SPEAKUP, MOBILE APPLICATION TO TRAIN AND OVERCOMING STUTTERING

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DECLARATION

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ABSTRACT

SpeakUp, mobile application will help users who are affected by stuttering to train themselves by following various methodologies customized for their level and type of stuttering and help them become better communicators. Stuttering is a speech disorder that repeats or prolongs sounds, syllables, phrases or words, disrupting the normal flow of speech in human beings. The purpose of the report is to put forward a solution to overcome stuttering by an acceptable level. This research project is about a hybrid mobile application called “SpeakUp” which will help users who are affected by stuttering to train themselves by following various methodologies customized for their level and type of stuttering. The mobile application will allow users to assist them and train themselves from stuttering by an acceptable level and help them become better communicators. The main research area contains about the syllable counter module which acts a key component for both the methodologies to detect the syllables and severity of the user. This component is built in a reusable plugin way for both native and hybrid development as this will be the main source for any stuttering curing methodology. One of the major challenges of the application will be to identify what the user is speaking to the application as a voice input. Speech to text conversion module focuses on identifying what the users has spoken using a defined language model by an open source framework. This allows calculating the accuracy of the voice provided by the users with the given paragraph. Slowed reading module allows the users to practice the methodology of speaking in a slower rate to improve their ability to speak clearly. The research component of the project focuses on identifying the level and severity of stuttering of the user and also studying the traditional methodologies “Slowed Reading” and “Easy Onset” with the help of a SLP and providing a methodology to develop it inside the mobile application. Research also focuses on identifying a best optimized methodology to get the users voice input and convert it to respective text. The main high-level object of the research is to come up with a syllable counter module to provide an application with acceptable level of improvement from stuttering. The application is a pocket guide for people who stutter and are looking ways to improve their speaking abilities to become better communicators.

Key words: Stuttering, Stammering, Speech to text analysis, Speech language pathologists

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LIST OF ABBREVIATIONS

GB	Gigabyte
MB	Megabyte
MHz	Megahertz
RAM	Random Access Memory
SLP	Speech Language Pathologists
PwS	People who stutter

1 INTRODUCTION

SpeakUp, hybrid mobile application will be useful for the people who stutter. The mobile application is designed to improve the user from stuttering by providing the user with various exercises process such as improving the rate of syllable, slow reading which would otherwise be performed by the therapist manually. The mobile application meets user requirements by providing the exercises and maximizes the chance to improve stuttering while remaining easy to understand and use. More specifically, this application is designed to enable the user to communicate with the application and to go through the mobile application training materials. Interfaces are designed after a research study on usability to provide a wide variety of users with the optimal screens to achieve their requirements. Research study was mainly focussed and carried out with the Syllable counter module which acts as a core reusable component of the application.

This application helps users who are affected by stuttering to train themselves by following various methodologies customized for their level of stuttering and help them become better communicators. The objective will be to put forward a solution with a proper research proof to improve the stuttering by an acceptable level. Methodologies to improve stuttering and treatments were studied. There is no single root cause factor for stuttering to identify and rectify it. Research shows there are multiple factors that contribute for stuttering. Some stutterers are always unable to get professional assistance. Some people prefer to be their own therapists. The mobile application allows users to assist them and train themselves from stuttering by an acceptable level. The reusable output component of this particular research contains a unit to allow users to speak and identify their severity and stuttering level with the variables collected from the users' voice. Since this is built in a hybrid application it can support both Android and iOS mobile development to target a large user base.

1.1 BACKGROUND

Stuttering is also known as stammering, it is a disorder in speech flow where disruptions are caused by involuntary repetitions and prolongations of sounds, syllables, words or phrases. It also consists of silent pauses or disruptions in producing sound output. There are mainly two types of Stuttering, Developmental stuttering occurs in young kids while still learning language and speech skills. It's the most common stuttering form. After a stroke, head trauma, or other type of brain injury, neurogenic stuttering may occur. Research study shows stuttering is found commonly among young kids at early stages of their life. [2][3][4]

Even though there is no accurate cure for this, stuttering is usually diagnosed by a speech-language pathologist (SLP), health professional trained in voice, speech and language disorders testing and treating people. The entire treatment process will vary based on the age, communication goals and other factors of a person. [4]

Suggested solution is to analyze the root cause factors of stuttering and produce an application which will train users to overcome stuttering by an acceptable level. The application will analyze the users stuttering effect and allow users to train their problem and get to an acceptable improvement from their home environment without any fears. The traditional existing solution means that individual feel uncomfortable talking to human beings (speech-language pathologists), whereas talking to a machine reduces the fear of speaking to their maximum abilities. [2][3][4]

1.2 OBJECTIVES

The objective of the research is to study the root causes of stuttering and improve the stuttering of the people by an acceptable level. The objectives will be achieved at the end of the project by understanding and studying the voice analyzing technologies and providing the courses and tips for the people to overcome / improve their stuttering on their own using the mobile application. Main objective is to build a syllable counter module which will act as the core of the application to calculate the syllable from the user voice and show the results to the user.

The initial component of the project delivers a methodology to get user inputs. The next process of the component is about cleansing/filtering the input to study data with acceptable voice quality to extract the exact input of the user for research purposes. The next component categorizes the users under the four basic types of stuttering. This contains of a prediction model related with user input and different types of users are categorized according to different stutter level. This passes the users training workflows under one of the four types of stuttering.

1. Research Study on Stuttering of Repeating a sound (e.g "c-c-c-can I have some chips?"). Analysis of ways of treatment for respective Stuttering type and Treatment methodologies through the application for Stuttering of repetition of sound.
2. Research Study on Stuttering of Repeating a syllable (e.g. "I can see an el-el-el-elephant"). Analysis of ways of treatment for respective Stuttering type and Treatment methodologies through the application for Stuttering of repetition of syllable.
3. Research Study on Stuttering of Repeating a word (e.g. "Give give-give-give-give me some ..."). Analysis of ways of treatment for respective Stuttering type and Treatment methodologies through the application for Stuttering of repetition of word.
4. Research Study on Stuttering of Repeating a phrase or sentence (e.g "I want-I want-I want-I want to-I want to go to the shops"). Analysis of ways of treatment for respective Stuttering type and Treatment methodologies through the application for Stuttering of repetition of phrase.

The application also detects the severity and type of stuttering and provide feedback exercises to allow the users to train and increase the confidence. For example, if a user stutters the word “water” as “wa-wa-wa-water”, the application identifies and provide users to train the word and increase his/her confidence level. The application also provides charts to the users to see their progress in a graphical way. The charts show the progress made by users over the time and the areas for improvement.

Past researches show that people who stutter are mostly less confident to come out and mostly shy away. Emotions too play a big role when it comes to sway away from stuttering. There is no one cure for stuttering, the only way to improve from stuttering is to keep working on the words, improve the confidence, practice and gradually improve day by day. This will be the main goal of the application, to give a platform to users who stutter to practice, improve their confidence, give them a good experience and gradually develop them.

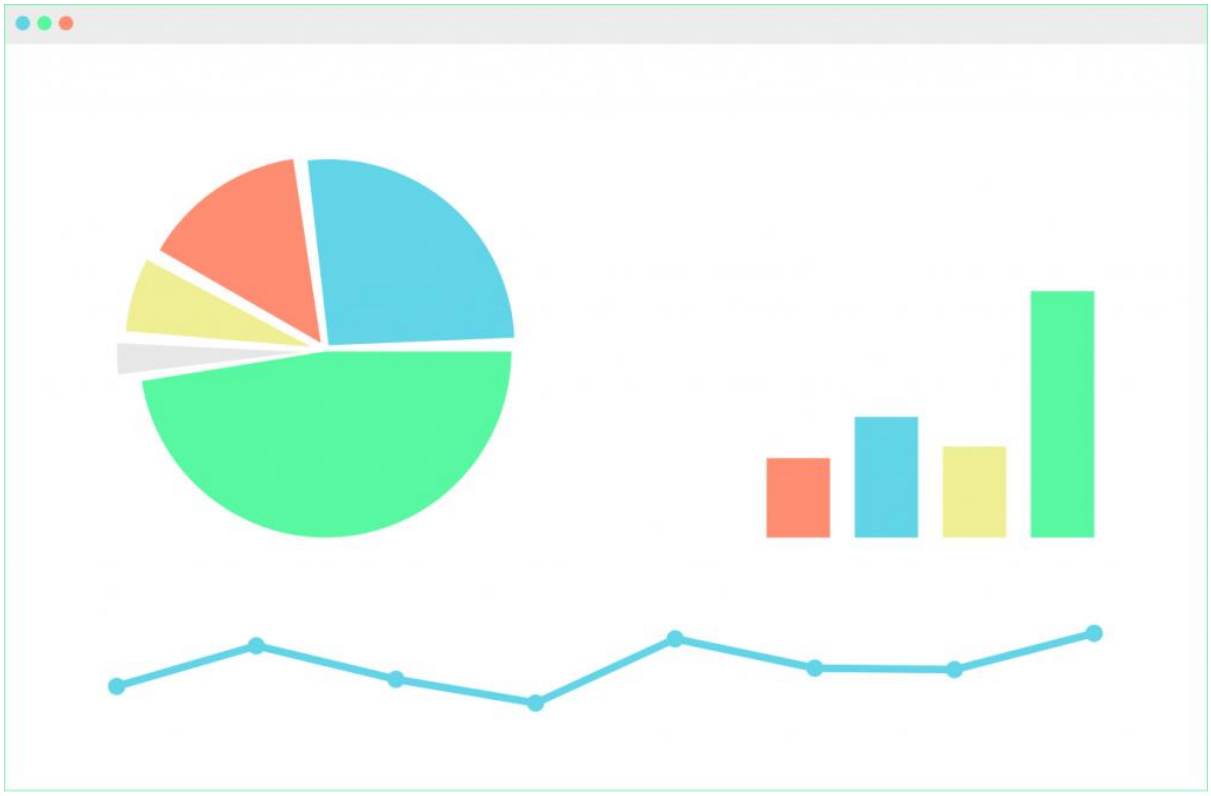


Figure 1-1 Progress charts for users

1.2.1 Main Objectives

- Voice filtering and optimization of user input
- Accurate speech to text conversion
- Study on wave pattern of user voice
- Approach to identify syllables from user wave pattern
- Implementation of traditional methodologies

1.2.2 Specific Objectives

- Wave pattern study to identify syllable count
- Identification of stuttering severity
- User experience study
- Study on open source libraries related to voice/wave pattern
- Accuracy evaluation if each component module

1.2.3 Thesis Outline

The remaining sections of the thesis is structured in a way to communicate all the activities carried out during the research of Speakup. Next chapter describes about the literature on the domain and work done before stating the uniqueness and the research gap this research study is destined to fill. Following that, chapter 3 puts forward the methodology on the solution and chapter 4 describes about the implementation and evaluation with proof. Finally, the report concludes with a summary of the whole content emphasizing on the main points in the conclusion chapter.

2 LITERATURE REVIEW

The recent literature on the domain stuttering was only few months back in 2018. StammerApp is a mobile application developed through this research which supports people who stutter by providing awareness and information about it. The research is about qualitative analysis and collection of information through surveys and workshops to address the needs of individuals who stutter on a daily basis. The application helps users on daily basis with providing information and helping with confidence of users. This research shows that the domain on stuttering research is presently ongoing and supports the study done on this report and thesis which adds on top of the qualitative analysis done on the paper StammerApp. The authors of the paper were in frequent communication for guidance on their results and advices to carry on the research SpeakUp. The researchers also stated that 1% of the worldwide population is affected by stuttering. [11]

Figure 2-1 Qualitative workshop on StammerApp

In 1962, a speech recognition model was proposed by Halle, M. and Stevens, K, where signals were studied and transferred from speech input to chunks of sequences of particles used to study and conversion rates were obtained. This created a change in research on speech recognition.

This inspired and paved the way for the future studies on the speech to text conversion models. [5] From the above literature, the idea behind the speech to text conversion mechanism was studied. Speech signal was passed as an input and the speech was recognized with matching the patterns.

In 2012 group of researchers from Scotland described about an Android mobile application solution which optimizes a monitoring module to detect speech rate patients and present real time results using a device. This helped individuals to identify their speech rate and analyze where the correct rate should be for improvement. The results were presented both graphically and numerically for a better understanding. An algorithm was described in the paper used to connect with the device on signals and update the rates. This also provides a real-time feedback like Speakup. Additionally, instructions were also given for users to understand and improve their speech fluency. Cloud service plan to track training materials was also discussed in the literature of this paper. [6]

A study in 2015 shows about a mobile application BroiStu, it is another stuttering awareness application without technical aspects of the domain. This application provides a platform to have a better understanding of stuttering and help people who stutter in day to day basis. The paper discussed about the types and approaches to train and overcome the stuttering types as well. [12]

In 2012 two researchers in India , P. Mahesha and D.S. Vinod found a new approach to classify three types of stuttering dysfluency, repetition, prolongation and interjection. Vector quantization domain was discussed on their research evaluation and Algorithms used for the speech extraction was also discussed in the paper. [8] Test samples were obtained from a London university and contained readings as well as conversation files. The study also put forward a program for SLP to detect and train their clients using the techniques discussed in the paper. The researchers also include the evaluation of the tests and an approach to use the algorithm to break voice samples and study the rate respectively.

According to research done by Uppsala University, Sweden in 2014 called Poster an application to bring awareness, the main study outcome is the people who stutter tries to speak more frequently when their own voice is played back to them with alterations. Though there are many special devices available to so this task one of the suggested device is using smartphones to accomplish the task. [9]

The basic techniques used to overcome stuttering is practicing over and over again and reading having conversations with others. One of the key factors when it comes to treating individuals who are stuttering is to keep them motivated and committed to the cause. This opened up an interesting area to use mobile applications to train individuals with the device and keep them motivated. This also shows how technology have advanced over the time. [7]

The sample techniques methods are

1. Masking noise: This mask the normal audio feedback from using the noise in headphones. Thought this won't remove the noise completely it will reduce the noise by an acceptable level.

2. Delayed Auditory Feedback: Sound is transmitted from speech to headphones with a delay of about 50 – 250ms. The advantages in this method are it may reduce the stuttering as well as allows the person to speak in a normal rate. The disadvantages in this feedback is the time duration being longer to reach the ear. But this disadvantage is considered as an additional advantage if the person uses training with slower phase.

3. Frequency shifted auditory feedback: In this technique, the main functionality is changing the pitch of the feedback. By changing the pitch up or down User will feel comfort in communicating. The main aspect of this feedback is though the new sound is not fully accurate as possible, but it's perceived as unpleasant.

4. Enhanced Auditory Feedback: This technique is an enhancement on finding reduced stuttering. Generally, feedback is inertly proportional to stuttering.

In 2003 polish researchers put forward a subjective evaluation of stuttering based on detection of stuttering in stop-gaps, syllable repetitions and pronunciation of vowels. The paper put forward an approach on normal and frequency altered feedback speech on voice recognition. Also, several methods of analyzing stuttered speech is discussed. [23]

In 2006 dysfluent speech processing is one of the areas where a lot of research study was conducted, A lot of automation work was researched and studied for detection and classification of stuttering. This helps the workload of SLP to treat their clients efficiently.

Types of dysfluencies researched on this paper was.

Type of dysfluencies	Example
Repetition	
Whole word	"What-what-what are you doing "
Part word	What t-t-t time is it?
Phrase	I want to-I want to I want to do it
Prolongation	
Sound/ syllable	"I am Booooobbbby James
Interjection (Filled pauses)	
Sound/syllable	"Um – uh -well, I had problem in morning",
Silent pauses	
Silent duration within speech considered normal	"I was going to the [pause] store
Broken words	
A silent pause with in words	" it was won[pause]derful"
Incomplete phrase	
Grammatically in complete utterance	I don't know how to ….let us go, guys"
Revisions	
Changed words, ideas	There was a dog, no rat named Arthur"]

Table 2-1 Types of dysfluencies

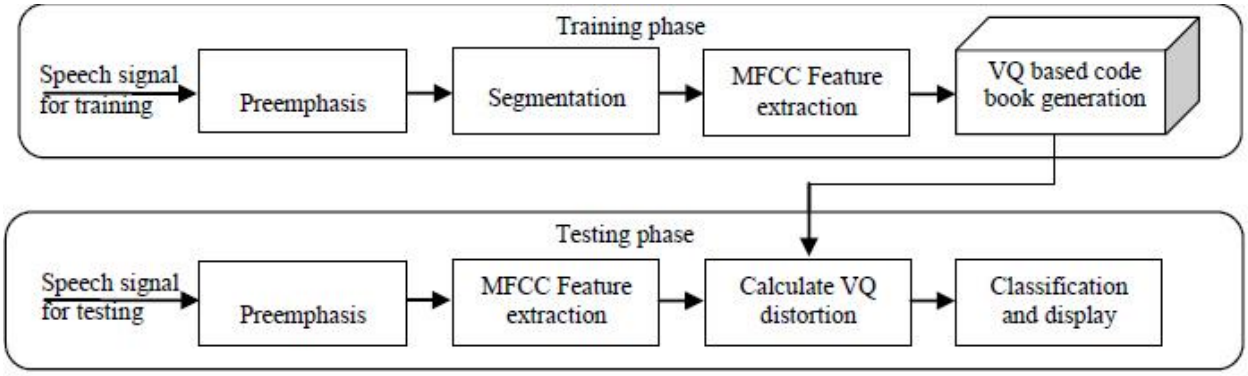


Figure 2-2 Research Model

"I aware my stuttering" is a mobile application research done by a group of Portugal researchers in 2013. The application circles on the target audience of stutterers to join by registration and input data regarding the stuttering and the occurring instances. The application collects the information and provides a report to help users understand their stuttering severity in the means of graphs and rate values. The application also contains a module to connect with SLP, where they can monitor individuals and give feedback. It also acts as a place to initiate discussion between SLP and clients. The application collects information from both SLP and clients and provide details reports on the analysis.

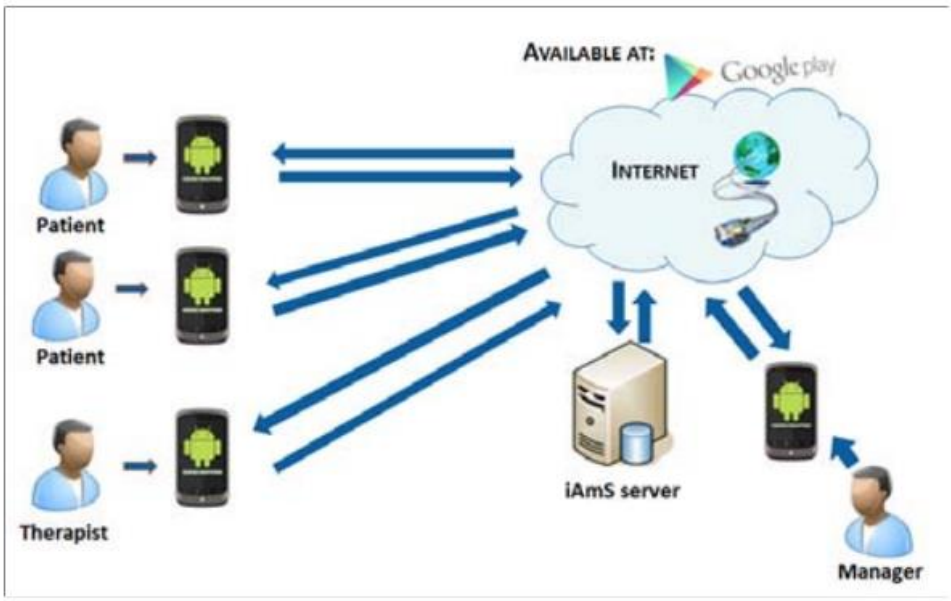


Figure 2-3 Architecture of "I aware my stuttering" app

2.1 Research gap

Many researchers who researched on stuttering and how to cure it have identified that there is no perfect cure for stuttering. But they also identified that there are several methods available to reduce the severity of the stuttering. According to the case study one way in which stuttering can be overcome is allowing the person to speak slowly and calmly.

The popular ways of therapies conducted by the speech pathologist try to cover many aspects which cause the person to stammer. The “Lidcombe Program” which mainly practice the parents to help with their young ones. This program provides a platform for a child, which he/she gets appreciation and reward for correct speech and eliminates the fear factor from the person who stammers. The main idea behind this was to give the stutterer an environment friendly area and comfortable experience. This aspect is considered as one of the main features of the application and bridges the gap between the traditional methods and automated solution [10].

Fluency correction therapy involves in all aspects of speech in stuttering. It is not the speaking portion which is only given priority. It also considers the mouth movements, body language, correct pronunciation aspects. The rate of speech and the style is also considered in this approach. [2].

The current mobile applications related to the stuttering mostly contain a guide to the users to read and identify the solutions to improve the stuttering. The lack in the current applications is the inability to analyze the voice of the user and accordingly giving the customized recommendations, which are useful for various categories of user. The proposed methods are identifying the user and recognizing the voice and accordingly analyzing the voice and providing the user necessary trainings to improve by an acceptable level.

2.2 Research problem

The literature review proves that stuttering and approaches to overcome them over a mobile application is a common domain and a lot of researches were conducted in the past. The main drawback or the research problem is there is very little technical research done on the topic and more qualitative and awareness approach was conducted to spread the message in the past studies. This research Speakup covers the technical aspects to conduct the research and puts forward a plan for two traditional approaches practices by SLP to be implemented in the mobile application.

