Stuttering Identification Using Machine Learning Approaches

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Project Proposal Report

Sanjeewa J.M.I.P – IT20012342

BSc (Hons) Degree in Information Technology Specialization in Data Science

Department of Information Technology

Sri Lanka Institute of Information Technology

Sri Lanka

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DECLARATION

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

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Name	Student ID	Signature
Sanjeewa J.M.I.P	IT20012342	

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

---------- 04/05/2023 ----------

Signature of the Supervisor Date

---------- 04/05/2023 ----------

Signature of the Co-Supervisor Date

ABSTRACT

Stuttering is a speech disorder in which the flow of speech is interrupted by involuntary repetitions and prolongations of sounds, syllables, words, or phrases as well as involuntary silent pauses or blocks in which the person who stutters is unable to produce sounds. It can have a profound impact on the daily life of people who experience it and affects around 1% of the world's population. To help people who stutter, researchers are investigating various medications and treatments including speech therapy, medication, and behavioral therapy. Speech therapy, which is said to be the main treatment type for stuttering involves the intervention of a speech-language therapist and requires in-person sessions that can be time-consuming, challenging, and expensive, which would ultimately discourage the patient from obtaining treatments. The objective of this research is to utilize the evolution of modern technology to identify and provide treatments for people who suffer from stuttering efficiently and conveniently. This is where machine learning approaches come in as a solution that would help to overcome the challenges in the traditional methodologies of identifying and providing treatments for stuttering. Ultimately, this research aims to make a significant impact on the lives of people who stutter and to help them live their lives better.

Keywords – Stuttering, Speech disorder, Speech therapy, Machine learning.

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I would like to extend my sincere gratitude to all the individuals who supported me to continue my fourth-year research project. First and foremost, I sincerely thank our Research Project supervisor Ms. Jenny Kishara for her invaluable guidance, encouragement, and support. I am also grateful for the advice and support given by our co-supervisor Ms. Thamali Kelegama. I extend my sincere thanks to the CDAP panel for their guidance throughout our project work. Additionally, I would like to express my appreciation to Ms. V.M. Rajapakse, our external supervisor, for her coordination and provision of information, which helped us in the initiation of our research project.

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LIST OF ABBREVIATIONS

Abbreviation	Description
ML	Machine Learning
NN	Neural Network
DL	Deep Learning
CNN	Convolutional Neural Network
RNN	Recurrent Neural Network
NLP	Natural Language Processing
API	Application Programming Interface
UX	User Experience

LIST OF APPENDICES

1 INTRODUCTION

1.1 Background

Stuttering is a speech disorder that can affect people of any age group and can significantly impact communication and quality of life [1]. Researchers have estimated that all around the world, there are about 70 million people who are suffered from this speech disorder and among them, males are being four times more likely to stutter than females [2]. Stuttering can be categorized by interruptions in the normal flow of speech, such as repetitions, prolongations, blocks, and interjections which can lead to frustration, anxiety, and social isolation.

Current methods of stuttering detection rely on clinical evaluations by speech-language pathologists. Those methods can be very subjective and time-consuming. Also, particularly in developing countries, there is a lack of qualified specialists to conduct these types of diagnoses. Due to this reason, there is a significant requirement to go for an alternative method of stuttering identification that is reliable, accurate, and applicable in a wide range of settings.

Machine learning approaches have shown promise in the domain of speech recognition and analysis, including stuttering detection. By analyzing speech patterns and features, machine learning algorithms can find the patterns that are predictive of stuttering. It identifies the people who stutter very accurately and efficiently. Classification models are used for detecting the stuttering type and CNN, and RNN models are used for detecting stuttering phrases down to the syllable level accurately.

