no previous attempts, then it will update the progress map with the current level of the user.

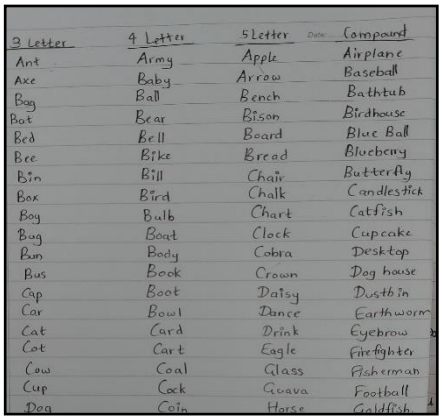
4.1.3 Content Gathering for Quiz River

The first challenge was figuring out how to determine the level of children. CEHIC was consulted for this, and all the group members got the chance to attend a field visit on CEHIC to observe the method of keeping track of levels of children. The method they use to categorize different levels of vocabulary was by the number of letters in a word. As an example,

- Three Letter Words
- Four Letter Words
- Five Letter Words
- Compound Words

This is how the difficulty of vocabulary levels are determined by CEHIC. The main thing that there was to be noticed on the field visit was there were only materials available for children in Sinhala medium. As the implementing tool intend to be able to be used globally as well as in Sri Lanka, the next challenge was to find content in English Medium.

For that an English medium pre-school situated in Rathnapura area was consulted and from them a set of more than 100 content/words for each category could be gathered.



3 Letter	4 Letter	5 Letter	Compound
Ant	Army	Apple	Airplane
Axe	Baby	Arrow	Baseball
Bag	Ball	Bench	Bathtub
Bat	Bear	Bison	Birdhouse
Bed	Bell	Board	Blue Ball
Bee	Bike	Bread	Blueberry
Bin	Bill	Chair	Butterfly
Box	Bird	Chalk	Candlestick
Boy	Bulb	Chart	Catfish
Bug	Boat	Clock	Cupcake
Bun	Body	Cobra	Desktop
Bus	Book	Crown	Dog house
Cap	Boot	Daisy	Dustbin
Car	Bowl	Dance	Earthworm
Cat	Card	Drink	Eyebrow
Cot	Cart	Eagle	Firefighter
Cow	Coal	Glass	Fisherman
Cup	Cock	Guava	Football
Dog	Coin	Horse	Goldfish

Figure 9 Sample of the Content Gathered

Those content needs to be in an appealing way to use in the quiz river. So, then child friendly images were found which were describing each word. After a set of cartoon-like, attractive images were gathered, voice clips of pronouncing of each word were collected in order to play in the background while the question is displayed. For this the voice clips were set to be high in volume and slow in speed to make it easy for children to catch the word.

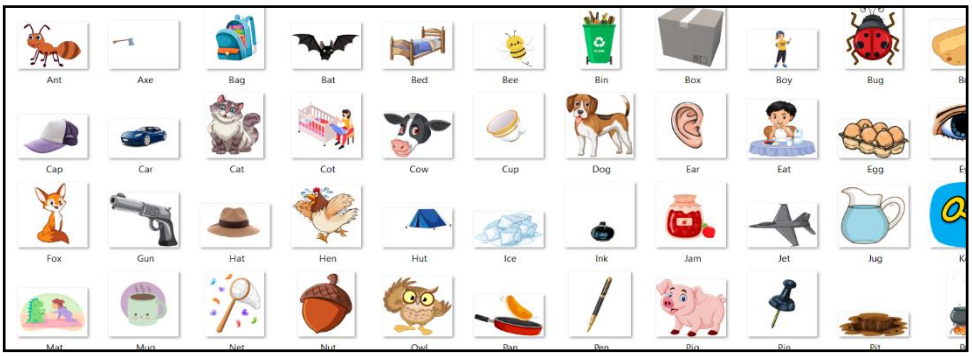


Figure 10 Sample of the image set collected.