SpeakUp, mobile application will be a pocket guide for people who stutter and are looking ways to improve their speaking abilities to become better communicators. The application will allow users to provide their input and train themselves to overcome stuttering by an acceptable level. Application adapts to methodologies used by speech language pathologists to provide users good training techniques and materials. This research project will be about developing a mobile application called “SpeakUp” which will help users who are affected by stuttering to train themselves by following various methodologies customized for their level and type of stuttering and help them become better communicators. There are few reasons behind this. People are not so comfortable reaching out to the therapist and explaining their situation to the therapist. The treatment is also expensive, and the therapy room increases the stutterers’ anxiety and affects their ability to speak. The mobile application allows users to assist them and train themselves from stuttering by an acceptable level. Practices and training according to each individual stuttering type and severity will help users feel customised and motivated to use the application. The graphical scoring model and gamification fuels the motivation and enable the user to practice over and over again.

3 METHODOLOGY

In this section of the report the methodology to solve the research problem is discussed. The main idea behind the application is to allow users to simply pick up the phone and speak out and provide them with results and improvement practices for them to practice and improve stuttering by an acceptable level. Even though it sounds straight forward it is not simple to process everything on the go at real time. The objective flow was broken out methodologically to independent modules, each with own roles and responsibilities to collaborate between them and build the whole application. This is a basic approach in any architecture where modules work together in efficient way, reusing most of their features for the end goal. High level picture of the architecture can be found below which will be a living document throughout the research.

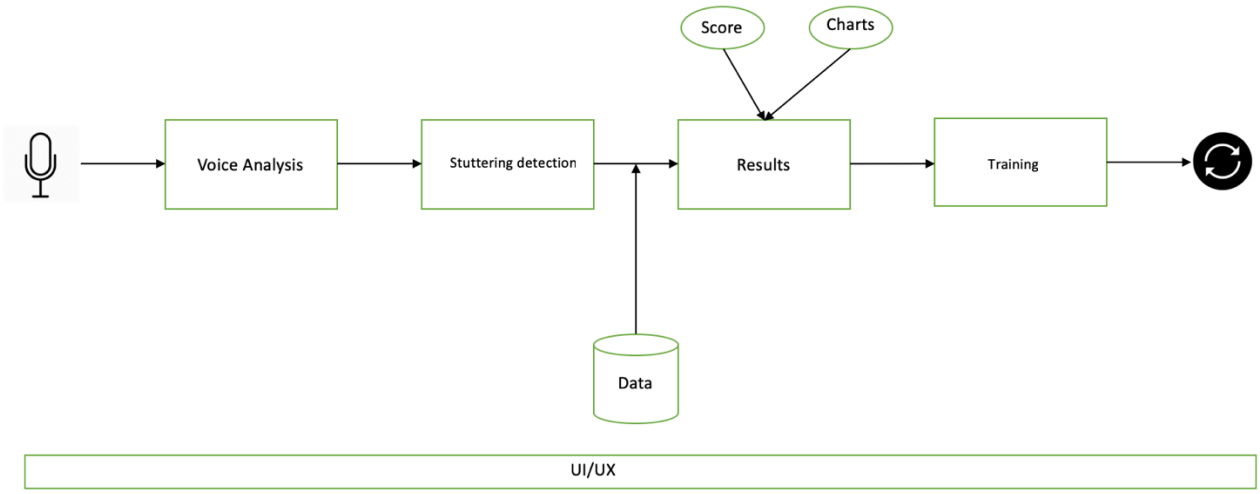


Figure 3-1 High level architecture methodology

The initial step of the application is voice detection and analysis module. The application will use the voice analysis technology to identify the user voice and differentiate from blank void and loud noises. This will help with processing and memory of the application. The application will use a technique to identify the noise and remove them to increase the accuracy. The main responsibility of the module will be initially to detect the user voice from the microphone and clean and filter the input to optimize the voice to be used in the next module. A valid technique will be researched related to voice optimization and included for high accuracy.

Figure 3-2 Voice optimization module

The frequencies of voice samples can be studied to understand wave pattern and implement a solution to use cut out frequency to optimize audio inputs. In reality expecting a clean audio input is tough as most of the scenarios will include noisy environments. It is the applications responsibility to make sure the initial steps involve activities to make sure audio input is processed and passed on so that it is in a state to study the input to derive into conclusions related to stuttering.

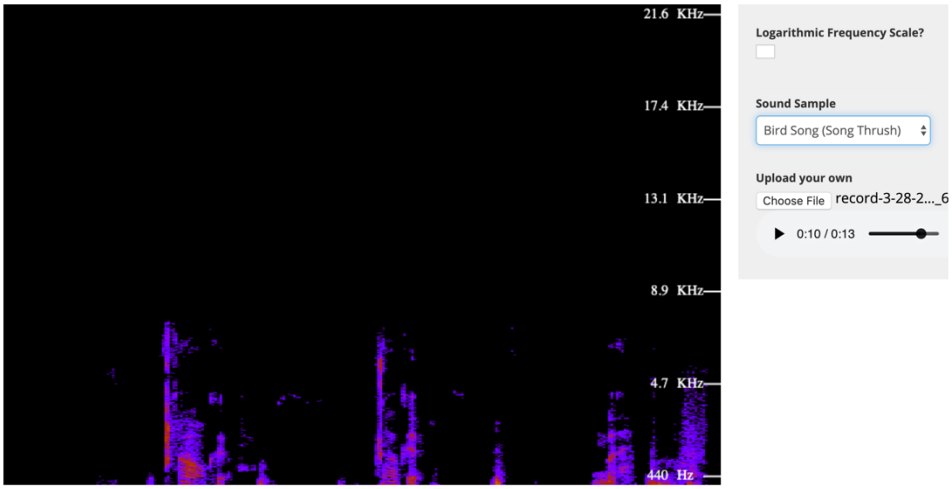


Figure 3-3 Frequency analysis of audio samples

After making sure we have a valid voice input the next step will be to detect the stuttering level and severity of the user. This is one of the main core module of the application as the main objective behind SpeakUp rely on this module output. Research will be carried out to identify the stuttering level of the user disregarding any language input used so that the application can be language independent. Even though there are 4 types of stuttering mentioned in this report, the main common way of stuttering at the initial stages of a word will be prioritised and using the wave pattern a methodology will be created to identify and provide users with results.

Another objective of the application will be to detect the words spoken by the user. There are many open source libraries with license which can be utilised for this purpose. Users speech will be identified to text and this will help to understand the syllables spoken by the user. Comparing the spoken syllables to the expected will solve a part of the puzzle to derive the final results of the user. Adding the results collected by studying the wave pattern of the voice, the final score will be derived. Each syllable in a word will create a peak hike in the wave pattern. By using the appropriate sample size and identifying the average of peaks we can detect the syllables spoken independent of the language to find the severity of the user.

Figure 3-4 Voice sample wave form

Figure 3-5 Speech to Text Sample

The next module will be the results module. Even though there is not much processing work compared to the first two modules, this will be a very sensitive area which plays with users' emotions. By using the application SpeakUp we are allowing users to practice and overcome stuttering by an acceptable level from home by themselves. Researches have shown this a positive approach to allow users to express with freedom without being anxious. To make sure users will come back without giving up using the application over and over again we need to promise a better emotional experience will be provided to the users at the end of the results. Gamification will be used to make users come back to the application to improve the score. Methodologies like star or level system can be used to motivate users to try the application more and leader board-based community can be created to motivate each other.

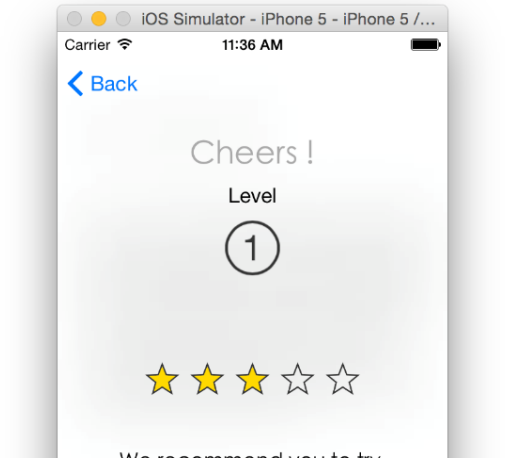


Figure 3-6 Gamification concept

Data of the results can be stored in the database to populate graphical charts to motivate the users. This will improve the confidence of the user and boost their moral belief.

Figure 3-7 Forms of charts

The next module, Training focus on delivering individual need-based activities to allow users to train their weak areas to get improved scores and increase their confidence level to use the application over and over again. Depending on the result of the initial test users can be allowed to practice the difficult word to gain confidence and retake the initial test to see their improvement. For example, if the user is struggling to pronounce the word “water” and stutters in saying that at the initial stage, the application will allow users to practise only that word within the time to make the user feel confident when he comes back again to the initial test. This will act as a factor to see improvements and make SpeakUp a daily driver for the people to practice and overcome stuttering. The whole process iterates over and over again to allow users to practice and save their score, see the results graphically and improve from stuttering.

SpeakUp will be a reusable module overall which can be placed initially before creating any stuttering related practices in a mobile application. To understand the real-world scenario two practices were studied from the SLP which are currently done manually, and proposal of the methodologies were discussed for implementation through the mobile application. The two methodologies are Slowed Reading and Easy Onset. These are couple of leading practices for people who stutter done by SLP manually. To automate the process in a mobile application initially user inputs the name and areas of his/her interests to the application. The reading paragraphed text can be categorized according to his/her interests. This will directly have an impact on how user interacts with the application.

User reads the initial paragraph and allows his/her voice to be recorded to the application. User views his/her score and how he/she have performed and navigated to one of Slowed Reading or Easy Onset methods to improve further. Slow reading method allows users to press and read a paragraph slowly in different repetition of syllable range (80/100/120). User earns scores according to how he/she performed in these methodologies. Additionally, support is given to the user to get access to how to read at correct speed with a recorded voice from the machine. Easy Onset allows users to go through the four steps of the methodology. Four steps in the traditional methodology are done through the mobile application. First user is prompted to get a good breath and the pronunciation movements are shown to the user visually. Users are next prompted to pronounce the word without sound to get the air breathing cycle correctly and finally the word is produced to complete the methodology. These processes are looped for better performance.

In slowed reading user will be going through several modules which will contain the same paragraph being played with an example of the sample in different speeds which will contains rate of syllable rate in 80,100,120 respectively. An average rate of syllable of the user falls between the category 120-140 syllables per minute. Scores are given for the user's ability to perform in required rate. From the tested rate of syllable if the user does not fall into the normal rate then the application will provide the user with modules from as low as 80 syllables per minute and increasing gradually to 100, 120 respectively. The reasons for improving rate of syllable with this methodology is that people who stutter tend to have a high rate of syllable as they tend to speak a lot faster than a normal person.

In Easy Onset user will be asked first to inhale a good breath and release the breathing. A normal person's breathing span is between 12-15 seconds. Stuttering people tend to have a small breathing cycle. The training modules in the easy onset will give the user an opportunity to improve his/her breathing and read the paragraph just as the way a normal user will read the paragraph. Secondly the user will be shown of the visual which will contain actual way of pronouncing a word. Stats say that many stutters have this initial syllable stuttering as a reason for stuttering. Users will be able to see how the normal people start the word and will be able to improve the way user starts pronouncing the word. User will be initially pronouncing the word without making any sound but releasing the air he/she breathed. Then the user will pronounce the exact word with the sound at the end of this technique. Scores are given for the user's ability to perform all the steps in the methodology correctly and in a required phase manner.

Even though the two practices are not implemented in the application, they were studied with the help of SLP to understand the real time usage of the reusability of SpeakUp to overcome stuttering. Additionally, focus will also be given to study and implement proper user interfaces to provide user with a positive user experience and improve their moods and emotions. The sample mock up interfaces are attached at the end of this document. The next chapter will discuss about the implementation of the methodologies discussed here.

4 IMPLEMENTATION

The mobile application will allow users to talk, train themselves and overcome stuttering by an acceptable level. To identify the exact stuttering type precisely, attributes of voice such as frequency, voice decibel and repeating patterns, which belong to a users' voice will be analyzed and recorded by the application. Then the user will be categorized into a group depending on his/her stuttering level. According to the severity a set of work flows will be undertaken to train the user. Progress will be shown in form of visual graphs to user to keep him/her committed and improve stuttering.

The user will interact with the application with voice. User's voice is extracted and studied to predict the stutter type and level. According to stutter type users are categorized into one of the type and workflows are designed to practice them and improve their stuttering. This process is done in iterative process until users have improved by an acceptable level. Interactive and user-friendly interfaces will make sure the user's commitment levels are not diminished and users will have a comfortable environment to talk to their maximum caliber. Research will be done from trainers with experience to provide an application with acceptable level of improvement. Even though there will be no accurate cure for this, the solution will improve individuals to an acceptable level. This section of the report will go through the methodology and the development workflow and decisions of the implementation of the application SpeakUp.

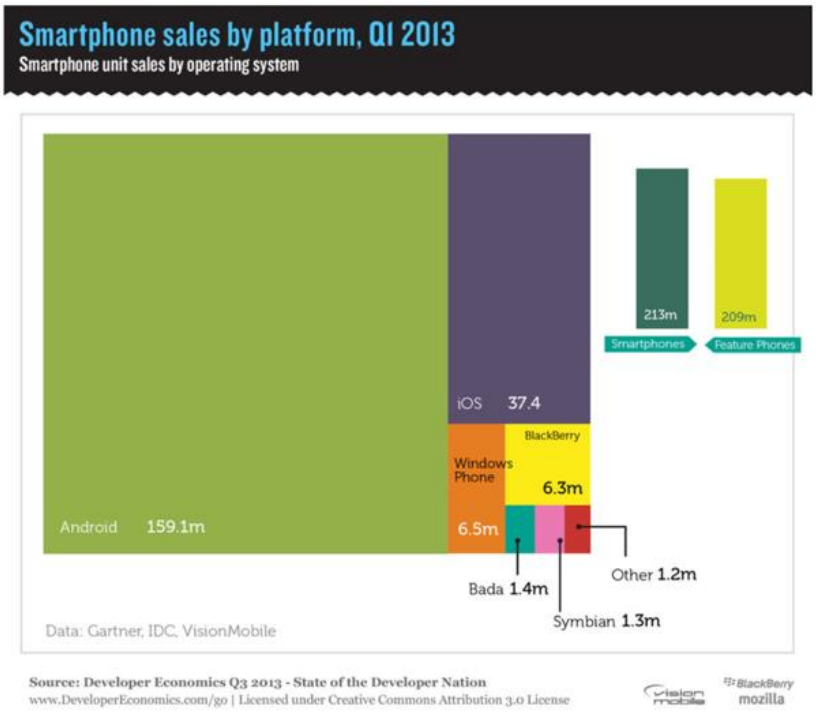
4.1 Technology Background

The main idea behind SpeakUp is to create a reusable module which can be used as an entry point for all the mobile device-oriented practices to overcome stuttering. The core idea is to do the initial work for all the practices so that the module can be reused efficiently. For any practices to overcome stuttering through a mobile device there are few common repeated tasks.

1. Identify the users' voice
2. Identify the users' speech
3. Identify the accuracy of the speech
4. Identify the stuttering type and severity

After all the above-mentioned steps are cleared the user can be redirected to the actual practices such as Slowed Reading and Easy Onset according to the respective individual requirement.

In order to cater for the large user base on a mobile device, Hybrid application development was decided the right way to go forward. The implementation of the application is written on React Native. Additionally, to give back something to the community users can simply download the application from Android (Google) / Apple store and use it free of charge. There are quite few platforms to develop. Even though researches show positive side towards Android development there is a huge iOS market outside the Asian geographical areas. Therefore, Hybrid solution will cater both Android and iOS users giving the module to be used in different areas.



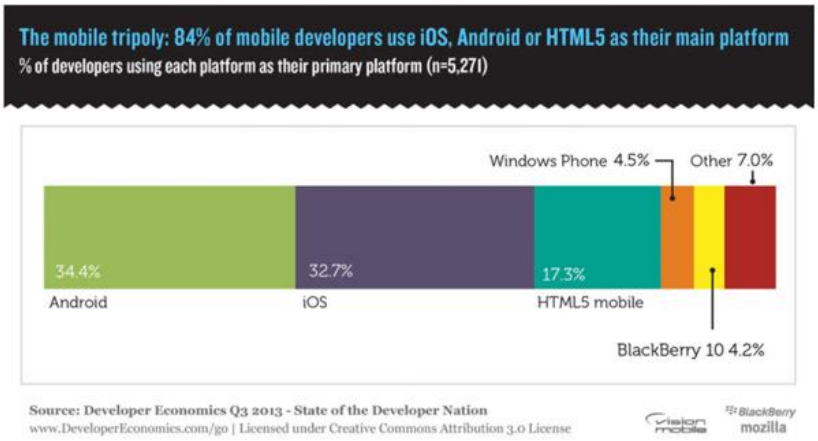


Figure 4-1 Research on Platforms

Stuttering is mainly categorized into 4 different types. These categorization is done on the occurrence level of stuttering. They can occur at the start, middle or end of words. Generally, most stuttering cases occur at the start/beginning. Other types are,

1. Repeating a sound (e.g "c-c-c-can I have some chips?")
2. Repeating a syllable (e.g. "I can see an el-el-el-elephant")
3. Repeating a word (e.g. "Give give-give-give-give me some ....")
4. Repeating a sentence (e.g "I want-I want-I want-I want to-I want to go to the shops")

There are other less common types such as,

1. Prolongations – Stretching a word/sentence long (e.g. "I waaaaaa-----nt to go outside to play")

2. Blocking – No sound produced at all and user is not able to communicate. This manily occurs at the start of the word/sentence.

The stutter level is identified and categorized so that the application will be diverse to all types of users and their stuttering severity level. The workflows to practice users and train them are created after research on each individual type and users are categorized before the practicing procedure. The input of the application was taken from the microphone of the user's device. Then the voice analysis techniques will be used to extract the voice component and remove the noise to accurately study user input and categorize the users accordingly. The voice detection model detects for user inputs and analyses them. The user's voice is studied and passed to the

next model. The speech recognition model optimizes the voice input and removes the noise to study the words pronounced by the user. After these steps, the user is categorized according to stuttering severity. Data Model acts as the main storage model and allows other model to access the data when required. The stutter level prediction model predicts the severity in the stutter level of the users and categorizes them according to respective groups.

The algorithm in this module will predict the respective users stutter level and allow the application to practice them differently by providing them different workflows. The categorization model categorizes the stuttering to its respective module. The training process for each model differs accordingly. After the training of the users it will be measured through the progress model to make sure the user realizes they are trained to an acceptance level. These scenarios are repeated iteratively to train the users.

There is a more risk of getting affected by stuttering if there is genetically history of stuttering in the family. This does not directly implement it is transferred from the parent, but a family background puts the individual at a higher risk to develop stuttering from younger days.

SpeakUp is developed on React Native, it is a JavaScript framework to write modern hybrid applications for both Android and iOS ecosystems. According to Stackoverflow survey results it is the leading programming language by the community for the past two years. It is relatively strong language created by Facebook and a lot of leading companies/products have adopted the language to build successful business. It integrates a lot of open source libraries to give freedom to developers to create hybrid application. This also give developers to use various light JavaScript libraries to integrate and develop functionalities. [14]

Fundamental process of React Native is ‘Learn once and write anywhere’ is the principle to create React apps and which is also true for React Native Development and also the main objective behind the research of SpeakUp. Reusability is the main software architecture concept practiced throughout the research. It involves a lot of rich UI creation and binding for the DOM to actively react and render mobile application.

Figure 4-2 Top 5 Hybrid technologies in 2019

4.2 Voice Analysis

The voice filtering and optimization module is used to filter and optimize the voice input. Voice filtering module is one of the core module that provide input to other modules to accomplish their respective tasks, Because the application is mainly depend on the users' voice input which might affected by the background noise, this might lead to wrong result. In order to get accurate result from the audio input, it has to optimize according to the other modules requirements.
The voice filtering and optimization module uses the Low pass filtering mechanism which is used to eliminate the background noise. A low pass filter is filter that passes signal with a frequency lower than a certain amount of frequency and attenuates signals with the higher than the frequency specified. The frequency used to specify the maximum frequency that passes is called cut-off frequency.

The implementation of the low pass filter is done through a JavaScript framework called Pizzicato, for example in iOS Core Audio framework is used, Core Audio provides a software interface for implementing audio features in mobile application it handles all aspects of audio. Core Audio capabilities file stream parsing, format conversion, sound effects, positioning as well as Automatic access to audio input and output hardware.

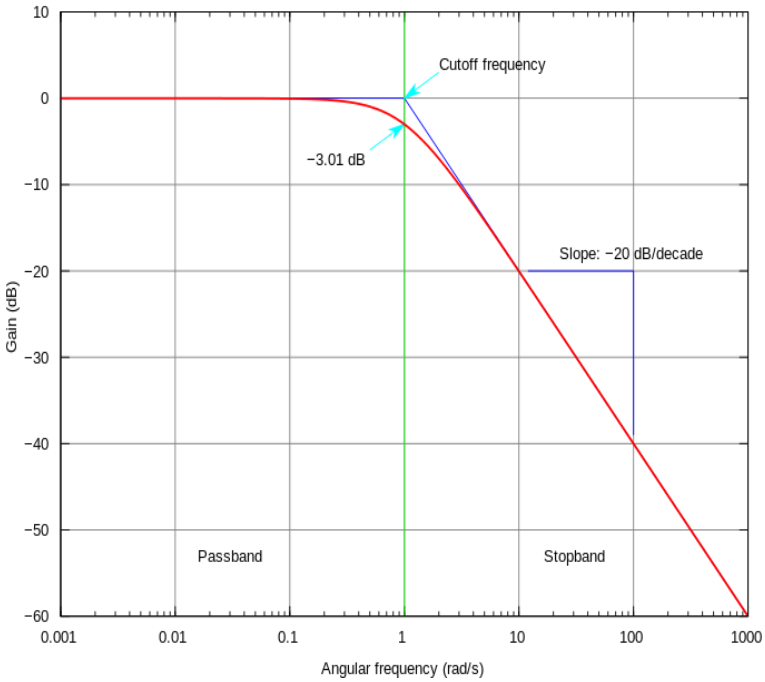


Figure 4-3 Low Pass Filter Mechanism

Since the Core Audio framework provide lower level access to the audio functionalities which makes it possible to do the modification to the signal. In order to make changes to the recorded audio firstly it is read by the Audio File Reader Class then the data that are in Audio File reader will be passed to the Signal Modifier Class which modify the signals. Then the modified signals will be passed to the Audio File Writer and Audio File Writer writes the modified signals and pass it to other modules.