This study will involve gathering speech samples from users through the proposed “StutterAI” application. The stuttering patients need to speak different types of paragraphs then the system detects the specific stuttering type, stuttering phrase, and the novelty of this component is detecting stuttering down to the syllable level by analyzing user speeches. The deeply analyzed stuttering results are displayed on a personalized dashboard on the suggested web application. Then the person can start treatments based on these analyzed data. Also, the proposed system can measure the progress of the treatments by providing necessary several vocal tests for the stuttering patient. The outcome of this research component has the potential to provide a significant impact on the field of stuttering identification and provide a real-time, consistent, and effective alternative method to currently available methods.

1.2 Background & Literature Survey

Stuttering is a speech disorder described by interruptions in the normal flow of speech, which can appear at the syllable, word, or phrase level [6]. Traditional methods of stuttering identification and treatments involve subjective assessments by speech-language pathologists or self-reported evaluations by stuttering people [7]. Modern advances in machine learning approaches have shown promise in real-time automated identification and measuring of stuttering at a more granular level, such as the syllable level.

We performed background research to get an idea of current approaches to stuttering identification up to the syllable level. The obtained details are described below.

One study published in the **Proceedings of the 2019 Conference of the North American Chapter of the Association for Computational Linguistics (NAACL-HLT)** explored the effectiveness of natural language processing techniques to analyze the speeches of stuttering people. The researchers used a neural network model to transcribe speech and identify stuttered syllables automatically, achieving an accuracy of over 70% [8]. But still, the results of this machine learning model were not reached up to the expected level of speech-language pathologists.

The article **"Systematic Review of Machine Learning Approaches for Detecting Developmental Stuttering" by Liam Barrett, Junchao Hu, and Peter Howell** reviews recent research on the use of machine learning for detecting the stuttering state of children. The researchers conducted a systematic review of existing literature on this topic, focusing on studies published between 2010 and 2020. The review identified 21 studies that met the inclusion criteria, which were then analyzed in detail. The authors found that machine-learning approaches have been used successfully to detect developmental stuttering, with accuracy rates ranging from 80% to 98%[13]. The review also detected several factors that affect the accuracy of machine learning models, such as the number of input features and their sizes, the size and quality of the training dataset after pre-processing, and the specific and most accurate ML and DL algorithms used. The research also discussed detecting stuttering up to the phrase level and still, a novelty remaining for detecting stuttering down to the syllable level. Overall, the researchers concluded that the use of machine-learning approaches for detecting stuttering in children has significant potential and that further research in this area could lead to more accurate and reliable diagnostic tools.

The article **"Sequence Labeling to Detect Stuttering Events in Read Speech"** presents a technique for detecting stuttering in read speech using sequence labeling techniques. The researchers, Hanyang Chen, Hongwei Ding, and Tiejun Zhao, propose a system that takes a voice recording as input and outputs a sequence of labels detecting the stuttering down to the syllable level. The system uses a combination of acoustic and linguistic features, including fundamental frequency, energy, spectral slope, and part-of-speech tags, to represent each syllable in the speech signal. These features are then used as input to a conditional random field (CRF) model, which labels each syllable as stuttered or fluent. The researchers evaluated the system using a dataset of read speech from 20 adult stutterers and 20 fluent speakers. They found that the system achieved a medium level of accuracy in detecting stuttering events, with an F1 score of 0.90 and an area under the receiver operating characteristic curve (AUC) of 0.96[14]. Overall, the researchers conclude that their system shows promise as a tool for detecting stuttering events in read speech, and that future work could explore its potential for use in clinical diagnosis and treatment of stuttering. However, they also note that further research is needed to evaluate the system's performance on different types of speech, such as spontaneous or conversational speech, and detection of stuttering down to the syllable level and on larger and more diverse datasets.

Also, we performed research by getting ideas from many speech-language pathologists on this research component to get domain knowledge including the external supervisor.

These background researches demonstrate the capability of machine learning approaches to improve the accuracy and efficiency of diagnosing and measuring stuttering, particularly at the syllable level. However, further research is needed to validate these findings and implement practical applications for integrating machine-learning approaches into clinical practice. The web application that we planned to implement will be a solution to this issue. The user can confirm the stuttering nature, can get a deep analysis of stuttering disorder, and can get a personalized treatment plan based on the severity of stuttering.