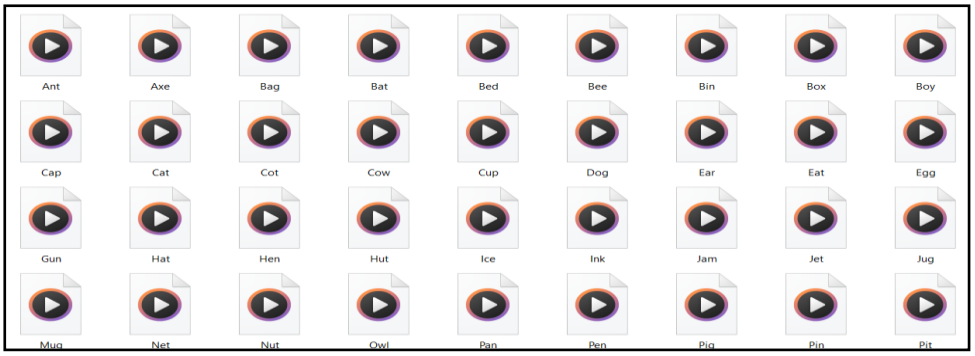


Figure 11 Sample of the voice clip set collected.

When the supervisor was consulted after gathering this content, another suggestion came from his side to add sounds without showing the word in letters as first quarter of questions in the quiz so that it can be used to determine whether the child is able to hear after all. So, that was also finalized to add as a level criterion for the quiz and required sound set and image set was gathered. Some of the example sounds that were added are,

- Sound of a Dog barking / Sound of a Cat meowing
- Sound of a Train moving

4.1.4 Dataset Gathering for Quiz River

After the content was gathered as explained in 4.1.3 the implementation of quiz river was started using unity game developer. Afterwards the dataset creation was started. This process included children who are studying at CEHIC. The quiz river was given to them as testing and as they play it the dataset was gathered. They were allowed to complete the quiz as many times they wanted so that I could gather more data. The quiz is implemented to randomly select words from the given set of words for each category. Therefore, there was no issue of re-doing the same question repeatedly. The children found it interesting to play and this has provided an overview of the user experience as well. Issues with the game were also found in this user testing and they could be addressed early in the development because of that.

The dataset gathered was collected into a csv file and at the end of the dataset gathering a dataset of 1000 records was collected. As I have previously mentioned as well, the factors which are evaluated in the model are answer accuracy, question difficulty and time spent for the quiz. Criteria were introduced for each one of those parameters.

Answer Accuracy: If the question is correctly answered it takes 1 and if the answer is wrong the value will be 0

Question Difficulty: As explained above, there were five difficulty levels of questions identified in the content gathering part. Those were given values according to their complex level and that will be multiplied with answer accuracy value to get the points earned for each question.

- Sounds – 1 point
- 3 Letter Words – 2 points
- 4 Letter Words – 3 points
- 5 Letter Words – 4 points
- Complex/Compound Words – 5 points

Time Spent – A question was given 15 seconds to be answered either correctly or incorrectly and after that the next question is loaded. If the child marks the answer correctly, they will be shifted into the next question without waiting for 15 seconds and if the child answers incorrectly they are given time until 15 seconds to answer the question correctly. Finally, the whole time spent on the quiz is taken and that is what passes as "Time Spent".

The dataset gathered from the children at CEHIC appears like this.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Difficulty Level 1 Question 1	Difficulty Level 1 Question 2	Difficulty Level 1	Difficulty Level 2	Difficulty	Difficulty	Difficulty	Difficulty	Difficulty	Difficulty	Difficulty L	Difficulty	Difficulty	Difficulty	Difficulty	Total Points	Time Spent	Level
0	1	1	2	0	0	3	3	3	4	4	4	0	5	0	30	54	Level 3
1	0	1	0	2	0	3	0	0	0	0	0	0	0	5	12	51	Level 1
0	0	0	0	2	2	3	3	3	0	4	0	0	5	0	22	56	Level 2
0	1	1	2	0	2	0	0	0	4	0	0	5	0	5	20	40	Level 2
0	1	1	2	2	0	0	3	3	4	0	4	5	5	0	30	44	Level 4
1	0	1	2	0	2	0	3	3	0	4	4	5	5	5	35	53	Level 3
0	0	0	0	2	2	0	3	3	0	4	4	5	5	5	33	57	Level 3
1	1	1	0	2	0	3	3	3	0	4	0	5	0	0	23	33	Level 4
0	1	0	0	2	2	3	3	3	0	4	4	5	0	0	27	31	Level 4
0	0	1	0	2	0	0	3	3	4	0	0	5	0	0	18	49	Level 2
1	1	1	0	2	2	3	0	3	0	4	0	5	0	0	22	41	Level 3
1	1	0	0	0	2	3	3	3	4	0	4	0	5	5	31	52	Level 3
1	1	1	0	0	0	0	0	3	0	4	0	5	0	0	15	44	Level 2
1	0	0	0	0	0	0	0	0	4	0	0	0	5	5	15	34	Level 2
1	0	1	0	2	2	0	3	3	0	4	0	0	0	0	16	34	Level 2
1	1	1	0	0	2	0	0	0	4	0	4	0	5	0	18	37	Level 2
1	0	1	2	2	0	0	3	3	0	0	4	5	0	0	21	52	Level 2
1	0	0	0	0	0	0	0	3	4	4	0	0	0	0	12	58	Level 1
1	1	1	0	0	2	0	0	0	4	4	0	5	5	5	28	55	Level 3
0	1	1	2	2	0	3	3	3	0	0	0	5	5	0	25	35	Level 4