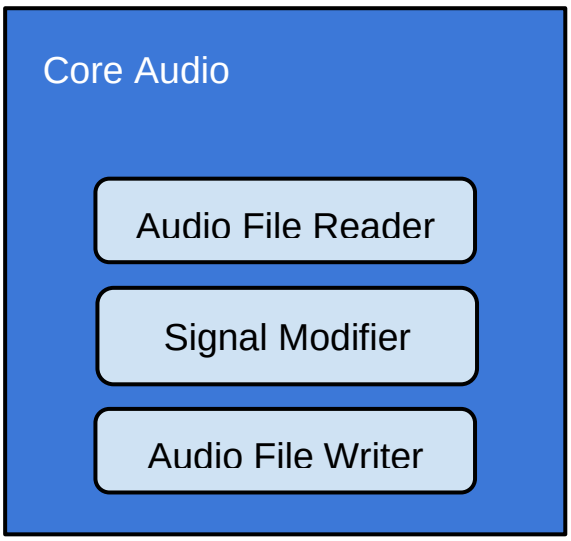


Figure 4-4 Core Audio in iOS

While sending to the inputs to another module it has to optimized, because there can be a situation where the user might not be talking but the device is recording, or user might take little later. Unless the users voice input is not in audio than the data become useless and also this useless data can

- Take space to store inside the device storage and the cloud (Firebase).
- Mobile devices have less amount of memory which makes the process hard.
- Waste of processing power.
- Inaccurate result from other modules.
- Hard to send data through the network.

A graphical output of an audio sample is given below which describe the simple scenario discussed above, in the below figure colored region show a long straight line which does not have any peaks this clearly shows that 0 – 4.5 seconds there is no relevant or useful information. In order to overcome this problem when the user stops peaking device also stops recording this makes the audio to exclude unwanted information.

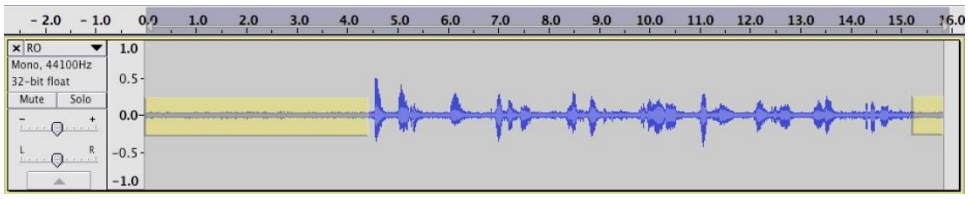


Figure 4-5 Shows audio with noise

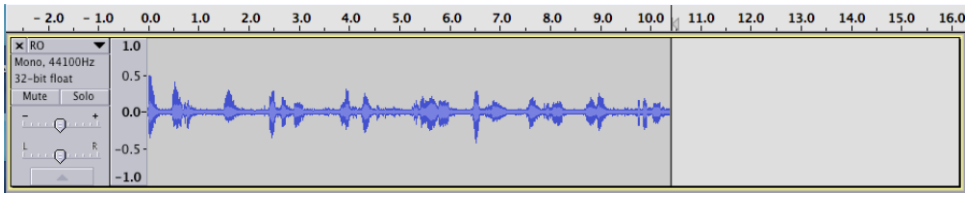


Figure 4-6 Optimized audio

The JavaScript framework handles with this work for both the native iOS and Android Audio components. The below image shows an example code from the library where the frequency and peaks are defined extracting the interface to input the audio through low pass filter.

Low-Pass Filter

```
var lowPassFilter = new Pizzicato.Effects.LowPassFilter({
    frequency: 400,
    peak: 10
});

sound.addEffect(lowPassFilter);
sound.play();
```

Figure 4-7 Low pass filter implementation

4.3 Syllable Counter

The main objective why the syllable counter is implemented in the application is that it will be the primary factor through which the application will allow/suggest the users the training modules which the user can follow analyzing the initial test from the user.

The below sample shows the study of voice patterns to come up with an accurate syllable counter which will be used as a main core component of the application.

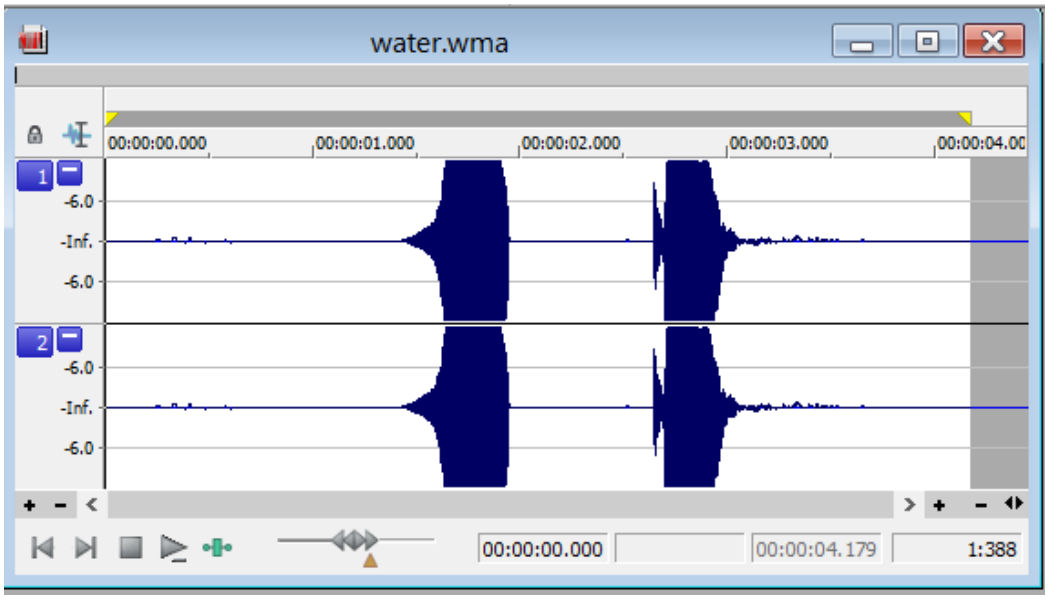


Figure 4-8 Voice wave of Water (2 syllables)

The above figure shows how the word water is represented in the wave form.

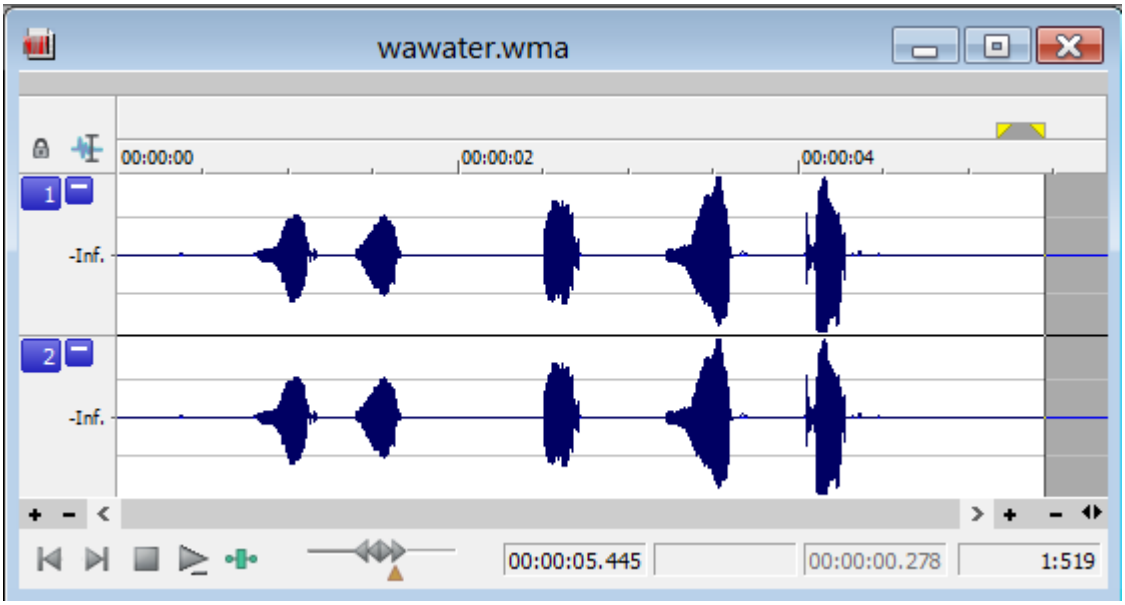


Figure 4-9 Voice wave of Water (Stuttered)

The above figure shows how the stutters when pronouncing the word water like wa-wa-wa-wa-ter is represented in the wave form.

Initially user reads the initial paragraph and allows his/her voice to be recorded to the application. User views his/her score and how he/she have performed and navigated to one of the training methods to improve from there. Additionally, Progress charts are in the application for the users to easily recognize their improvements. User can again check his/her progress and score and allowed to test repeatedly with the above techniques to improve his/her score and level in the application and overcome stuttering by an acceptable level.

The main objective why the syllable counter was implemented in SpeakUp is that it will be the primary factor through which the application will allow/suggest the users the training modules which the user can follow after analysing the initial test from the user. Initially the syllables were counted from the database where each word and the number of syllables were stored. But the results were not accurate due to several reasons.

1. The stutter will not stutter the word as the same way it has been defined in the database
2. Inability of the framework to detect the correct word when broken in to syllables. For example, when defining the word “Water” as “Wa” and” Ter” and defining the word “Our” the framework when the user spells the word water will identify “Wa” sometimes and “Our” the other time depending on the volume and pronunciation user makes.

3. Depending on the accent of the user the framework recognises the same word in different ways.
4. When the user pronounces the word while stuttering the framework will neglect the word if he speaks correctly again.

These barriers resulted in a need to research for a new way to find the syllable in the application through the syllable counter module. According to the speech therapist [1] the syllables are counted considering the stuttered words as well. For example, if the word spoken is elephant then it will contain 3 syllables (el-e-phant). Suppose the person pronounces the word like (el-el-el-e-phant) the word will contain 5 syllables even though the actual word contains 3 syllables. So, this syllable counter is implemented from the research paper written by Paul Mermelstein on Automatic Segmentation of Speech into Syllabic units. The first objective of identifying the syllables is to visually look at the audio input of the user. With the use of the Ezaudio framework user's speech was visually represented through a graph as below.

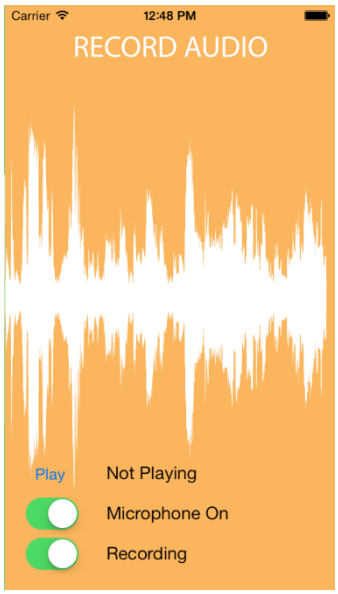


Figure 4-10 Graph of the user's voice input.

The next objective is to divide the audio file into small samples. The key factors in deciding the number of samples is the time duration the user has spoken.

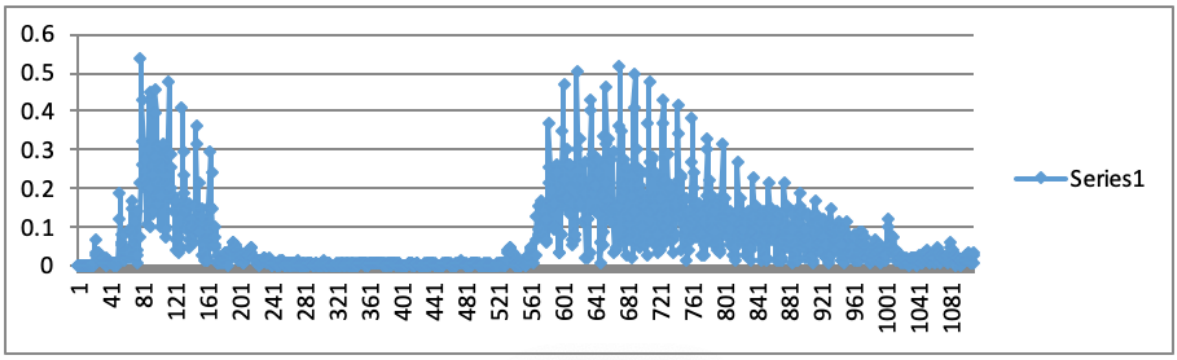


Figure 4-11 Samples and the Noise are plotted in a graph

Above figure represents the samples being mapped into a graph. The X axis of the graph shows the sample space and Y axis denotes the frequency level. The entire 1081 samples are taken from a 1 second audio file where the user has spoken the word "Water".

Next mean and the median values of the samples are calculated. Then the samples are inserted into an array. And the array is divided into small arrays depending on the audio file duration.

Duration of the audio in seconds	One sample Audio time	No of samples needed to get 0.1 seconds	No of samples needed to get 0.2 seconds	No of samples needed to get 0.3 seconds
1	0.000925926	108	216	324
2	0.001851852	54	108	162
3	0.002777778	36	72	108
4	0.003703704	27	54	81
5	0.00462963	21.6	43.2	64.8
10	0.009259259	10.8	21.6	32.4
20	0.018518519	5.4	10.8	16.2
30	0.027777778	3.6	7.2	10.8
40	0.037037037	2.7	5.4	8.1
50	0.046296296	2.16	4.32	6.48
60	0.055555556	1.8	3.6	5.4
70	0.064814815	1.54286	3.08571	4.62857
80	0.074074074	1.35	2.7	4.05
90	0.083333333	1.2	2.4	3.6
100	0.092592593	1.08	2.16	3.24
110	0.101851852	0.98182	1.96364	2.94545
120	0.111111111	0.9	1.8	2.7
130	0.12037037	0.83077	1.66154	2.49231
140	0.12962963	0.77143	1.54286	2.31429
150	0.138888889	0.72	1.44	2.16

Figure 4-12 Grouping of number of samples

Above figure represents the matrix where the number of samples is grouped into one whole sample in order to find the syllables. Then from the grouped samples the maximum values from each sample are obtained and are taken into the calculations. Then the samples maximum values are compared against the median value and the number of samples which have the values greater than the median value are considered to be the number of syllables. This methodology in implemented to calculate the highest value as the peak of each sample and identifying as a syllable.

Advantages of the new syllable counting method

1. Independent of the language.

   Since the calculations are done from the raw voice input. This calculation methods can be extended to the other languages also as the method is independent of the language. And also, the method eliminates the accent of the user into considerations. The same word can be pronounced by different people in different way, but the number of syllable must be the same. This syllable counting mechanism allows the opportunity to accomplish the task.
2. Captures the stuttering words also into calculations.

   Most importantly this mechanism takes the stuttering parts of the word also into calculations. For example, when the water is pronounced as “Water” the syllable counter results in 2 syllables and if the water is pronounced as “Wa-Wa-Wa-Water” then the syllable count results in 5 syllables.

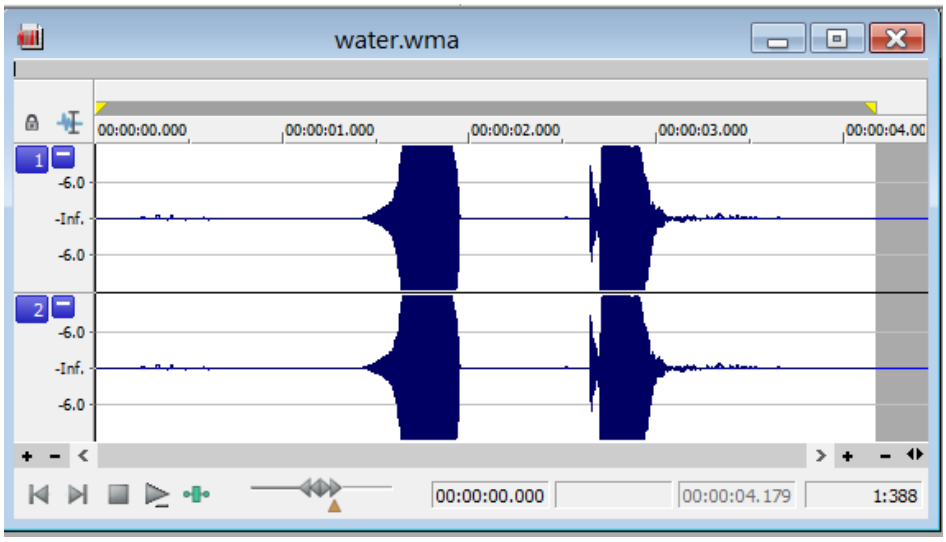


Figure 4-13 The word “Water” in wave form

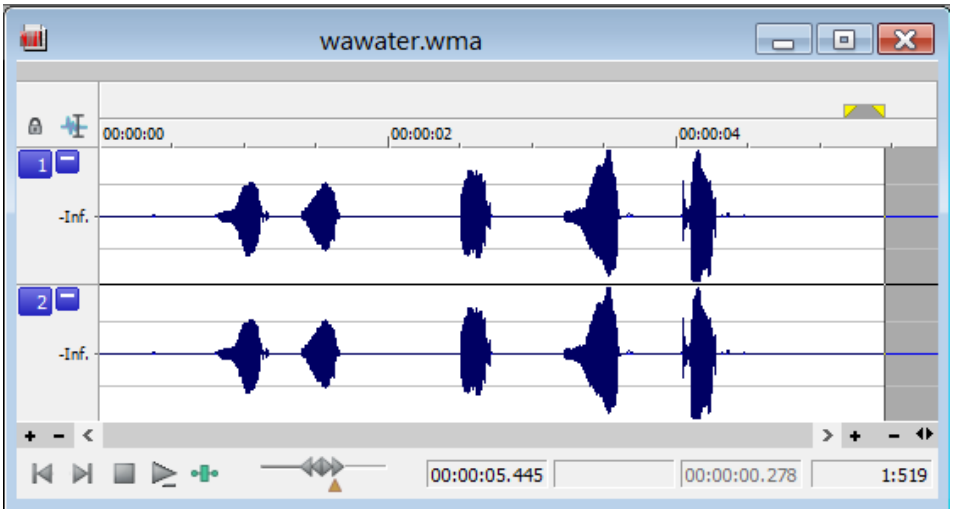


Figure 4-14 The word “Wa-Wa-Wa-Water” in wave form

From the figure 3.3F we can see that when a user pronounces the word “water” correctly how the word is shown in the graph. And in the figure 3.3G when the same word “water” is stuttered. The syllable counting module will be able to pick up the both the voice input and display 2 and 5 respectively as the output of the syllables count.

```
2015-06-15 21:26:38.283 SpeakUp[810:215053] Accuracy is 4.166667
2015-06-15 21:26:38.286 SpeakUp[810:215053] Total Duration of Audio File 1.393197
2015-06-15 21:26:38.287 SpeakUp[810:215053]   Sample Rate:              44100
2015-06-15 21:26:38.287 SpeakUp[810:215053]   Format ID:                 aac
2015-06-15 21:26:38.287 SpeakUp[810:215053]   Format Flags:                0
2015-06-15 21:26:38.287 SpeakUp[810:215053]   Bytes per Packet:            0
2015-06-15 21:26:38.287 SpeakUp[810:215053]   Frames per Packet:        1024
2015-06-15 21:26:38.287 SpeakUp[810:215053]   Bytes per Frame:             0
2015-06-15 21:26:38.288 SpeakUp[810:215053]   Channels per Frame:          2
2015-06-15 21:26:38.288 SpeakUp[810:215053]   Bits per Channel:            0
2015-06-15 21:26:38.288 SpeakUp[810:216323] Array Size  value is 1042
2015-06-15 21:26:38.289 SpeakUp[810:215053] Pocketsphinx has stopped listening.
2015-06-15 21:26:38.292 SpeakUp[810:216323] Median is 0.0
2015-06-15 21:26:38.293 SpeakUp[810:216323] Mean Value is 0.026200
2015-06-15 21:26:38.293 SpeakUp[810:216323] Threshold Value is 0.176200
2015-06-15 21:26:38.293 SpeakUp[810:216323] Number of Smaples 3.000000
2015-06-15 21:26:38.293 SpeakUp[810:216323] Sample braker value is 186
2015-06-15 21:26:38.293 SpeakUp[810:216323] Max Value is initial 0.100000
2015-06-15 21:26:38.293 SpeakUp[810:216323] Max Value is initial 0.100000
2015-06-15 21:26:38.294 SpeakUp[810:216323] Max Value is initial 0.200000
2015-06-15 21:26:38.294 SpeakUp[810:216323] Max Value is initial 0.100000
2015-06-15 21:26:38.294 SpeakUp[810:216323] Max Value is initial 0.000000
2015-06-15 21:26:38.294 SpeakUp[810:216323] Max Value is initial 0.000000
2015-06-15 21:26:38.294 SpeakUp[810:216323] Number of Syllables Detected is : 1
2015-06-15 21:26:38.294 SpeakUp[810:215053] Number of Syllables Detected is : 1.000000
2015-06-15 21:26:38.294 SpeakUp[810:215053] Audio Duration is is : 1.393197
```

Figure 4-15 Console Output of the module

Figure above represents the sample outputs of the data values obtained for a sample.