Figure 12 Snapshot of the Dataset

The dataset includes points earned for each question in the quiz, Total points earned, Time spent for the quiz and finally the level of that child. CEHIC has categorized children into 4 levels and these data and levels were used to train the model.

4.1.5 Choosing an algorithm to determine the level.

Three algorithms were considered and compared together to come up with an algorithm to develop the model to determine the level of the user/child. Those were,

- Random Forest Algorithm
- KNN: K-Nearest Neighbors
- SVM: Support Vector Machine

Among them, Random Forest algorithm is selected for developing the model to determine the level of the user as it turned out to be the most effective one for the scenario.

As KNN is considered, Random Forest was chosen because it gives better performance on high-dimensional data, ability to handle categorical data, reduced sensitivity to noisy data which can be there because level determination at CEHIC was done manually for a long period of time and faster training time compared to KNN. This is also crucial because in future if there is a need to train the model with another set of datasets to be used at other organizations instead of at CEHIC, then faster training will be advantageous.

As SVM is considered, Random Forest was chosen because it gives better scalability, Ability to handle categorical data and less sensitivity for hyperparameters. Random forest is less sensitive to the choice of hyperparameters than SVM which can be a tedious and time-consuming process.

Random Forest Algorithm is a machine learning technique that is used for classification, regression, and other tasks in which the data is labeled or has a target variable. It is an ensemble learning method that builds a collection of decision trees and combines their predictions to make a final prediction. Each tree in the Random Forest is built using a random subset of the training data and a random subset of the features. This random sampling helps to reduce overfitting and improve the generalization performance of the model.

During training, the Random Forest algorithm generates a large number of decision trees, each of which is grown using a different subset of the training data and features.

The algorithm then combines the predictions of all the trees to produce a final prediction. The final prediction is based on a majority vote in classification problems or an average in regression problems.

Here the algorithm is used for regression. Regression uses one or more independent variables to describe the relationship between a dependent (target) and independent (predictor) variables. More specifically, regression analysis enables us to comprehend how, while other independent variables are held constant, the value of the dependent variable changes in relation to an independent variable. [23]

A model using regression algorithm can be implemented to determine the progress level of the user based on the values retrieved by the factors which are answer accuracy, difficulty level and time spent.

Random forest regression has several hyper-parameters that needs to be set before training the algorithm. Some of the parameters are listed below,

- N_estimator
- Max_depth
- Min_sample_leaf
- Min_samples_split
- Max_features
- Random_state

Among these hyper-parameters, essentially three of the hyper-parameters should be tuned to provide optimal accuracy for the algorithm. The chosen hyper-parameters according to the scenario are,

1. N_estimator : This hyperparameter sets the number of decision trees in the forest. Increasing the number of trees can improve the performance of the model
2. Max_depth: This hyperparameter sets the maximum depth of the decision trees. A deeper tree can capture more complex relationships in the data
3. Min_sample_leaf: This hyperparameter sets the minimum number of samples required to be at a leaf node. A higher value can prevent the algorithm from overfitting the data.

4.2. Implementation

4.2.1 Quiz River Implementation

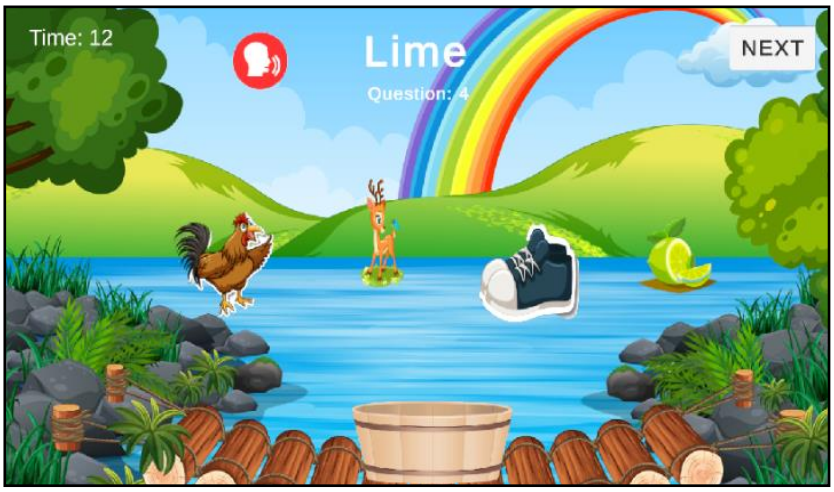


Figure 13 Quiz River UI

Quiz River User Interface for one question appears like this. If the basic functionality is explained, a word is displayed at the top of the interface and the question number is mentioned below that word. The total number of questions in a quiz is fifteen. As soon as a question loads, a timer will start to countdown from fifteen seconds to zero. Once the timer exceeds fifteen minutes, the next question is loaded. A voice clip pronouncing the word that is displayed will be played in the background with the loaded word. The child can listen to the pronunciation again and again by tapping on the red human-voice symbol next to the word. The child can decide to go to the next question before the fifteen seconds are exceeded by tapping on the next button.

The child has to drag and drop the correct image into the basket at the bottom of the interface in order to select the answer. If the answer is incorrect, an error message will be displayed stating that the answer is wrong and asking the child to try again. They can answer the question until fifteen seconds are over. If the answer is correct, a success message will be displayed stating that the answer is correct, and the next question will be loaded.

Some of the important code snippets are added below.

- Creating scriptable objects for each set of words, voice clips and images.

```
[CreateAssetMenu(fileName = "ImageAndNameData", menuName = "ScriptableObjects/ImageAndNameData")]
public class ImageAndNameData : ScriptableObject {

    public ImageAndName[] mImageAndNameDataSet;

}

[Serializable]
public class ImageAndName {
    public string mName;
    public Sprite mImage;
    public AudioClip mAudioClip;
}
```

Figure 14 Scriptable Object Creation

A Scriptable Object is a type of asset in Unity that allows storing data as an asset in the project. It's essentially a serialized class that can be saved as a file and reused in different parts the game.

Scriptable Objects are commonly used in Unity to create reusable, data-driven assets that can be edited outside of the game engine. For example, in here a Scriptable Object that stores information about different types of words in the game, including image, voice clip, and name then creates instances of this Scriptable Object for each word type, and use these instances to configure word's behavior in the game.

- Randomly select a word within the current difficulty level

```
for (int i = 0; i < DragObjects.Length; i++) {

    int ranDataIndex;

    do {
        ranDataIndex = UnityEngine.Random.Range(0, ImageAndNameData[(int)currentLevel].mImageAndNameDataSet.Length);
    } while (selectedIndexs.Contains(ranDataIndex) || askedQuesIndexsInThisLevel.Contains(ranDataIndex));

    selectedIndexs.Add(ranDataIndex);


    DragObjects[i].GetComponent<Image>().sprite = ImageAndNameData[(int)currentLevel].mImageAndNameDataSet[ranDataIndex].mImage;

    DragObjects[i].transform.localPosition = DragObjects[i].GetComponent<DragObject>().defaultPosition;

    if (i == correctObject) {
        DragObjects[i].GetComponent<DragObject>().isCorrectObject = true;
        TargetName.text = ImageAndNameData[(int)currentLevel].mImageAndNameDataSet[ranDataIndex].mName;
        TargetAudioSource.clip = ImageAndNameData[(int)currentLevel].mImageAndNameDataSet[ranDataIndex].mAudioClip;
        askedQuesIndexsInThisLevel.Add(ranDataIndex); ;
        TargetAudioSource.Play();
    } else {
        DragObjects[i].GetComponent<DragObject>().isCorrectObject = false;
    }
}
```

Figure 15 Randomly selecting and setting correct object

4.2.2. Progress Map Implementation

Figure 16 Progress map

Progress map has four levels for the four levels of vocabulary levels. The level of the child according to their most recent attempt is marked in the map.

The level from the previous attempt of the use is compared with the level from the current attempt and a comment message is displayed at the top of the interface accordingly. Below table shows how it will be displayed.

Table 3 How progress is displayed by comments.