- All Peaks above thresh hold value is considered potential syllables.
- Calculating the mean and median values of the audio file.
- Breaking the audio file into samples.
- Getting the maximum value of the samples.

4.4 Data Model

There are two main data storage points.

1. Real time user scores and progress – Mobile local storage
2. Connection to SLP – Backend database (Firebase)

React native uses a local storage manager to persist data to device local storage, it's called AsyncStorage where it allows to read/write small data chunks in user devices. This is used to store user scores to populate the charts and graphs in the progress screen. To make sure the size limit is maintained, and no excess storage is required only the last 10 attempts done by the user is stored for this purpose. Furthermore, users can also decide whether to store or not their data attempt. AsyncStorage is React Native's API for storing data persistently over the device. It's a storage system that can use and save data in the form of key-value pairs. It resembles a lot like local Storage in browser API. AsyncStorage API is asynchronous, so each of its methods returns a Promise object and in case of error, an Error object. This mechanism is implemented in the application to persist user score data and calculate the score module of the user. AsyncStorage can prove very helpful when we want to save data that the application would need to use, even when the user has closed it or has even closed the device.

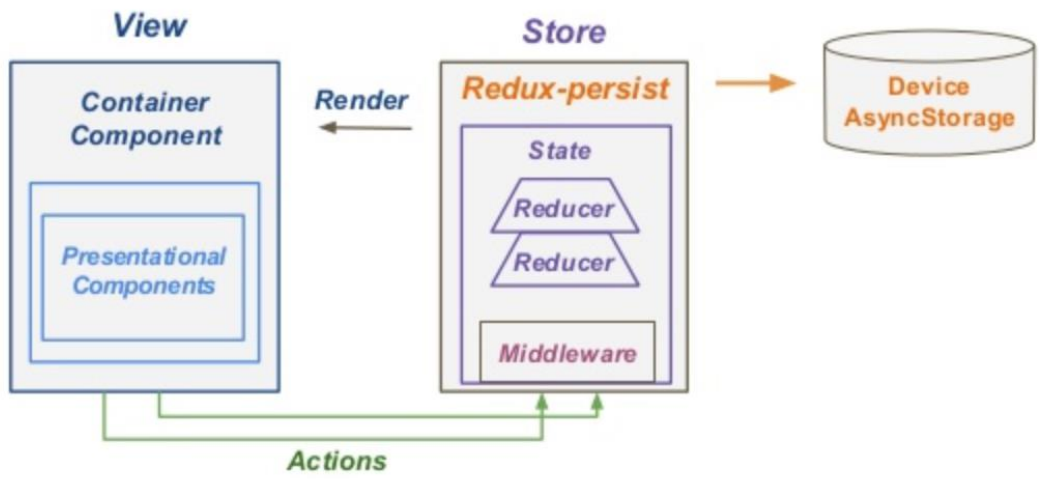


Figure 4-16 Async Storage

Firebase data storage was tested out to store the user information, recordings and scores so that a pathologists (SLP) can be reached out through the application and can give feedback to the user. Application also focus to integrate SLP so that it connects users with a person with background knowledge in this topic. Firebase frees developers to focus crafting fantastic user experiences while it manages all the aspects related to data and APIs calling them.

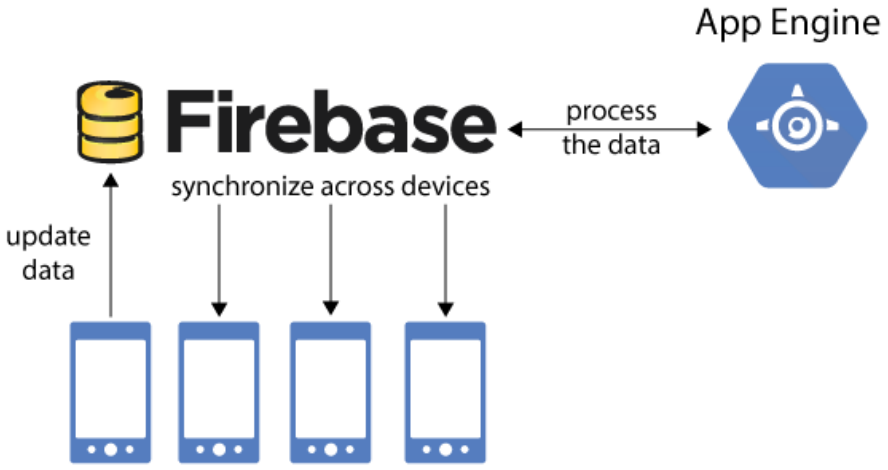


Figure 4-17 Firebase architecture

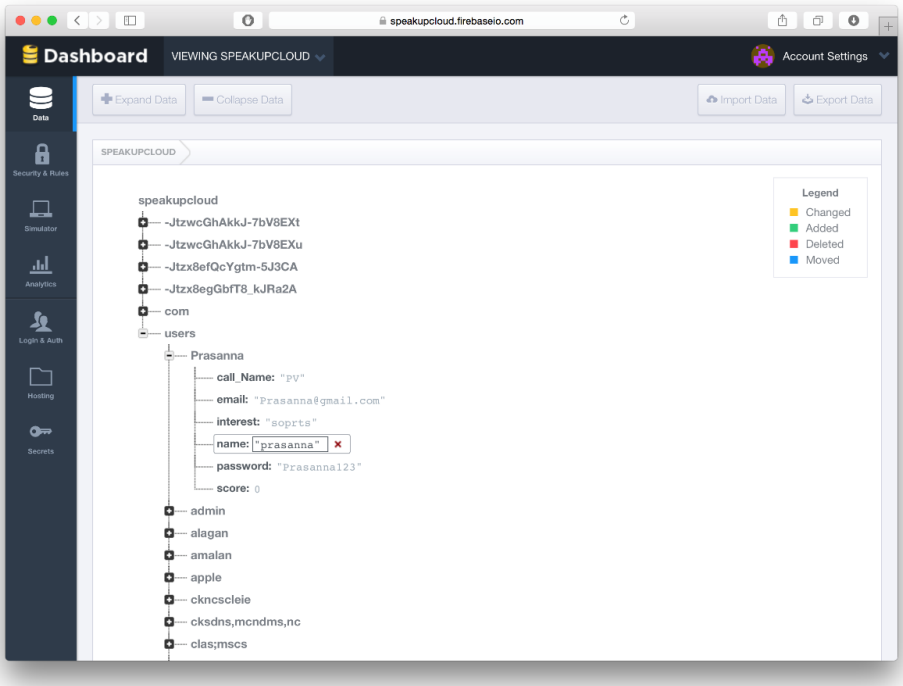


Figure 4-18 Firebase Backend

4.5 Application Architecture and Implementation

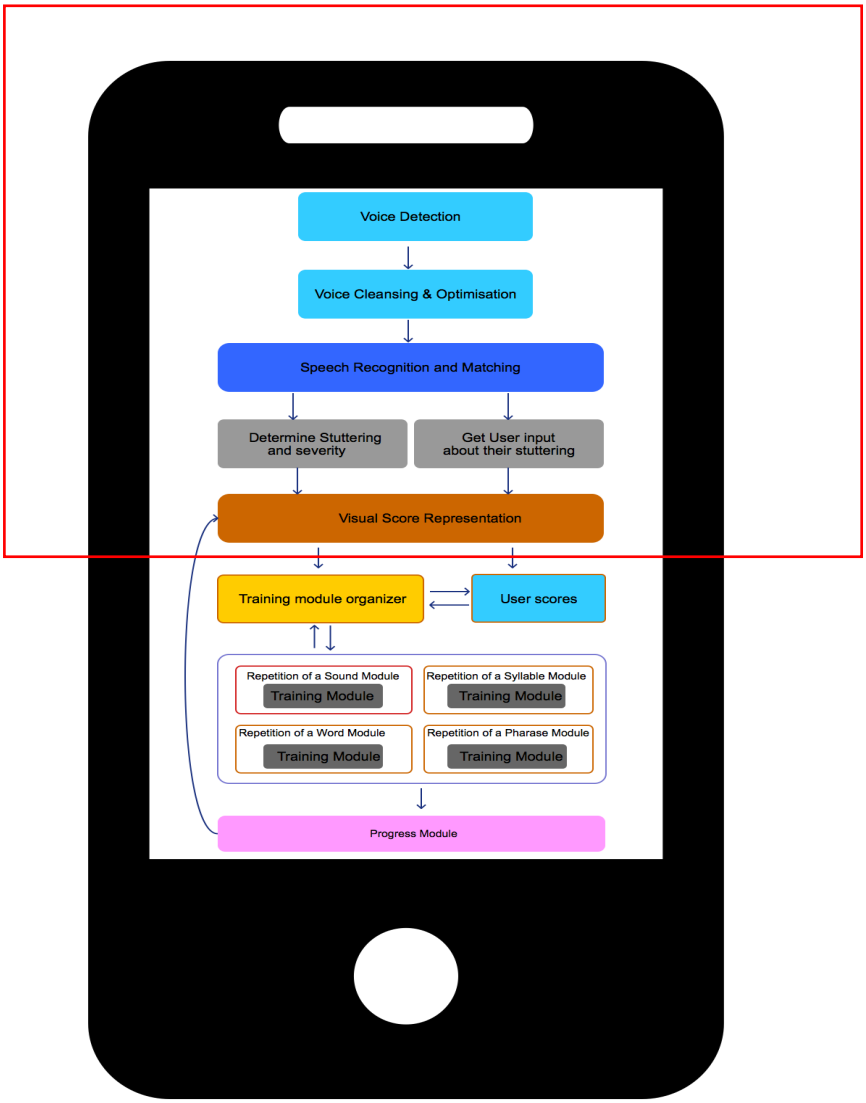


Figure 4-19 SpeakUp Architecture

The above boxed section represents the main architecture proposed for the research solution. The main input of the application SpeakUp is users voice input collected from the microphone of their phone device. Afterwards the voice input follows the below modules mentioned in the architecture diagram.

1. Voice Detection

   The main goal of this module is to detect voice and pass it to the next filtering module. React-Native-Voice library is used for this purpose. The library implements the listeners and the language model to check the input and identify the voices. Once the voice is identified it is passed to the next module for optimization.

2. Voice Filtering and Optimization

   The filtering and optimization is used to make sure the voice sample going forward to the speech recognition is in an accurate state. Using the low pass filter and the cleansing implemented by the JavaScript framework this is achieved. If the voice has a lot of noise and background clutters, it will be detected and removed before passing forward to the next module.

3. Speech Recognition and Matching

   This is a main core module in the application which takes the voice input and identifies the spoken words of the user. React-Native-Voice library extracts few method APIs which can be used to attach to the device listeners and identify the words of speech. This speech is then passed forward as an identified array list of words to the next module.

4. Identifying the stuttering severity

   The severity of the stuttering is identified with the accuracy of the speech passed from the speech recognition module and the number of syllables identified using the wave peaks of the users' voice. Also, the real time errors made by the users are identified and the severity is calculated. This final calculation will get passed to the Score module.

5. Score Module

   The score modules get the score passed and allows users to persist it to the local storage, so they can view their progress. Also uses an inbuilt star rating mechanism to show the users their score out of 5. Minimum score is kept to 1 and respective feedback message according to the scores are provided.

6. Progress Module

The progress module contains two graphs, one to show the progress made by the user in his/her last saved attempt scores and the other to show a percentage of the accuracy speech done by the user. This will make users to gain confidence and adds a gamification aspect to the application.

Additionally, users can connect to a SLP directly from the application as well for further assistance. The SLP's can access the history of users including the recordings which is pulled from the cloud database Firebase.

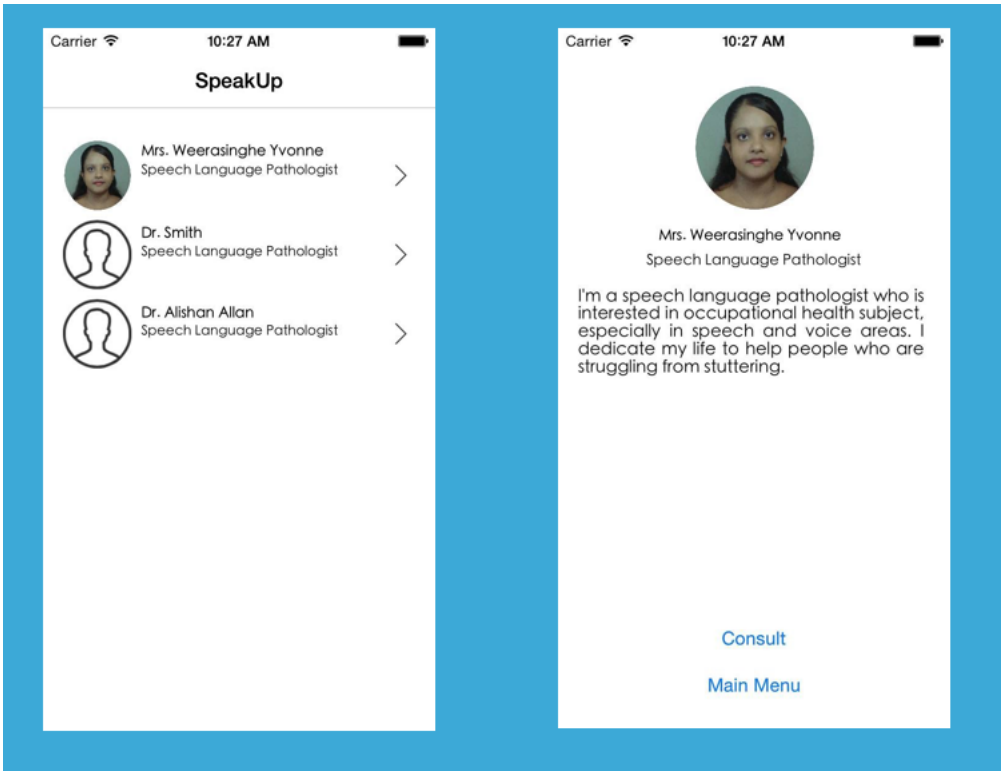


Figure 4-20 Connect to SLP

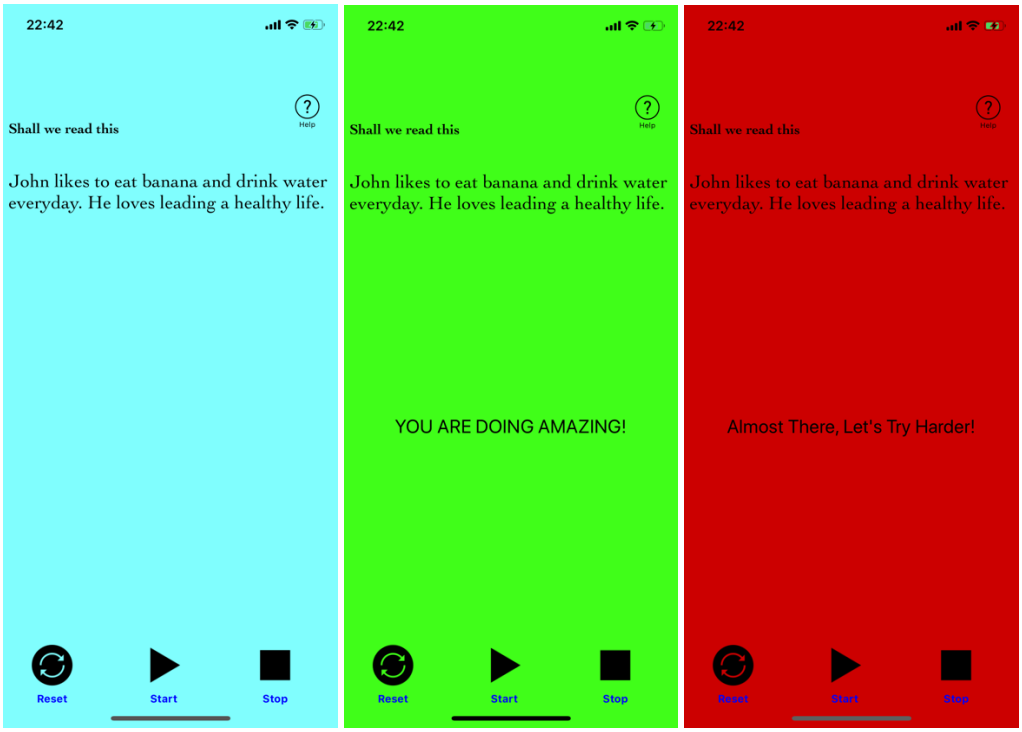


Figure 4-21 SpeakUp - Home Screen

The Home Screen of the application consists of most of the high processing modules behind it. User is greeted with a paragraph to try out. The user can start by pressing the start control and press on stop to navigate to the results screen. While the user is speaking the screen responds to the users voice real time. If the user is speaking out the expected word it will turn green and show a positive message, else it turns red and assists the user to try harder. The reset control allows users to try again before progressing to the next screen.

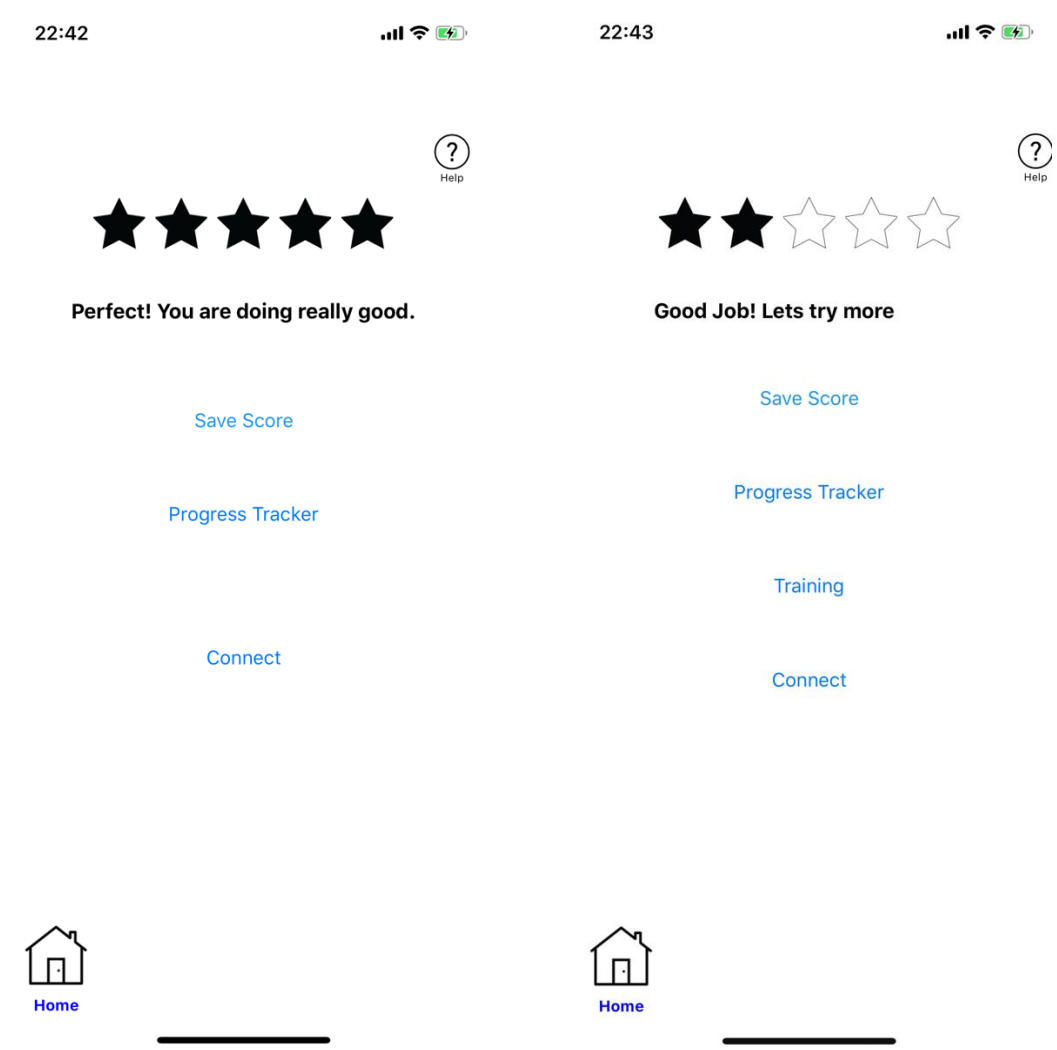


Figure 4-22 SpeakUp - Score Screen

The Score screen of the application shows the result of the test carried forward in the previous screen. User is greeted with his/her score out of 5 in the form of stars and allowed to save his/her score if needed. This screen also identifies if there is any special practice needed for the user according to his severity and allows to navigate to the individual test screen. Also, users can click on the Progress button to view their progress in graphical form.