	Level 1	Level 2	Level 3	Level 4
Level 1	Same Level	1 Level Down	2 Levels Down	Bad
Level 2	1 Level Up	Same Level	1 Level Down	2 Levels Down
Level 3	2 Levels Up	1 Level Up	Same Level	1 Level Down
Level 4	Great	2 Levels Up	1 Level Up	Same Level

If it is the first-time user is doing the quiz, then no comment message will be displayed and just the map will be updated to the current level.

4.2.3 Model Implementation

The model using Random Forest Algorithm is implemented to determine the level of the user.

In random forest regression, a correlation matrix is a table that displays the correlation coefficients between a set of variables. The correlation coefficient is a measure of the strength and direction of the linear relationship between two variables. A correlation matrix can help identify the relationships between the input features used in the random forest regression model. By analyzing the correlation matrix, one can determine which input features have a strong correlation with the target variable, and which input features are highly correlated with each other. This can help in feature selection and feature engineering, which are important steps in building an accurate random forest regression model.

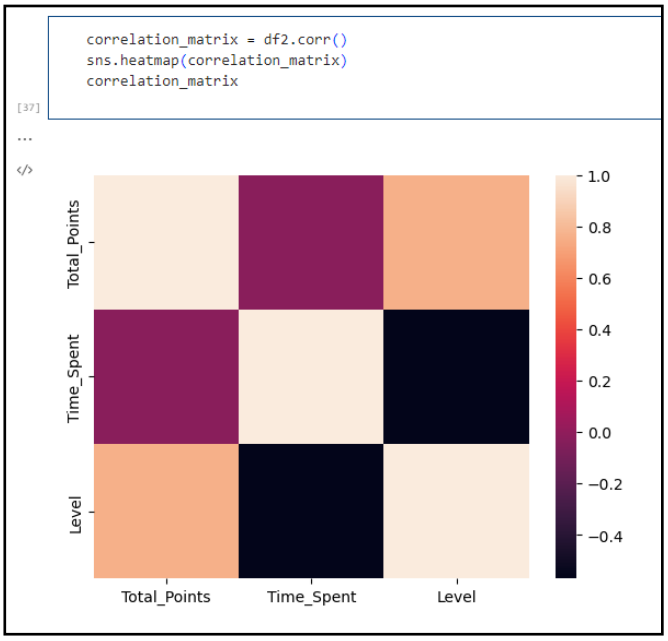


Figure 17 Co-relation matrix generation

Test Train split is a common technique used in machine learning to evaluate the performance of a model. The idea behind test-train split is to split the data set into two parts: the training set and the testing set. The training set is used to train the model, while the testing set is used to evaluate the performance of the model on unseen data.

Typically, a percentage of the data is randomly assigned to the training set, and the remaining data is assigned to the testing set. The ratio of the data assigned to the training set and the testing set can vary, but a common split is to assign 70% of the data to the training set and the remaining 30% to the testing set. This split ensures that the model is not overfitting the training data and can generalize well to unseen data.

After the model is trained on the training set, it is evaluated on the testing set to determine how well it performs on new, unseen data. The performance metrics of the model on the testing set, such as accuracy or mean squared error, can be used to assess the model's performance and make any necessary adjustments.

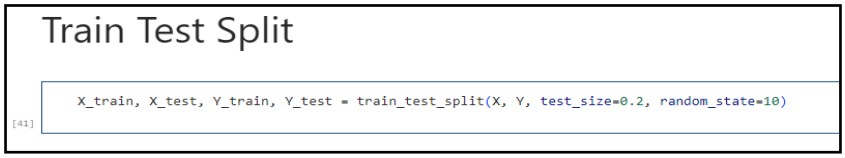


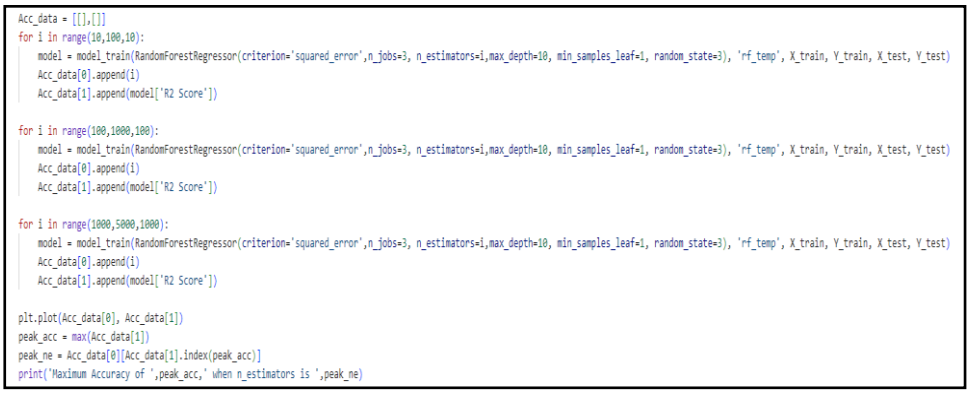
Figure 18 Test Train Split

Hyperparameter tuning is an important step in the process of building machine learning models. Machine learning algorithms often have a set of parameters that need to be set before the algorithm can be applied to a dataset. These parameters are known as hyperparameters, and they can have a significant impact on the performance of the model.

Hyperparameter tuning is the process of finding the optimal set of hyperparameters that maximizes the performance of the model. This involves trying out different values for the hyperparameters and evaluating the performance of the model on a validation set. The goal is to find the set of hyperparameters that produces the best performance on the validation set.

There are various techniques for hyperparameter tuning, including grid search, random search, and Bayesian optimization. Grid search involves trying out all possible combinations of hyperparameters within a specified range. Random search involves randomly sampling hyperparameters from a predefined range. Bayesian optimization uses a probabilistic model to predict the performance of different hyperparameter combinations and selects the best combination based on the predicted performance.

Hyperparameter tuning is an iterative process that involves training and evaluating the model multiple times. It can be computationally expensive, especially for complex models and large datasets. However, finding the optimal set of hyperparameters can significantly improve the performance of the model and lead to better predictions.



```
Acc_data = [[],[]]
for i in range(10,100,10):
    model = model_train(RandomForestRegressor(criterion='squared_error',n_jobs=3, n_estimators=i,max_depth=10, min_samples_leaf=1, random_state=3), 'rf_temp', X_train, Y_train, X_test, Y_test)
    Acc_data[0].append(i)
    Acc_data[1].append(model['R2 Score'])

for i in range(100,1000,100):
    model = model_train(RandomForestRegressor(criterion='squared_error',n_jobs=3, n_estimators=i,max_depth=10, min_samples_leaf=1, random_state=3), 'rf_temp', X_train, Y_train, X_test, Y_test)
    Acc_data[0].append(i)
    Acc_data[1].append(model['R2 Score'])

for i in range(1000,5000,1000):
    model = model_train(RandomForestRegressor(criterion='squared_error',n_jobs=3, n_estimators=i,max_depth=10, min_samples_leaf=1, random_state=3), 'rf_temp', X_train, Y_train, X_test, Y_test)
    Acc_data[0].append(i)
    Acc_data[1].append(model['R2 Score'])

plt.plot(Acc_data[0], Acc_data[1])
peak_acc = max(Acc_data[1])
peak_ne = Acc_data[0][Acc_data[1].index(peak_acc)]
print('Maximum Accuracy of ',peak_acc,' when n_estimators is ',peak_ne)
```

Figure 19 Code Snippet of n_estimator tuning

5 TESTING

Test planning involves creating a plan that outlines the necessary tests to ensure that the software is functioning as intended. This plan serves as a baseline and includes a list of tasks, as well as objectives to track progress. On the other hand, a test strategy is a set of steps and procedures used to regulate the software testing process. It details the different elements and functions to be tested based on the risks they pose to users.

<<to be continued>>

5.1 Test Cases

<<to be added>>

6 RESULTS & DISCUSSION

As a result of this research, the crucial factors for determining a level of a child who is improving their vocabulary are identified. Furthermore, a set of content which can be greatly advantageous in teaching students in English medium was collected.

6.1 Results

The model is implemented to provide 98% of accuracy in predicting the level of the child. There are three hyper-parameters tuned in the model training and those are n_estimator, min_sample_leaf and max_depth.