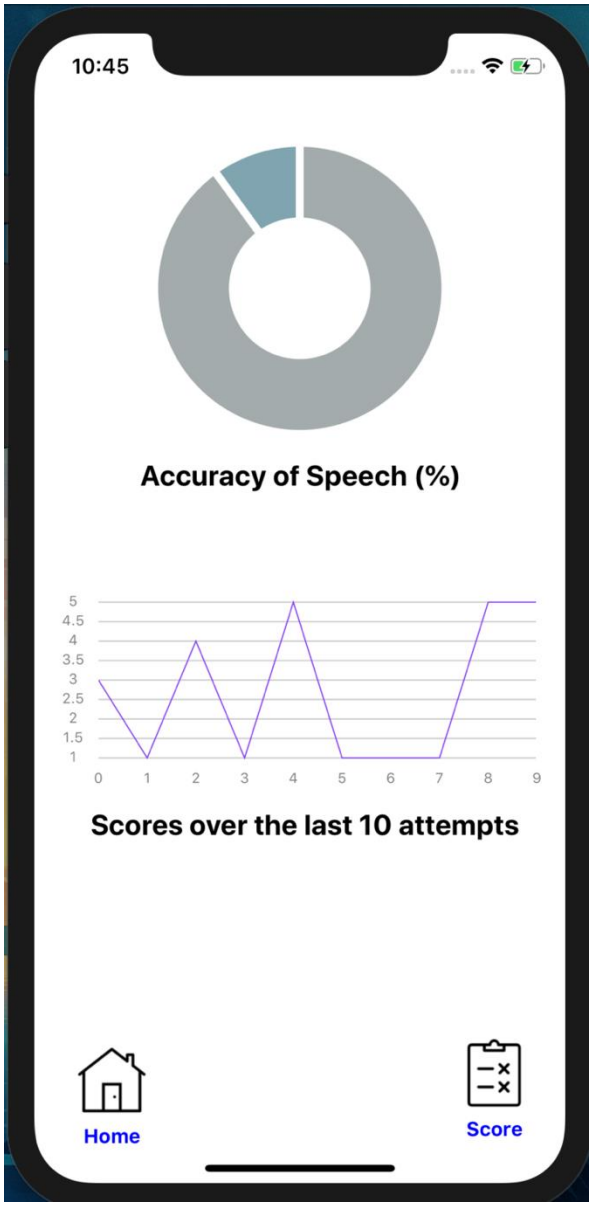


Figure 4-23 SpeakUp - Progress Screen

The progress screen shows users couple of charts in graphical form indicating the records of the score and accuracy. This will help users to gain confidence and keep coming back to improve themselves. React-Native-SVG-Graphs library is used to draw the charts and show users from the data stored in local storage.

Figure 4-24 SpeakUp – Individual Assist Screen

Individual Test allows users to practice a word which they had difficulty in the initial test. This is mainly done to improve the confidence of the user who are struggling with the initial test. The initial test identifies the areas users struggled on real time before creating the Individual Tests for the users.

3.6 UI and UX design of the application

Psychological factor plays a huge role in the success of this application where user's reactions are considered as a main step towards achieving the main goal. Psychological conditions such as mood and anxiety affect the final results of the application. In order to provide a user-friendly interface to the users' research study was conducted before designing the user interfaces. Throughout the application the screen is mainly divided into three areas. They are status bar, content and user control. Additionally, help interface is provided for each interface to notify the users how each interface works and how to get the maximum out of them. Users can disable them in settings when they are comfortable using the application.

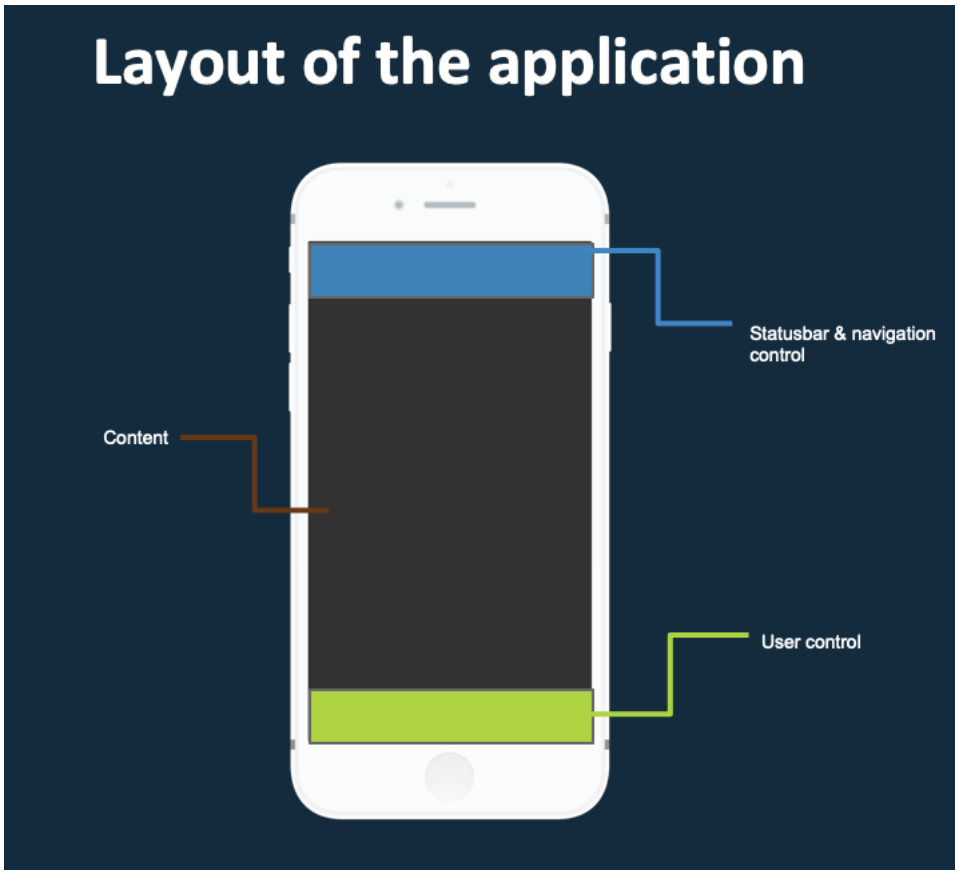


Figure 4-25 Structure of SpeakUp UI

User interfaces place a huge part in the modern era of building mobile applications. In a real-world scenario, we need to create a feeling of belonging emotionally with the user when building application. Choosing the correct color and the position of the elements to the eye level plays a huge role to keep the user interested in the application. Research studies were done on color scale and user accessibility to make sure better user experience was provided to the end users. Since the domain of stuttering is directly affected with the user moods and experience it plays a huge role for the success of Speakup. Proper icons, navigation and help guide also plays a longer way for the users to understand and use the application efficiently.

Figure 4-26 Icons of SpeakUp

Figure 4-27 Help Interface

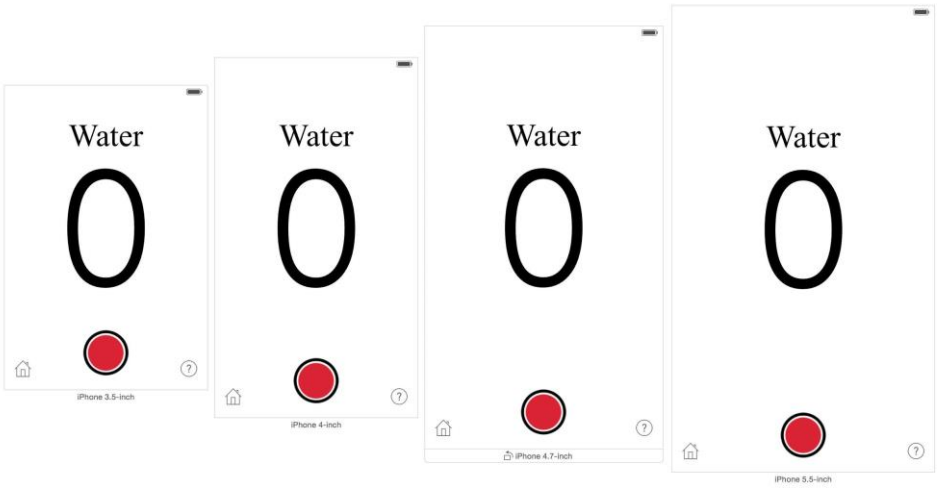


Figure 4-28 Interfaces tested in different size devices.

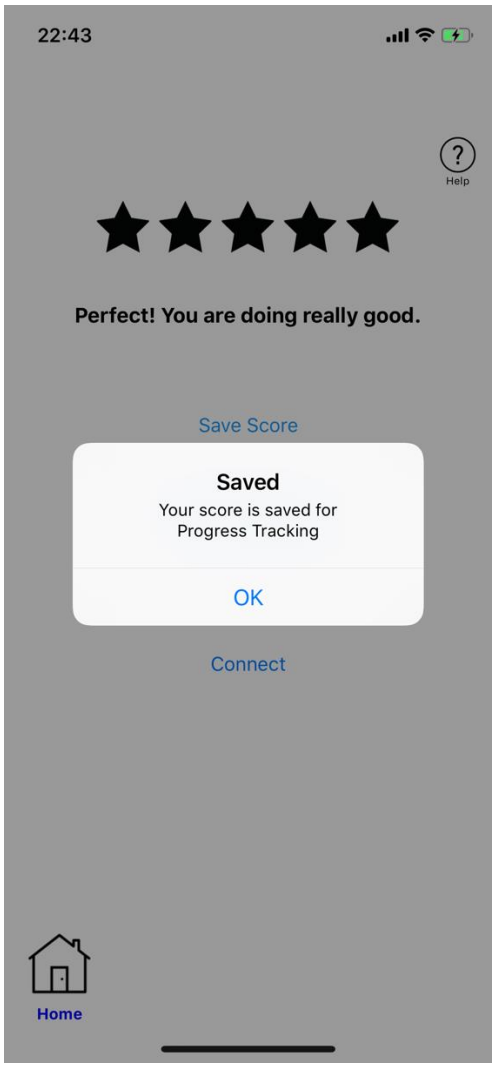


Figure 4-29 Local Storage Confirmation

5 EVALUATION

5.1 Testing and Experiments

Each core module of the application was tested both unit, individually and as an integrated system. Continuous integration was done throughout the lifecycle to identify potential errors in the early stages and rectified them. The application was finally tested for user acceptance testing with real clients and pathologists. Each individual module is tested and resulted with an overall average of 76% accuracy.

Application is tested for a defined time period of 30 days with an individual who is affected by stuttering. The case study shows the improvement of the user with continuous training, though there are few lower scores resulted by psychological conditions such as mood and anxiety. The end result of the application depends on the commitment of the user with the training techniques. To keep the users committed features like Gamification and materials with interests of the respective users are implemented. The application results were justifiable to produce a conclusion that there were improvements by an acceptable level.

The figure below shows the real time testing with a stutter and the results obtained. It was evident that the user scored more stars when he practised slowly and improved gradually. Real world setting was set up to test the module with respect to voice filtering and optimisation. Even though the accuracy of the modules was not consistent it was shown that they provided and acceptable level of accuracy at all times.

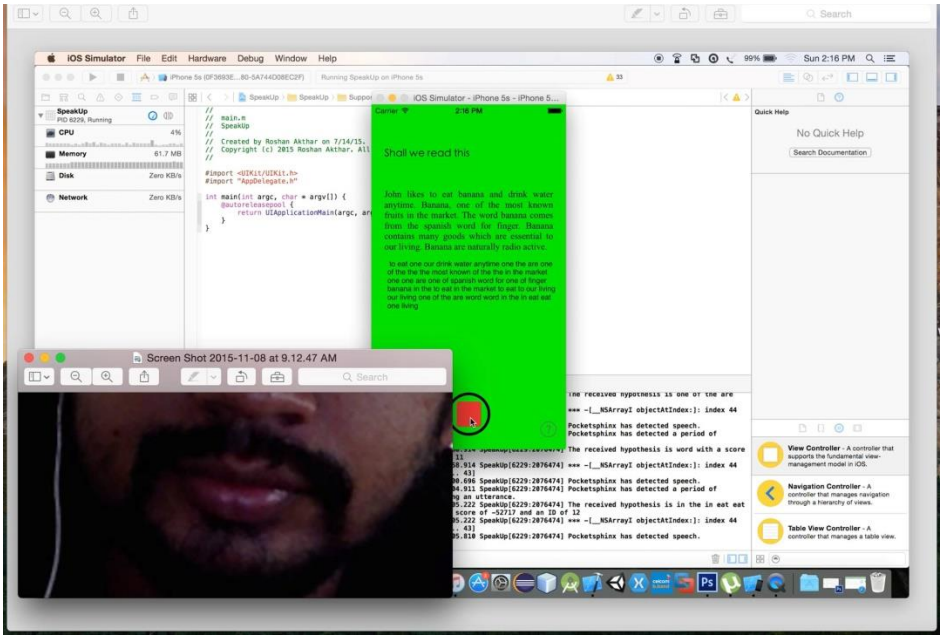


Figure 5-1 Real World Testing

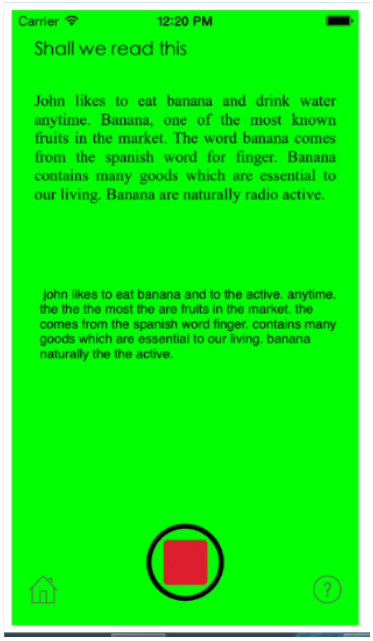


Figure 5-2 Speech to text accuracy testing

The above shows the output of the speech to text module in order to test the module with accuracy. The module resulted with an overall average of 85% accuracy.

5.2 Test Results

Three categories of the users were tested with the application with diverse sample space to cover most of the real-world scenarios. They are

1. People who are identified as stutterers previously – 4 individuals
2. Clearly speaking individuals – 7 individuals
3. Kids category stutterers – 3 individuals

Each scenario the process was consistently practiced. Initially the user is allowed to go through the application by their self to monitor and understand if it is clear to operate within all variety of audiences. After the initial test is done they are briefed about the application and the usage features. Application was deployed to their mobile devices using Expo, a simplified runtime for React Native applications directly to mobile phones. Users were given a period of 30 days to use the application and report any issues they faced. At the end of the period using the local storage and database information was gathered to analyze the results and also direct feedback form was provided to the users to understand their day to day experience with the application.

Using the help of SLP and the data storage information the results were analyzed to derive conclusions. The feedback of the users is also attached at the bottom section of this report. Additionally, few other sample set of users were given the application in hand to determine the user experience and user interface study results of SpeakUp.

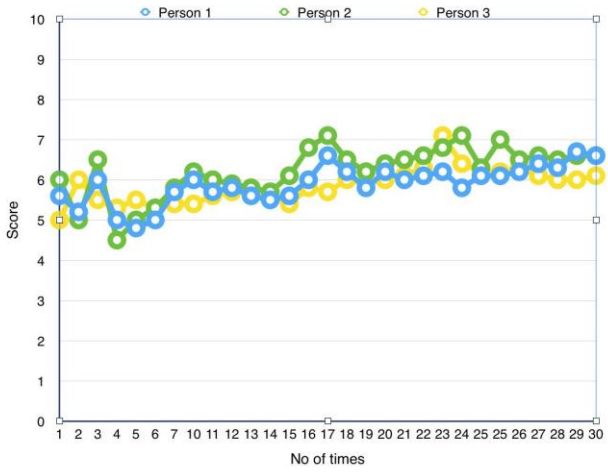


Figure 5-3 Image of a graph indicating the case study of the user categories

Words	User															Average time Taken
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Water	4.9	5	5.1	4.2	4.6	3.2	5.8	4.3	5.8	6	5.3	5.6	5.4	4.4	5.4	5
Elephant	5.2	7	4.6	6.3	5	7.2	6.2	6.8	5.7	5.2	5.1	6.4	6.8	6.2	6.3	6
Banana	5.7	6.2	6.5	5.8	5.4	6.5	6.3	5	5.9	6	6.8	6.1	6.6	5.2	6	6
Pillow	4.1	4.3	4.1	3.5	4.5	3.8	4.2	3.9	3.7	4.5	3.8	4.1	3.5	3.4	4.6	4
Wonderful	5.9	5.9	6.2	5.2	5.4	6.2	6.5	6.3	5.8	6.1	5.4	6.6	4.9	7.4	6.2	6
Icecream	3.8	4.2	3.9	3.5	4.5	3.5	4.1	3.5	4.5	4.3	4.1	4.2	3.8	4.2	3.9	4
Books	1.5	2.3	1.6	1.7	2.4	2	2.5	2.7	2.1	1.5	2.1	2.1	1.2	2.2	2.1	2
Car	1.8	1.4	2.2	2.3	2.1	1.5	2.3	2.2	1.2	2.4	2.1	2.3	1.9	2.2	2.1	2
Encyclopedia	9.3	8.4	10.5	10.2	11.1	10.3	8.5	10.7	10.6	9.1	9.3	11.6	9.3	10.4	10.7	10
Bread	2.1	1.6	2.3	2.1	2.5	1.4	1.2	2.2	2.6	1.4	1.3	2.6	2.8	1.6	2.3	2
Pencil	4.3	4.2	3.1	3.6	2.7	3.3	3.6	3.6	4.5	4.7	3.4	4.2	3.8	4.4	6.6	4
Grapes	3.8	3	3.3	4.4	3.9	3.7	4.1	4.6	4.1	4.3	4.2	3.7	3.8	3.9	5.2	4

Figure 5-4 Case study information on average time taken for sample words

Main Key points from the results

- Each use case scenario users found improvement with time
- Users main feedback was to change the speaking text to increase interests and difficulties
- Users found that user experience was really good
- Couple of scenarios were reported where the scores were not calculated correctly due to the issue in the noise of microphone input
- Users agreed a mobile application solution was friendlier and allows themselves to express more than directly with SLP.

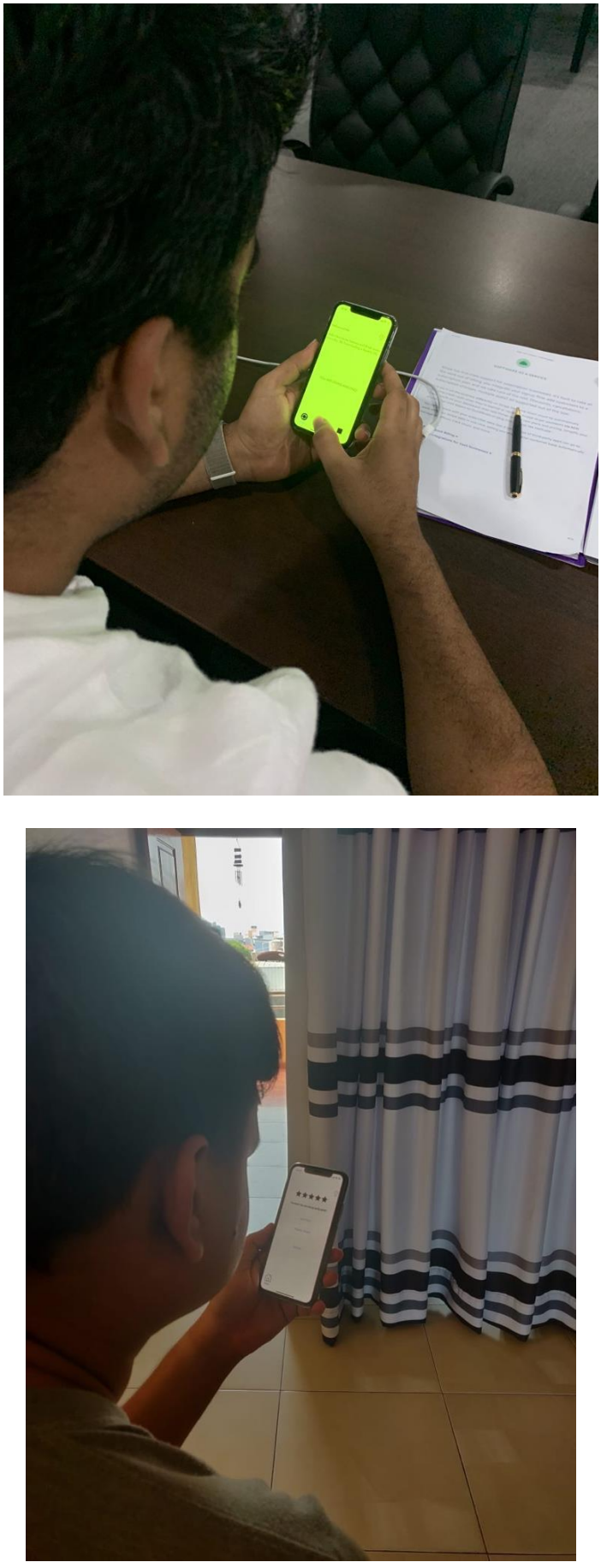


Figure 5-5 Real world testing with SpeakUp

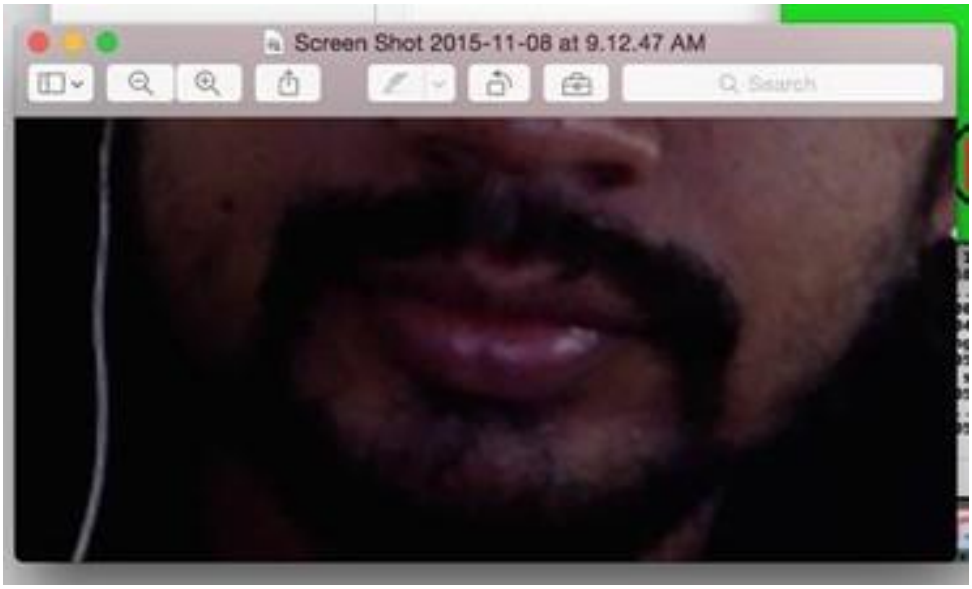


Figure 5-6 Testing the application with stutterers

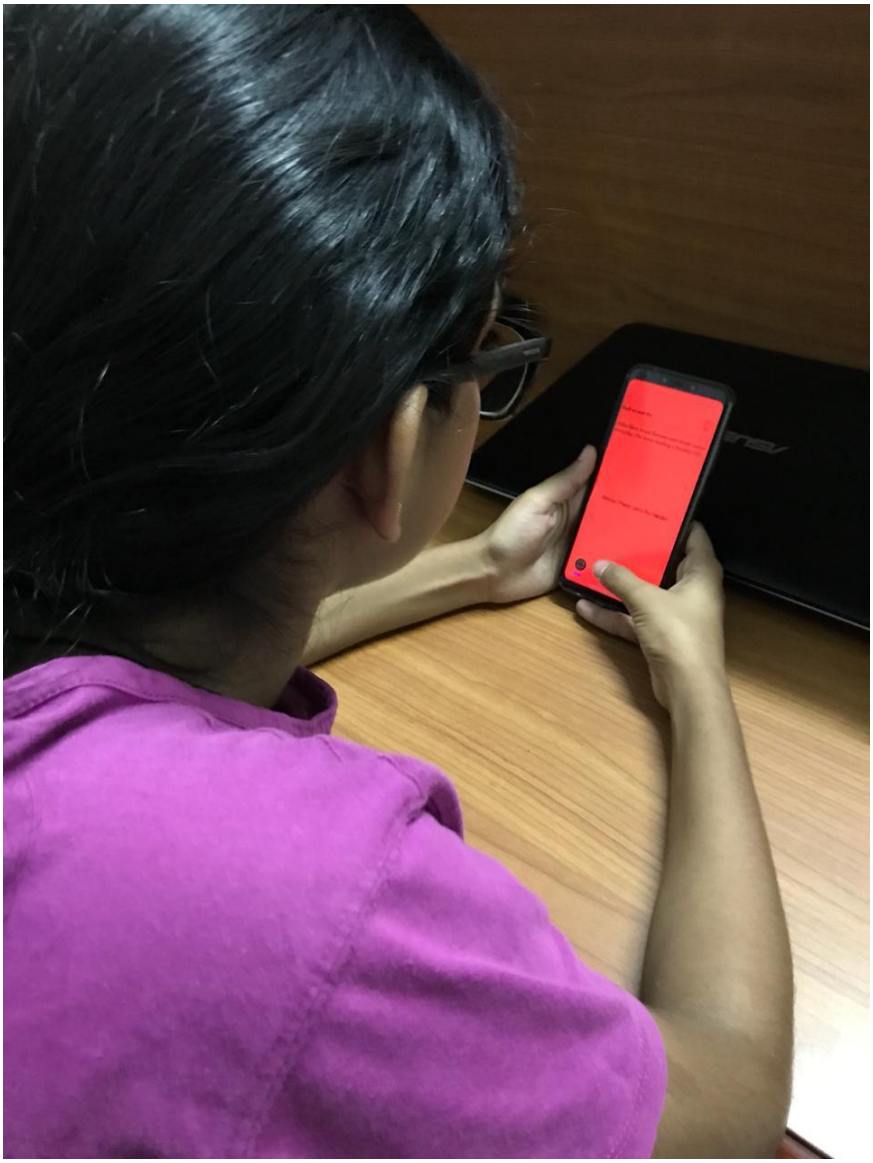


Figure 5-7 Application testing with kids

5.3 Voice analysis verification

Voice analysis verification was done to make sure with evidence that the optimization of the voice input was done correctly for the identification of stuttering. Initially different audio inputs were tested out with noise, using an online tool Online voice recorder a web-based illustration of the input was studied. Additionally, TwistedWave, an online tool to upload and understand the voice wave was used to analyze the difference with and without noise. EZAudio, an audio visualization framework built upon Core Audio for real-time, low-latency audio processing and visualizations framework was used to graphically understand the different waveforms and evaluate the improvement done from the application SpeakUp module.

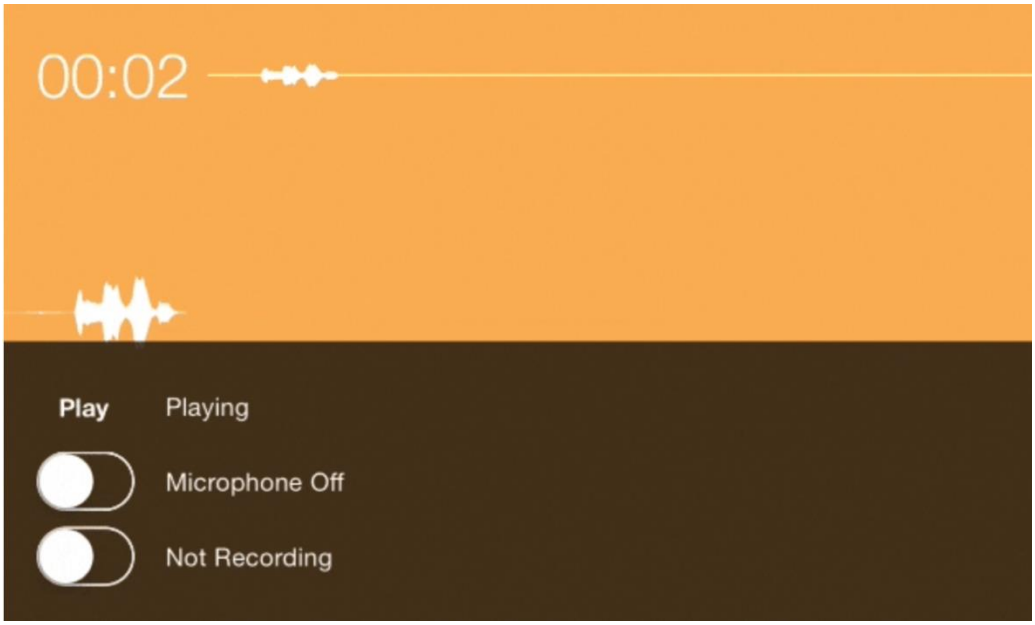


Figure 5-8 EZAudio real-time output of words used in SpeakUp

Figure 5-9 EZAudio waveform from an audio file

Evaluating the application on different mobile devices proved that the low pass filter mechanism impact was highly found on older devices. For example, iPhone X which was a latest device showed less improvement compared to an old model iPhone 6 as the microphone of latest devices have the hardware capability to remove noise from incoming audio input on them. This provides less or no work for the application module to clean the noise. But improvement of removing noise was seen visually in older devices as shown below.

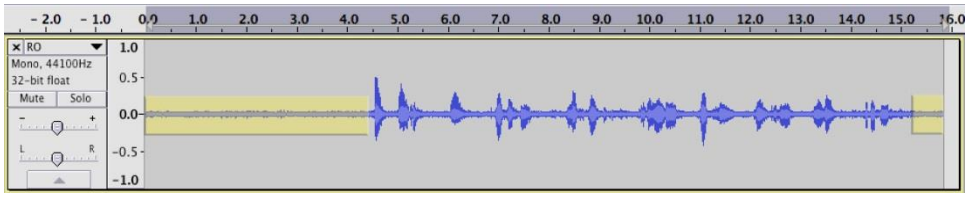


Figure 5-10 Audio wave of input without the optimization module

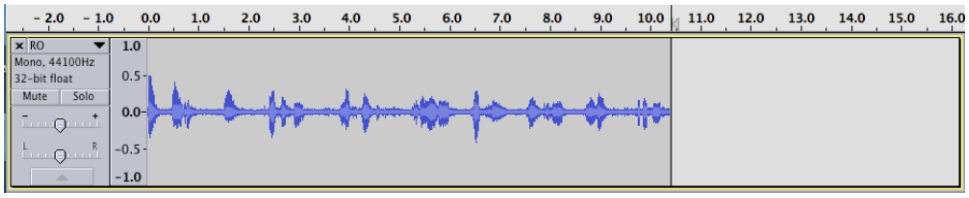


Figure 5-11 Audio wave of input with the optimization module

Various online tools were used to map the audio samples to understand the different patterns in wave peaks and frequency. Big audio files were broken down into few smaller chunks for accuracy. It was evident that the breaking of the stuttering severity on voice peaks was accurate of 81%.

Figure 5-12 Sample audio wave pattern

5.4 Speech to Text verification

Speech to text recognition was tested out with different samples of wordings. Application on debug mode prints out the spoken words real time. This showed that the speech to text conversion module had accuracy of 89% on all the sample tests tried out. This is a main achievement of this research as this component impacts on the final result of the user as well as real time impact as we are changing the background color on the correctness of the users' speech each second at real time of the application SpeakUp.

Long paragraphs as well as small words were experimented as well, and all scenarios showed positive outcome towards the results. Only impact of wrong results was observed when accent was used in speech of similar pronunciations as the machine detects few words as same type. For example, "banana" with a different accent was detected as "Ann-ana". Overall normal speech and the voice samples which was gathered as data input for evaluation proved positive outcome from this module.

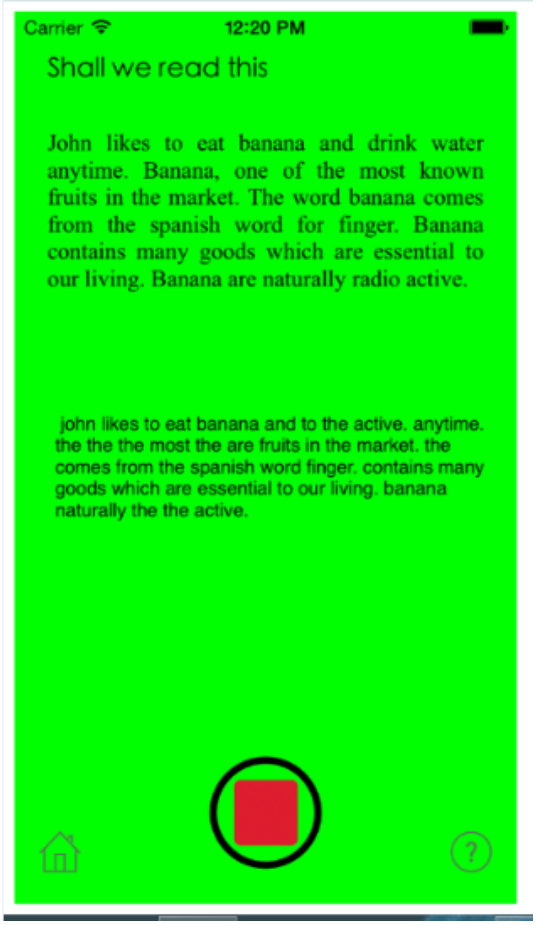


Figure 5-13 Speech to text verification

5.5 Feedback

Feedback from the users were a main motivation part of this research. Feedback was collected from the real sample users and the SLP. Unbiased sample was taken into consideration when feedback was collected.

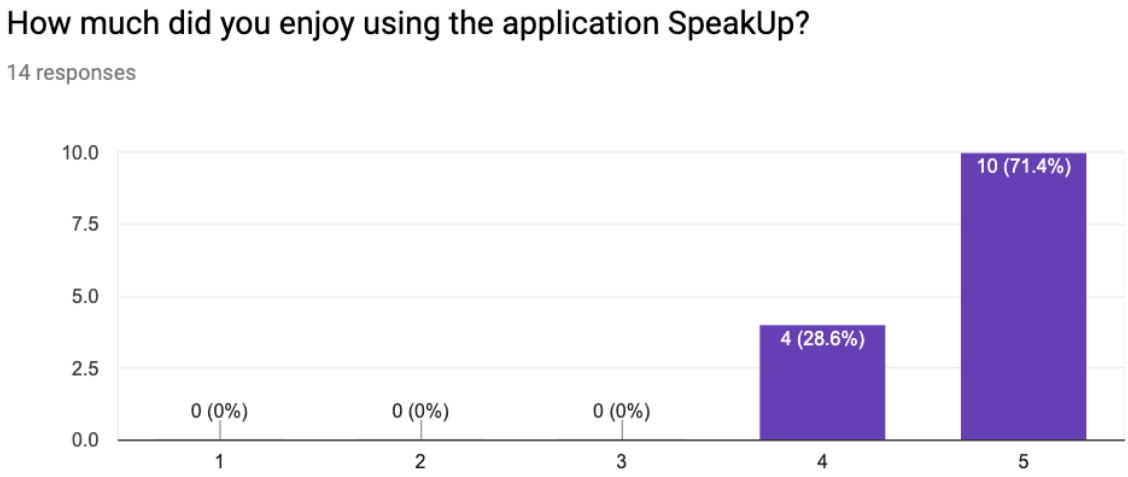


Figure 5-14 Feedback - Enjoyment rating

71% of the users rated the application to be enjoyable, this was one of the research area where user experience was studied to make sure less frustrations were caused to the user while using the application. As emotions plays a huge part for stutterers to perform to their best, proper user interface practices were followed to provide good experience and enjoyment to the user. Furthermore 93% was rated toward the success of the UI/UX as per below feedback chart.

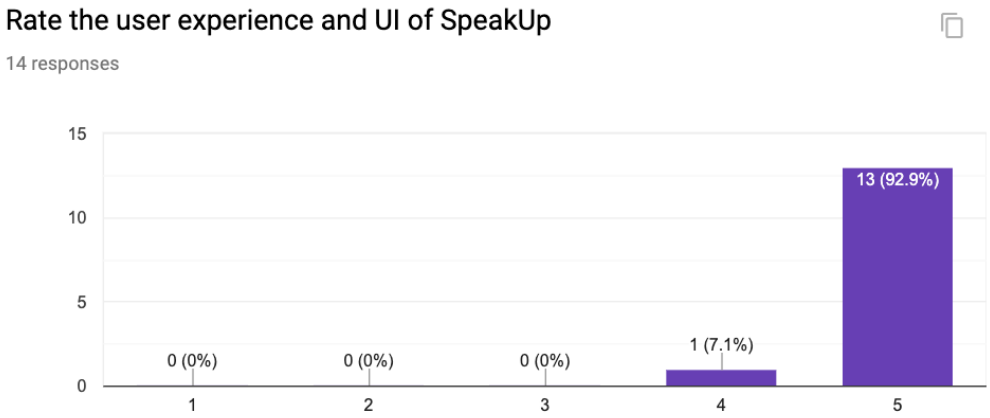


Figure 5-15 Feedback - UI/UX rating

Feedback on the progress improvement seemed really positive as users found the application useful and showed progress with the use for a period of time. The main improvement point is about the availability of interactive help guide as users seems to get lost in navigating to help page and returning back to working screen. Improvement can be made to give users interactive assistance according to their landing screen. Couple of incidents were noticed where users did not understand the help guide specially with small kids.

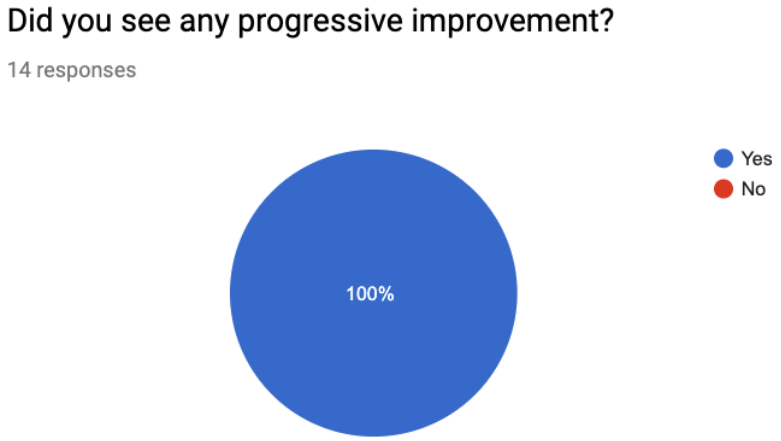


Figure 5-16 Feedback - Progress improvement

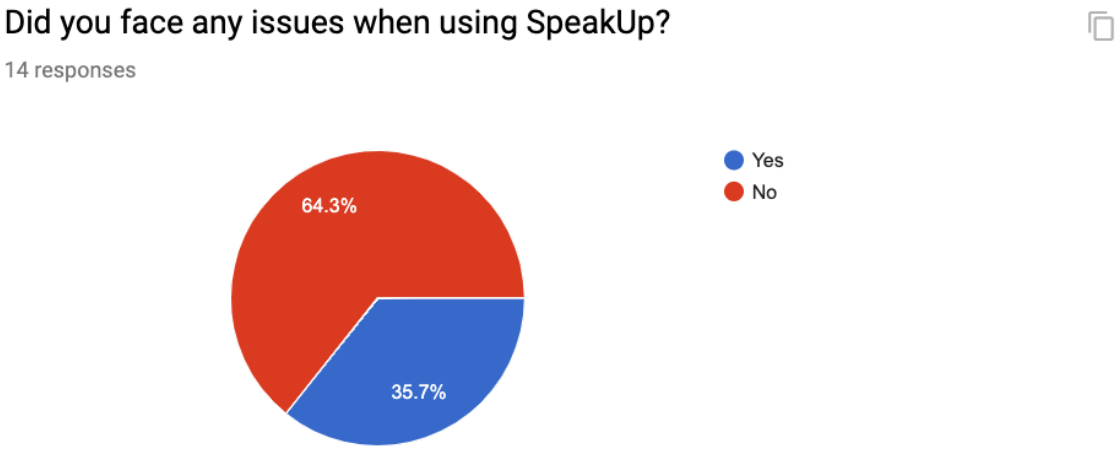


Figure 5-17 Feedback - Errors

Figure 5-18 Feedback - Improvement areas

Motivation was another key role when it comes to overcoming stuttering. Only way of positive results from this application is to be motivated enough to come back over and over again and train to speak up. It was successful to see this aspect being achieved with 78% voting they were highly motivated.

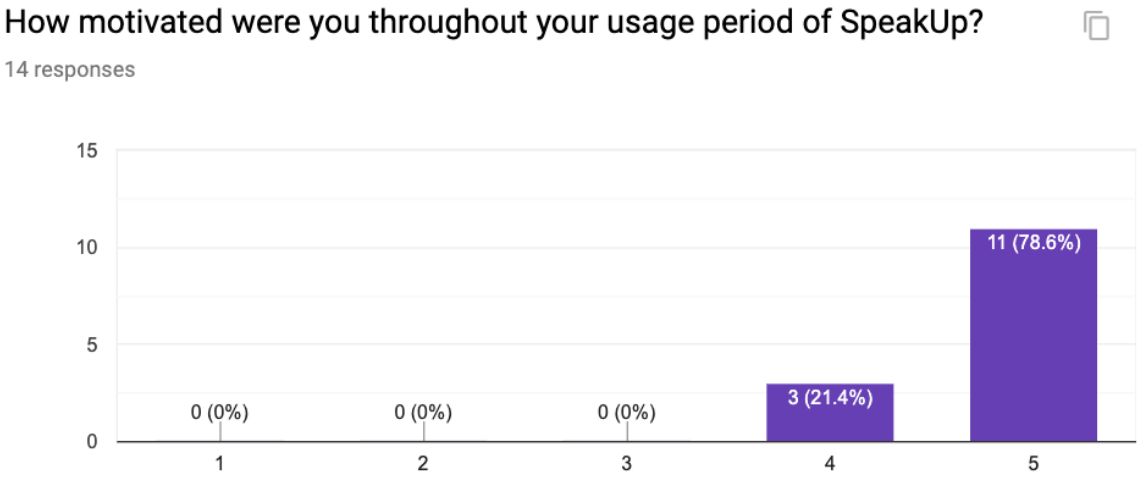


Figure 5-19 Feedback - Motivation

Please leave any feedback of your experience

14 responses

Really good application which serves the purpose and have a really good UX
Really good service for people who stutter, can improve on the accuracy
Help page can be improved like other UI
Really good app and good experience
I faced one issue on my score, it kept to 0 always. restarting the app worked fine after that.
It was a good application for stutters, I felt more confident with time
Nice app
Helped to practice and improve my stuttering well, nice concept
I like to practice on app everyday than visiting a doctor
Really good concept, hoping to see in app store soon
Really good to see a real time application for stuttering
Nice concept

Figure 5-20 Feedback - Overall feedback

What is the feature you enjoyed the most?