- N_estimator tuning

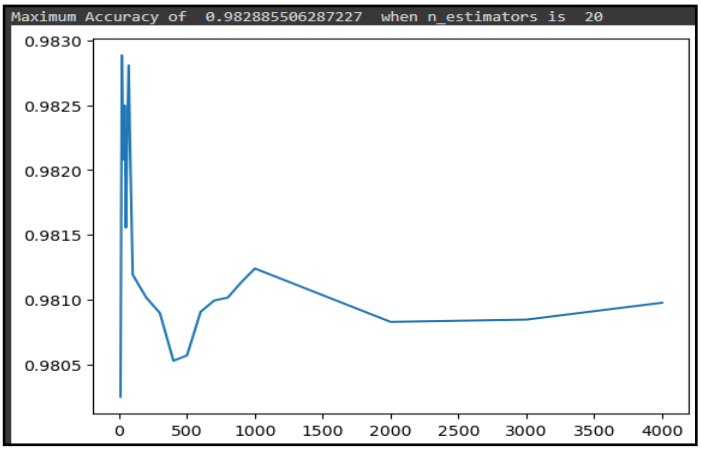


Figure 20 n_estimator tuning

The model gives 98% accuracy when the n_estimator is used as 20.

- Max_depth tuning

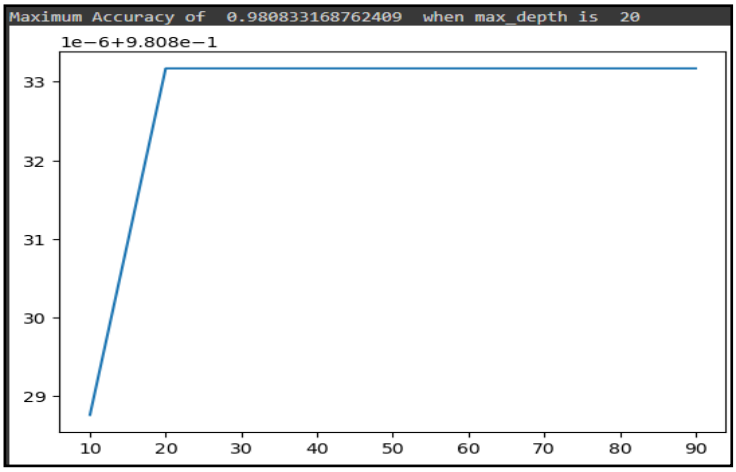


Figure 21 max_depth tuning

The model gives 98% of accuracy when the max_depth hyper-parameter is used as 20

- Min_sample_leaf tuning

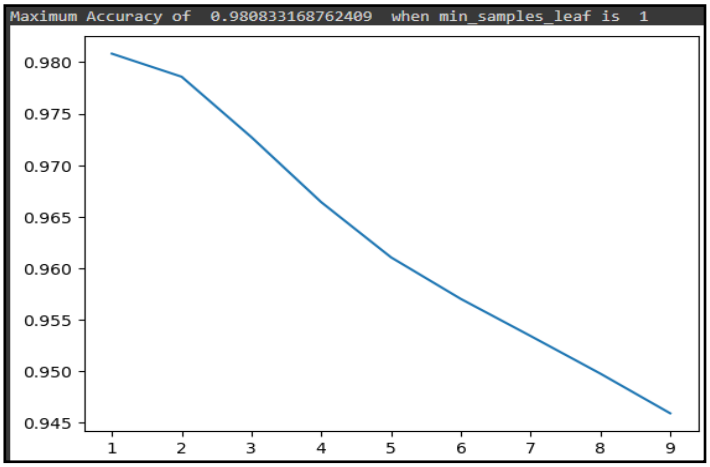


Figure 22 min_sample_leaf tuning

The model gives 98% of accuracy when the min_sample_leaf is used as 1

<<to be continued>>

7 Commercialization

This system is proposed as a solution to the problem which was mainly raised at the visits to the Ratmalana Audiology Center and Deaf Student's school on our field visit. Once developed, the application can be introduced to the doctors and speech therapists at Ratmalana audiology center and teachers at island wide deaf schools. Then the system can be recommended by them to be used by children. Then children who are identified as hearing impaired and has a little chance of functioning as normal and children who can hear after adapting hearing aids and implants can use this system to improve their language proficiency. The systems come in two versions.

• Free version will determine the initial status of the user and track the progress and then show it in a map.

• The premium version will show the progress map for pronunciation and lip movements separately and it will suggest online tutorials to improve their pronunciation and lip movements according to their weak areas. This feature will be added as a future implementation.

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APPENDIX A: TITLE (Example: SUERVEY RESULTS)

APPENDIX B: TITLE (Example: WORKBREAKDOWN CHART)

APPENDIX C: TITLE (Example: GANTT CHART)

APPENDIX D: TITLE (Example: PLAGIARISM REPORT)