14 responses

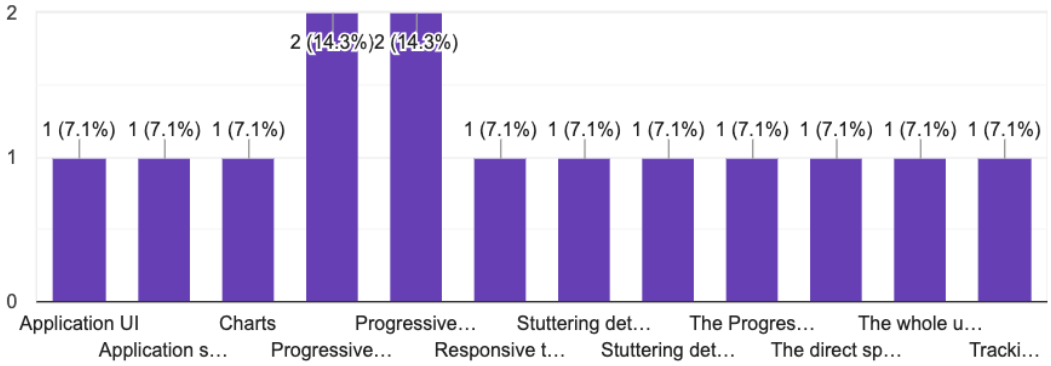


Figure 5-21 Feedback -Enjoyed features

5.6 Evaluation Results

Research Module	Accuracy
Voice optimization	81%
Speect to Text	89%
Score	89%
UI/UX	95%

Table 5-1 Evaluation Results

Above results were obtained from evaluating the application with different sample set of data and actual real users feedback. One of the main challenge of evalating SpeakUp application was to get real data of stutterers. Due to legal terms the SLP was not able to directly send the audio recordings but was able to use online tools such as Youtube and recordings played by the SLP with the clients permission to evaluate the application. Total of 100 recordings were evaluated with additional 14 real users having the application to use in their mobile device for a period of time. Additionally researchers from england who recently published simlar study six months back were in touch and communicated for advices frequently. [11]

	A	B	C	D	E	F	G	H	I	J
1	No of words	Frequency of Speech (Avg)	Syllables Expected	Syllables Detected	SpeakUp Score	SLP Rating	Attempts	Recording Reference	Conclusion	
2	13		16	18	5	Very Good	1	Rec-00000005		
3	12		23	46	1	Very Bad	3	Rec-00000134		
4	11		23	30	3	Neutral	1	Rec-00000105		
5	10		25	25	5	Very Good	2	Rec-00000345		
6	15		23	30	4	Bad	2	Rec-00000025		
7	12		19	20	5	Very Good	1	Rec-00000231		
8	12		27	15	3	Neutral	1	Rec-00003005		
9	11		26	24	5	Very Good	1	Rec-00000012		
10	15		21	23	5	Very Good	1	Rec-00000011		
11	18		21	45	1	Very Bad	1	Rec-00000290		
12	14		20	43	1	Very Bad	1	Rec-00021005		
13	14		18	34	2	Bad	1	Rec-00000411		
14	13		16	30	1	Very Bad	1	Rec-00005629		
15	12		14	5	1	Very Bad	1	Rec-00000009		
16	11		13	5	1	Very Bad	1	Rec-00000042		
17	10		25	27	5	Very Good	1	Rec-00000873		
18	17		26	26	5	Very Good	1	Rec-00001853		
19	14		29	29	5	Very Good	1	Rec-00011983		
20	13		25	10	2	Bad	3	Rec-00000023		
21	14		21	51	2	Very Bad	1	Rec-00000011		
22	12		24	34	3	Neutral	1	Rec-00000105		
23	11		21	22	5	Very Good	1	Rec-00060005		
24	14		23	22	5	Very Good	1	Rec-00034005		
25	11		24	22	5	Very Good	2	Rec-00000105		
26	12		22	10	2	Bad	3	Rec-00000345		
27	11		23	30	3	Good	1	Rec-00000025		
28	10		25	25	5	Very Good	2	Rec-00000231		
29	15		23	30	3	Neutral	1	Rec-00003005		
30	12		19	20	5	Very Good	1	Rec-00000005		
31	12		27	15	3	Neutral	1	Rec-00000105		
32	11		26	24	5	Very Good	1	Rec-00000345		
33	15		21	23	5	Very Good	1	Rec-00000025		
34	18		21	45	1	Very Bad	4	Rec-00000231		
35	14		20	43	1	Very Bad	1	Rec-00003005		

Figure 5-22 Data set for evaluation

Above data set (complete dataset attached at the end of report) was listened thorugh the application to compare the application rating and the SLP feedback of the stutterer. Since the actual recordings were not passed and only the audio was listened through the microphone multiple attempts were made to get the output due to factors such as noise. Also the application results were only found different on 7 incidents in which couple of the recordings were very soft on volume.

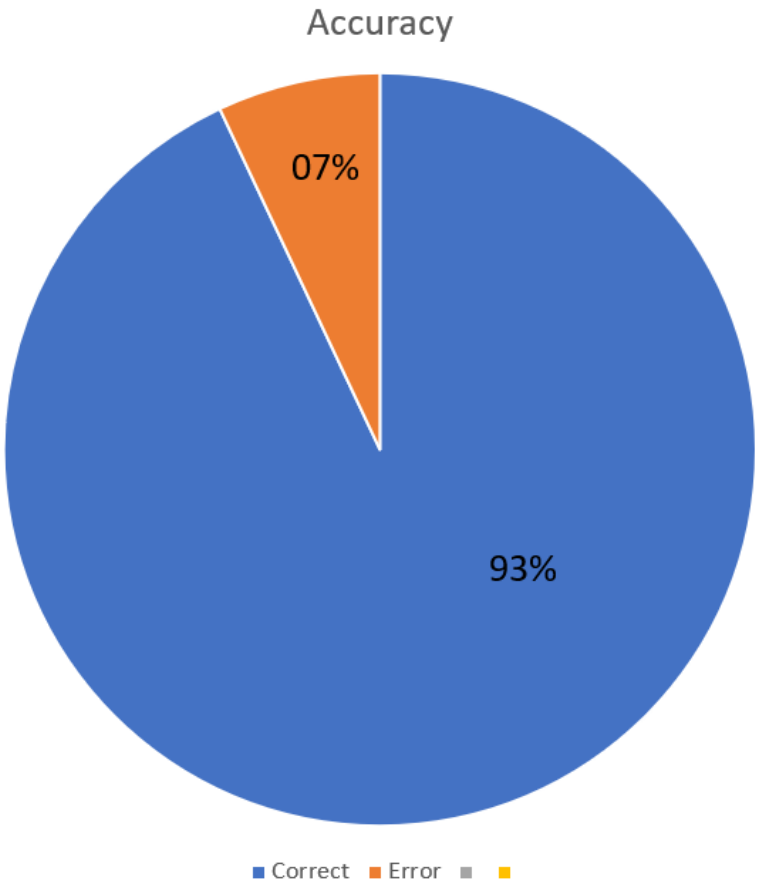


Figure 5-23 Accuracy of the sample data set

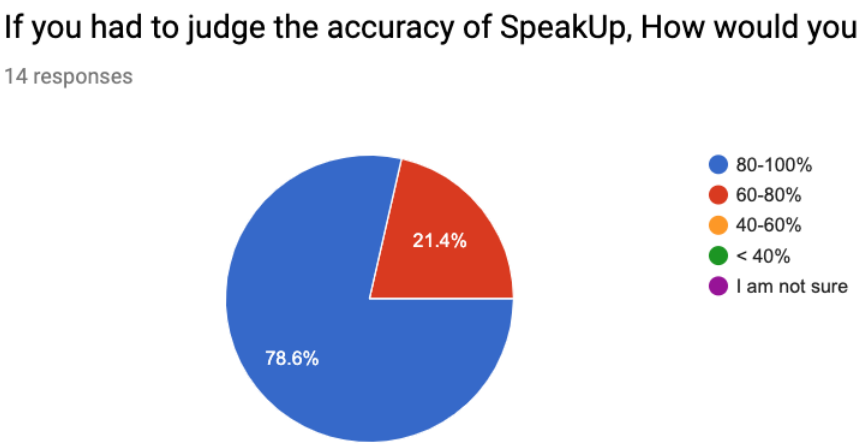


Figure 5-24 Feedback – Accuracy

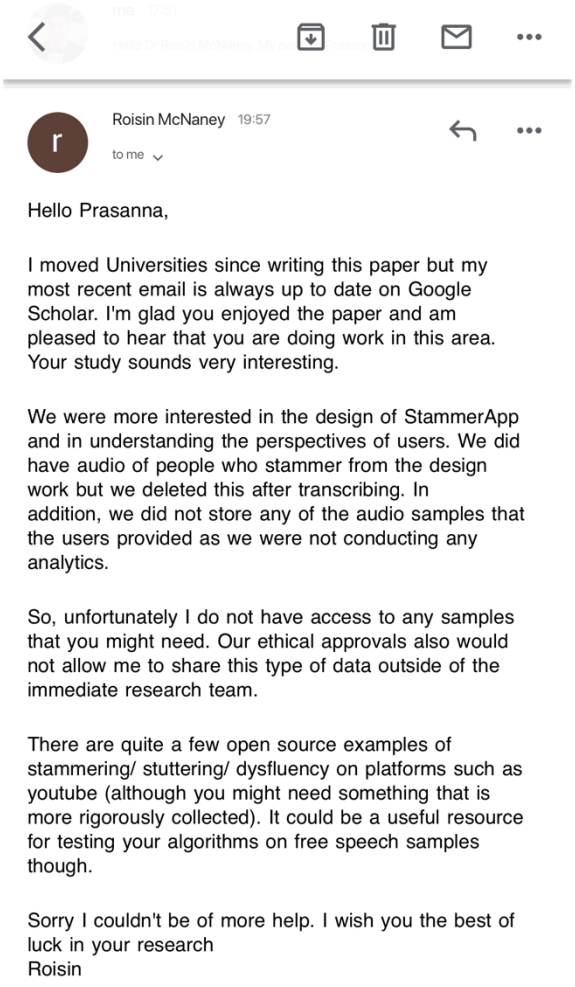


Figure 5-25 Communication with StammerApp researchers

6 CONCLUSION

In this document, a methodology to train and overcome stuttering using a mobile application was presented. The mobile application mainly targets the individuals who have stuttering. Users' commitment plays a positive role on the final outcome. Users will be provided with a scoring model and star rating to keep them interactive with the application. Furthermore, this application allows users to consult a Speech and language pathologist (SLP) to get additional guidance. The document states how the research was carried out for literature. By providing the exercises the mobile application will meet the user requirements and maximize the chance of improving the stuttering while user friendly and easy to access to everyone. The application allows individuals to train and overcome stuttering by an acceptable level and be aware and spread the positive message in the community.

To prove the necessity of research are on-going literature was provided including the latest study on this research domain only 6 months before last year and the researchers of the study from England were contacted frequently to get advice and guidance. Additional literature done before on the same domain knowledge was addressed and presented how this research is carried forward on its unique way. Syllable Counter is a core part of the application which can be reused for all the training methodologies. There are many challenges when coming up with the perfect Syllable Counter but with necessary research and applying the best principles of software architecture I believe it was achieved in reusable and efficient way. This module can be replaced at any stuttering overcoming exercises such as Slowed reading and Easy Onset to get the initial user input and process them before the actual practices to determine the severity of the user. There is no single cure from stuttering directly, past researches and SLPs have proved that an individual commitment of practising over and over again for a period of time will allow to improve from stuttering gradually. Therefore, motivation factors such as progress charts and gamification were added to SpeakUp to keep the users committed to the cause.

User interfaces and the whole experience plays a huge role in keeping users coming back to the application. After research study on UI/UX, elements placement and colour on mobile screen, user centric experiences were targeted in this research project. When evaluated from the users for feedback this was significantly seen as a positive factor of the application. The main objective of the application is to improve the stuttering by an acceptable amount. In reality stuttering cannot be taken away it can only be overcome with time by practicing the methodologies consistently. SpeakUp allows users to input their voice and see how they scored from their speech, in need of special attention it also suggests additional word by word exercises to give confidence to the user. Progress charts and score model will motivate users to try more to see their progress up to date in real time. At any point to get support from SLP users can export their data stored on the application data model and connect directly to SLP from the application. SpeakUp acts as a pocket assistance to people who stutter and for SLP it acts as a database to keep track of their clients. Main concepts of software architecture were carried out in the process of this research study with trending technology backing up the product.

As of future work, research can be carried out to use the time variable included when breaking sample audio for peak identification in the stuttering detection module. Methodologies such as template matching can be researched to compare the wave pattern between normal users and stutterers to improve the accuracy of the syllable counter module research module.

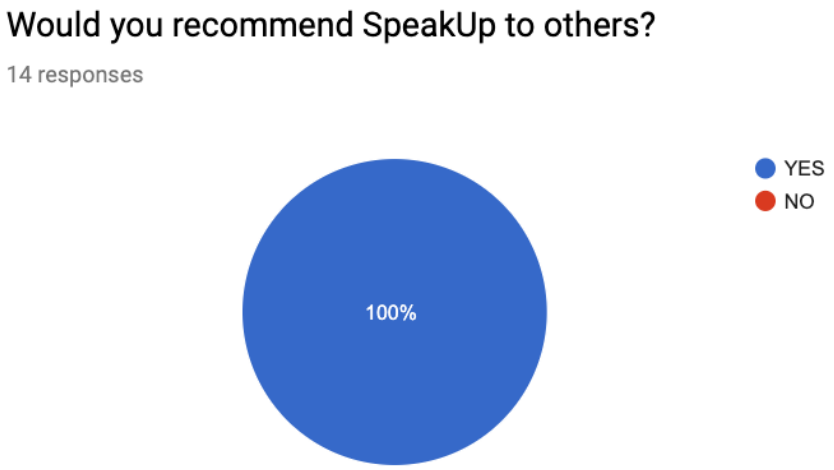


Figure 6-1 Feedback - Recommendation

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   Book by Malcolm Fraser
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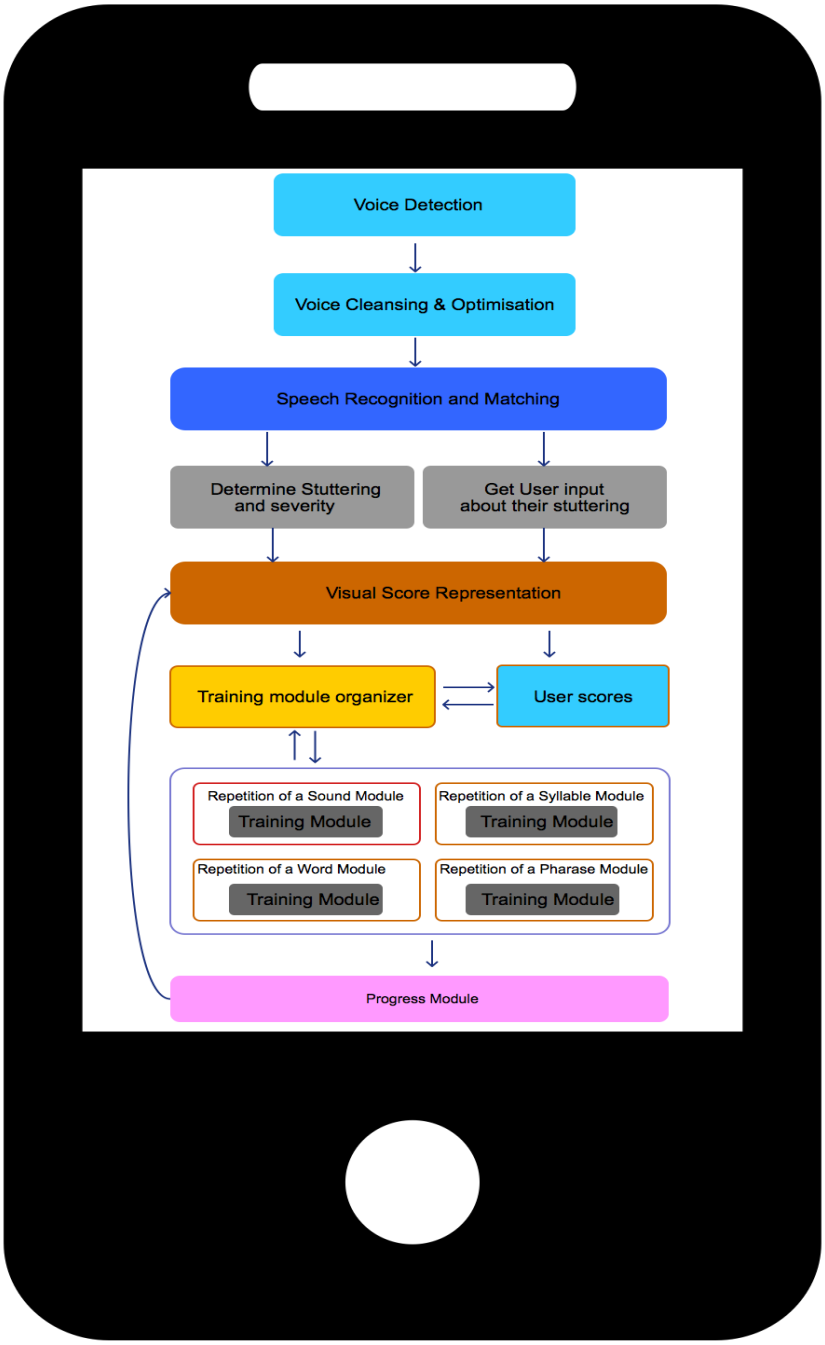
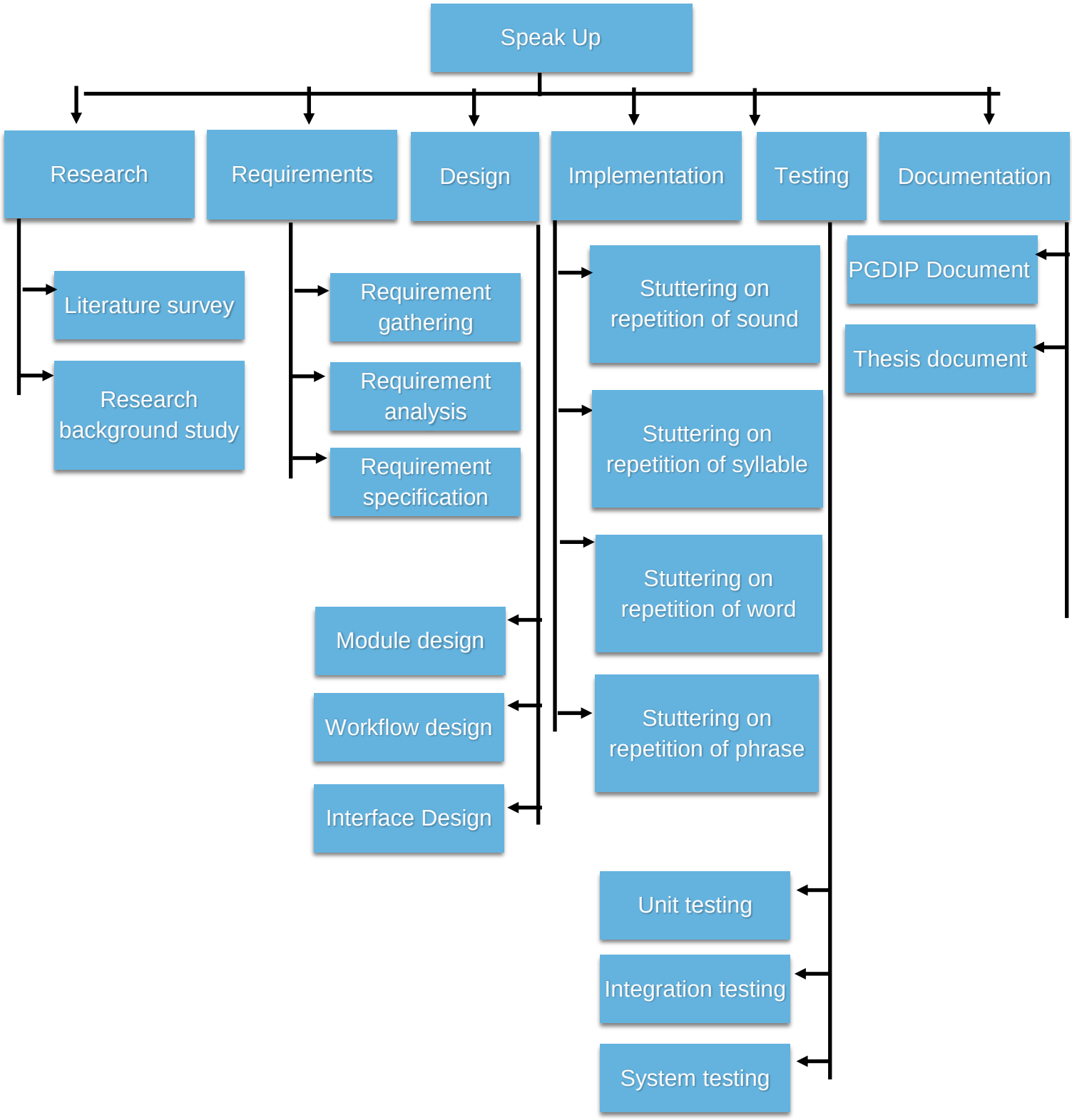
    - Book by Bjorn Schuller
22. Speech Analysis for Automatic Speech Recognition
    - Book by Noelia Alcaraz Meseguer
23. Public attitudes toward stuttering in Poland (Conference Paper November 2013 by Aneta Przepiorka, Agata Błachnio)

Appendices

High level Architecture diagram



Work Breakdown Structure

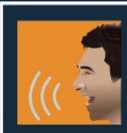


SpeakUp Competitor Analysis

Existing solutions

Android	iOS	Windows phone
Stuttering Help Trial	How to Stop Stuttering-Proactive Speaking Mobile Speech Trainer App	Stuttering Analysis App
DAF Delayed Auditory Feedback	MPiStutter	Stuttering
Stutter Rater	Speech4Good	STUTTERING

Existing solutions — Android

 Stuttering Help Trial	 DAF Delayed Auditory Feedback
Add words	DAF Delayed Auditory Feedback
DAF Delayed Auditory Feedback	Multitasking

Existing solutions

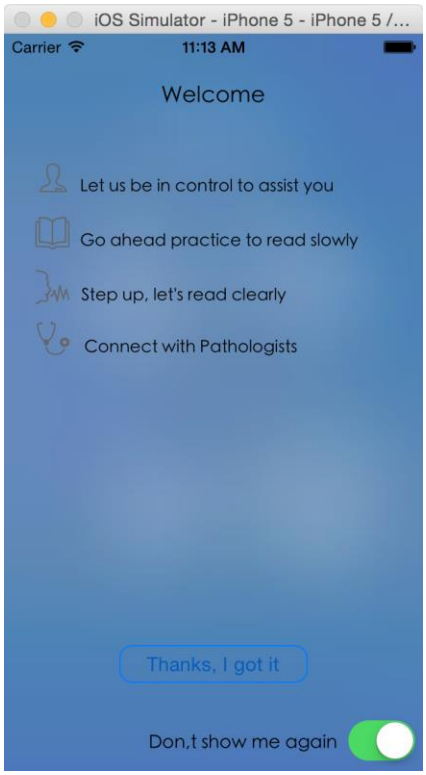
IOS

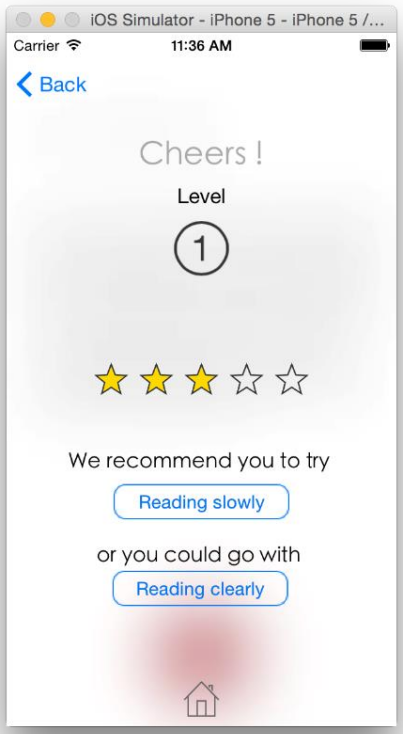
MPI stutter	How to Stop Stuttering – Proactive Speaking mobile Trainer app
Delayed Auditory Feedback	30 seconds speech trainer
Requires microphone to detect vocal Activity	Written PDF Guides and Books

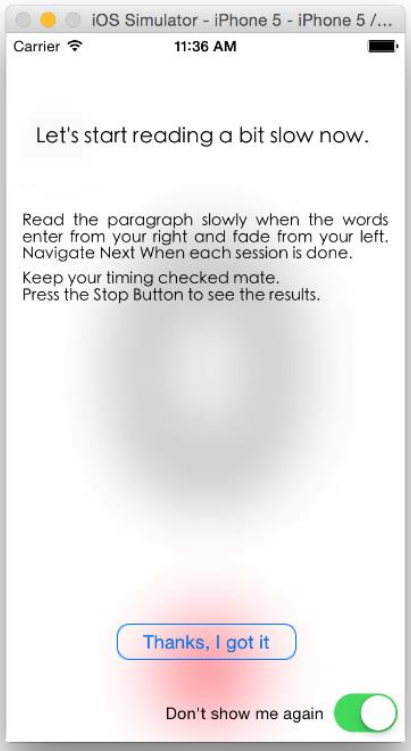
Total Sample Set of 100 voice inputs

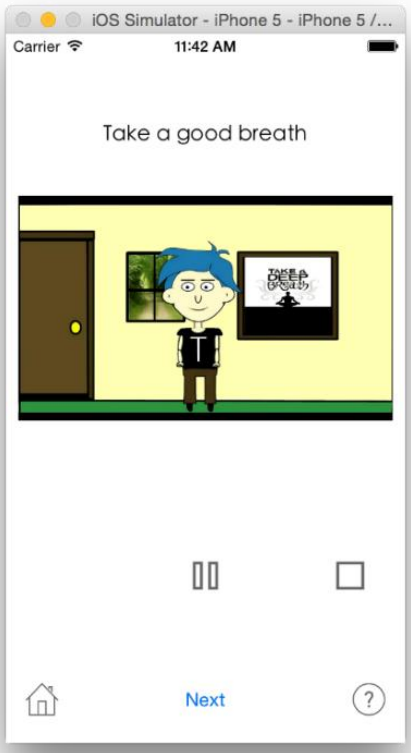
	A	B	C	D	E	F	G	H	I
1	No of words	Frequency of Speech (Avg)	Syllables Expected	Syllables Detected	SpeakUp Score	SLP Rating	Attempts	Recording Reference	Conclusion
2	13		16	18	5	Very Good	1	Rec-00000005	
3	12		23	46	1	Very Bad	3	Rec-00000134	
4	11		23	30	3	Neutral	1	Rec-00000105	
5	10		25	25	5	Very Good	2	Rec-00000345	
6	15		23	30	4	Bad	2	Rec-00000025	
7	12		19	20	5	Very Good	1	Rec-00000231	
8	12		27	15	3	Neutral	1	Rec-00003005	
9	11		26	24	5	Very Good	1	Rec-00000012	
10	15		21	23	5	Very Good	1	Rec-00000011	
11	18		21	45	1	Very Bad	1	Rec-00000290	
12	14		20	43	1	Very Bad	1	Rec-00021005	
13	14		18	34	2	Bad	1	Rec-00000411	
14	13		16	30	1	Very Bad	1	Rec-00005629	
15	12		14	5	1	Very Bad	1	Rec-00000009	
16	11		13	5	1	Very Bad	1	Rec-00000042	
17	10		25	27	5	Very Good	1	Rec-00000873	
18	17		26	26	5	Very Good	1	Rec-00001853	
19	14		29	29	5	Very Good	1	Rec-00011983	
20	13		25	10	2	Bad	3	Rec-00000023	
21	14		21	51	2	Very Bad	1	Rec-00000011	
22	12		24	34	3	Neutral	1	Rec-00000105	
23	11		21	22	5	Very Good	1	Rec-00060005	
24	14		23	22	5	Very Good	1	Rec-00034005	
25	11		24	22	5	Very Good	2	Rec-00000105	
26	12		22	10	2	Bad	3	Rec-00000345	
27	11		23	30	3	Good	1	Rec-00000025	
28	10		25	25	5	Very Good	2	Rec-00000231	
29	15		23	30	3	Neutral	1	Rec-00003005	
30	12		19	20	5	Very Good	1	Rec-00000005	
31	12		27	15	3	Neutral	1	Rec-00000105	
32	11		26	24	5	Very Good	1	Rec-00000345	
33	15		21	23	5	Very Good	1	Rec-00000025	
34	18		21	45	1	Very Bad	4	Rec-00000231	
35	14		20	43	1	Very Bad	1	Rec-00003005	
36	14		18	34	2	Very Bad	1	Rec-00000005	
37	13		16	30	2	Bad	1	Rec-00000105	
38	12		14	5	1	Very Bad	1	Rec-00000345	
39	10		25	27	5	Very Good	1	Rec-00000025	
40	17		26	26	5	Very Good	2	Rec-00000105	
41	14		29	29	5	Very Good	1	Rec-00000345	
42	13		25	10	2	Bad	1	Rec-00000025	
43	14		21	51	1	Very Bad	1	Rec-00000231	
44	10		25	25	5	Very Good	1	Rec-00003005	
45	15		23	30	3	Neutral	1	Rec-00000105	
46	12		19	20	5	Very Good	1	Rec-00000345	
47	12		27	15	3	Very Bad	1	Rec-00000025	
48	11		26	24	5	Very Good	2	Rec-00000231	
49	15		21	23	5	Very Good	3	Rec-00003005	
50	12		19	20	5	Very Good	1	Rec-00000345	
51	12		27	15	3	Neutral	3	Rec-00000025	
52	11		26	24	5	Very Good	1	Rec-00000231	
53	15		21	23	5	Very Good	1	Rec-00003005	
54	18		21	45	1	Very Bad	1	Rec-00000005	
55	14		20	43	1	Very Bad	1	Rec-00000105	
56	14		18	34	2	Bad	1	Rec-00000345	
57	13		16	30	2	Bad	1	Rec-00000025	
58	11		13	5	1	Very Bad	1	Rec-00000105	
59	10		25	27	5	Very Good	1	Rec-00000345	
60	17		26	26	5	Good	1	Rec-00000025	
61	14		29	29	5	Very Good	1	Rec-00000005	
62	13		25	10	2	Bad	1	Rec-00000005	
63	14		21	51	1	Very Bad	1	Rec-00000005	
64	12		24	34	2	Bad	1	Rec-00000345	
65	11		21	22	5	Very Good	1	Rec-00000025	
66	14		23	22	5	Very Good	1	Rec-00000231	
67	11		24	22	5	Very Good	1	Rec-00003005	
68	12		22	10	2	Bad	1	Rec-00000005	
69	11		23	30	3	Nuetral	1	Rec-00000105	
70	10		25	25	5	Very Good	1	Rec-00000345	
71	15		23	30	3	Nuetral	1	Rec-00000025	
72	12		19	20	5	Very Good	1	Rec-00000005	
73	12		27	15	3	Nuetral	1	Rec-00000345	
74	11		13	5	1	Very Bad	1	Rec-00000025	
75	10		25	27	5	Very Good	1	Rec-00000231	
76	17		26	26	5	Very Good	1	Rec-00003005	
77	14		29	29	5	Very Good	1	Rec-00000005	
78	13		25	10	2	Very Bad	1	Rec-00000105	
79	14		21	51	1	Very Bad	1	Rec-00000345	
80	12		24	34	2	Bad	1	Rec-00000025	
81	11		21	22	5	Very Good	1	Rec-00000005	
82	14		23	22	5	Very Good	1	Rec-00000345	
83	11		24	22	5	Very Good	1	Rec-00000025	
84	12		22	10	2	Bad	1	Rec-00000231	
85	11		23	30	3	Bad	1	Rec-00003005	
86	10		25	25	5	Very Good	1	Rec-00000005	
87	15		23	30	3	Nuetral	1	Rec-00000105	
88	12		19	20	5	Very Good	1	Rec-00000345	
89	12		27	15	3	Nuetral	1	Rec-00000025	
90	11		24	22	5	Very Good	1	Rec-00000005	
91	12		22	10	2	Bad	1	Rec-00034005	
92	11		23	30	3	Nuetral	1	Rec-00000105	
93	10		25	25	5	Very Good	1	Rec-00000345	
94	15		23	30	3	Nuetral	1	Rec-00000025	
95	12		19	20	5	Very Good	1	Rec-00000231	
96	12		27	15	3	Nuetral	1	Rec-00003005	
97	11		13	5	1	Very Bad	1	Rec-00000005	
98	10		25	27	5	Very Good	2	Rec-00034005	
99	17		26	26	5	Very Good	1	Rec-00000105	
100	14		29	29	5	Very Good	1	Rec-00000345	
101	13		25	10	2	Very Bad	1	Rec-00000025	

UI Mock Ups for Stuttering methodologies (Future work)



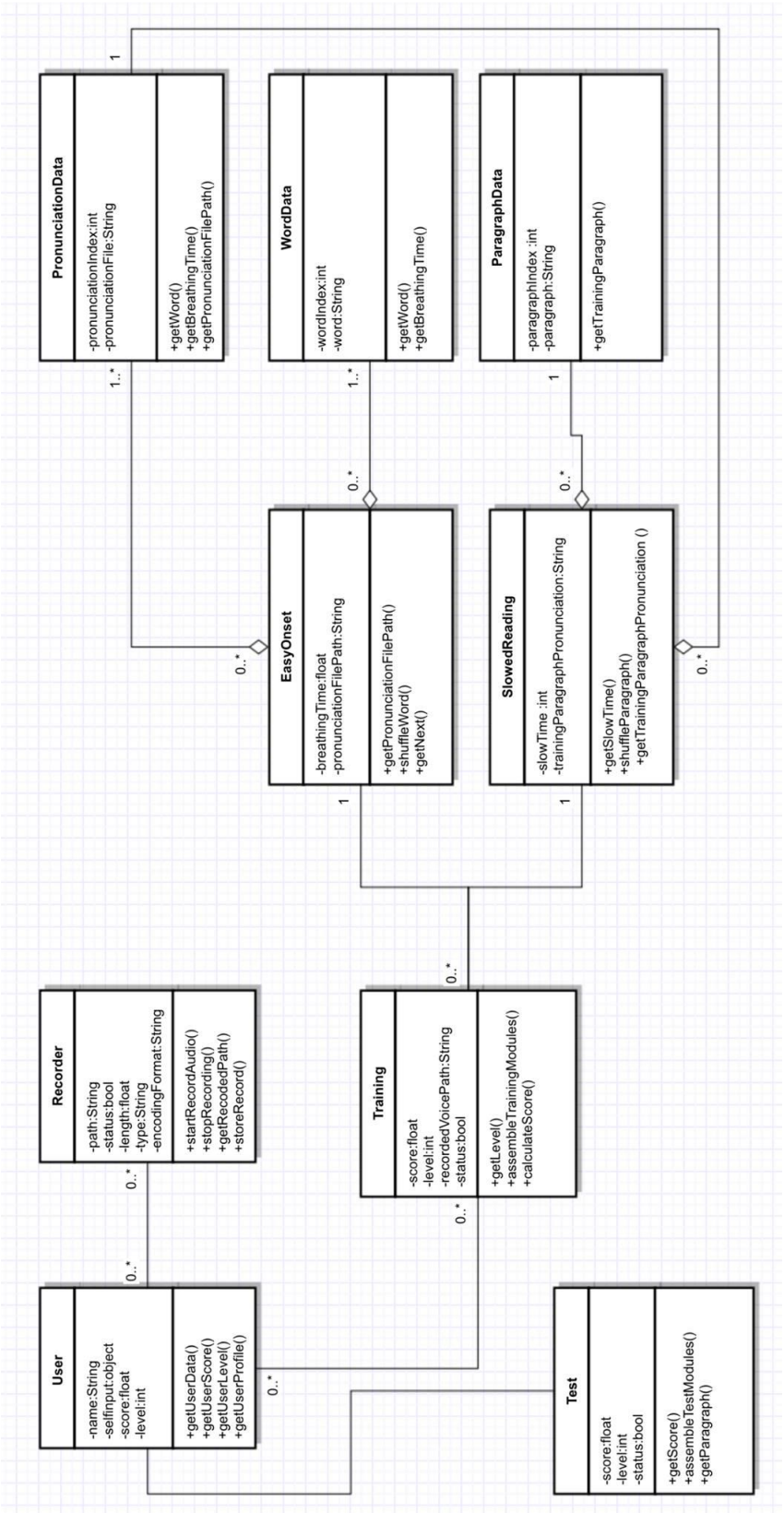



iOS Simulator - iPhone 5 - iPhone 5 /...
Carrier
11:36 AM
Let's start reading a bit slow now.
Read the paragraph slowly when the words enter from your right and fade from your left. Navigate Next When each session is done.
Keep your timing checked mate.
Press the Stop Button to see the results.
Thanks, I got it
Don't show me again

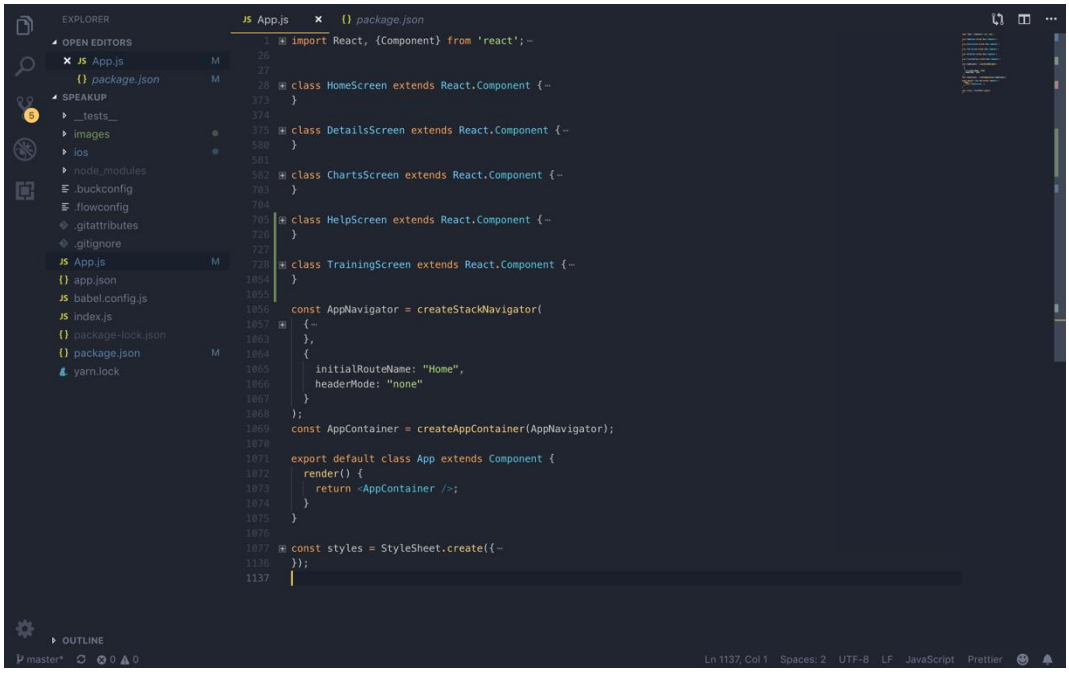

iOS Simulator - iPhone 5 - iPhone 5 /...
Carrier
11:42 AM
Take a good breath
Next

Proposed architecture with the methodologies

Class Diagram



Important Code Snippets (React Native)




```
constructor(props) {
  super(props);
  Voice.onSpeechStart = this.onSpeechStart;
  Voice.onSpeechRecognized = this.onSpeechRecognized;
  Voice.onSpeechEnd = this.onSpeechEnd;
  Voice.onSpeechError = this.onSpeechError;
  Voice.onSpeechResults = this.onSpeechResults;
  //Voice.onSpeechPartialResults = this.onSpeechPartialResults;
  Voice.onSpeechVolumeChanged = this.onSpeechVolumeChanged;
}
componentWillUnmount() {
  Voice.destroy().then(Voice.removeAllListeners);
}

onSpeechStart = e => {
  // eslint-disable-next-line
  console.log('onSpeechStart: ', e);
  this.setState({
    started: '√',
  });
};

onSpeechRecognized = e => {
  // eslint-disable-next-line
  console.log('onSpeechRecognized: ', e);
  this.setState({
    recognized: '√',
  });
};

onSpeechEnd = e => {
  // eslint-disable-next-line
  console.log('onSpeechEnd: ', e);
  this.setState({
    end: '√',
    backgroundColor: '#80FFFF'
  });
};
```

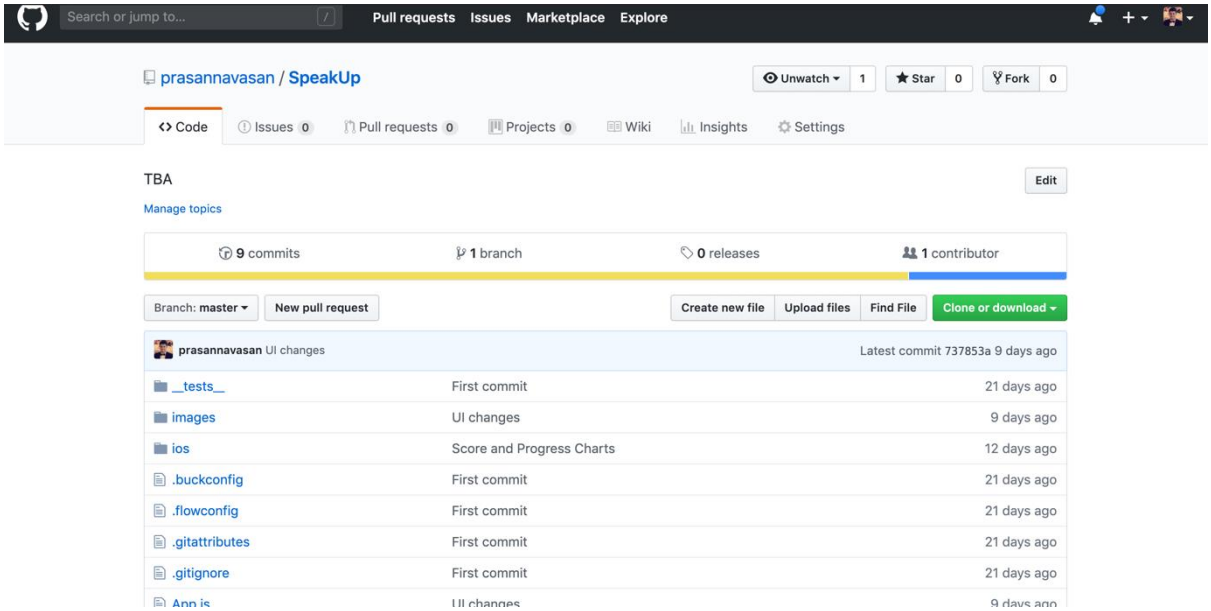
X

```
  stutterCheck(arr) {
  var a = [], b = [], prev;

  arr.sort();
  for (var i = 0; i < arr.length; i++) {
    if (arr[i] !== prev) {
      a.push(arr[i]);
      b.push(1);
    } else {
      b[b.length - 1]++;
    }
    prev = arr[i];
  }

  return [a, b];
}

  _cancelRecognizing = async () => {
    try {
      await Voice.cancel();
    } catch (e) {
      //eslint-disable-next-line
      console.error(e);
    }
  };
```




App.js
package.json
}}
>
<View style={{ top: 120 }}>
<TouchableHighlight
onPress={() =>
this.props.navigation.navigate("Help", { from: "Details" })
}
>
<ImageBackground
style={{
width: 30,
height: 30,
left: 280,
top: -20
}}
source={require("./images/help.png")}
>
<Text
style={{
textAlign: "center",
color: "black",
marginVertical: 5,
fontSize: 10,
top: 25
}}
>
Help
</Text>
</ImageBackground>
</TouchableHighlight>
<Stars
display={score}
spacing={8}
count={5}
starSize={40}
backingColor="white"
fullStar={require("./images/starFilled.png")}
emptyStar={require("./images/starEmpty.png")}
/>
<Text style={styles.titleText}>{"\n"}</Text>
<Text style={styles.titleText}>{message}</Text>