1.3 Research Gap

Stuttering is a speech disorder that impacts the fluency and rhythm of speech. Currently, there are a large number of studies conducted on stuttering, but there is still a research gap in stuttering identification using machine learning approaches.

Most of the existing studies are mainly focused on manual diagnosis by clinicians, which is time-consuming and subjective [3]. The use of machine learning approaches has the potential to automate and real-time diagnosis of stuttering, making it more effective and precise.

However, there is a lack of research on the efficiency of different machine-learning algorithms for stuttering identification and related treatments suggestion. More specifically, there is a requirement for experiments that compare the performance of different machine learning algorithms and deep learning models, in detecting stuttering.

Over the years, speech analysis has been successful in detecting stuttering and its various types. However, there is a new approach that can identify stuttering down to the syllable level, which is significant progress in the field of speech analysis. The research gap of the component described in this proposal is detecting stuttering down to the syllable level. This trending research gap has the potential to significantly improve the understanding and treatment of stuttering. It can provide clinicians with more accurate and objective measures of stuttering severity, which can help to guide treatment planning and monitor treatment progress. Instead of human interactions, our proposed system itself can suggest treatments based on the deeply analyzed speeches of stuttering people. It can also help to identify specific aspects of speech that may be targeted in treatment, such as syllable repetitions or prolongations.

Overall, the research gap in stuttering identification using machine learning approaches focuses on the requirement of more studies that investigate the efficiency of different algorithms for training and testing these models, and the development of real-time stuttering identification and treatment suggestion approaches using the latest available technologies.

Comparison of Proposed System & Existing Systems

Table 1: Comparison of the proposed system with existing systems

	Fluency SIS	Speech Assistant AAC	StutterTester	SpeechAgain	**StutterAI**
Stuttering Type Detection	✓		✓		✓
Virtual Assistant Model		✓			✓
Stuttering Syllable Detection					✓
Stuttering Phrase Detection	✓				✓
Personalized Report Generation	✓			✓	✓

1.4 Research Problem

The research problem “Identifying stuttering down to the syllable level using machine learning approaches” is a challenging task in the field of speech analysis. Machine learning has shown huge advancements in detecting stuttering, but identifying stuttering at the syllable level requires high precision and accuracy to achieve clinical relevance.

Under this research problem, need to develop precise and consistent machine-learning algorithms that can identify stuttering at the syllable level. This requires the use of large and complex datasets of speech samples that include both stuttered and fluent speech, as well as the implementation of feature extraction procedures that can perfectly capture the relevant aspects of stuttering. The development of these types of algorithms is necessary for the development of objective and standardized measures of stuttering seriousness at the syllable level.

Validating the accuracy and clinical relevance of implemented machine learning algorithms to identify stuttering down to the syllable level is another research problem that comes under this speech analysis component [4]. The knowledge of industry experts is essential to validate the accuracy and clinical relevance. To overcome this issue, we have gotten the help of a speech therapist for the validation and accuracy-checking process. Machine learning models can be overfitted, where the machine learning model gives accurate predictions for training data but not for new data [5]. To address this issue, have to validate the accuracy and clinical relevance of these models on independent datasets that are not used in the model training process.

There is a need to explore the interpretability of machine learning models for stuttering identification at the syllable level. Interpretability is important for clinical use, as it can provide a deep understanding of the speech disorder into the underlying mechanisms of stuttering and help clinicians to better understand the condition. Visualizations such as saliency maps, bar graphs, and dynamic gauges can be used to identify the specific aspects of speech that contribute to stuttering.

Also, need to address the ethical considerations associated with the use of machine learning techniques in stuttering identification. These include issues related to advised permission, data privacy, and biases in the data or algorithms. Properly addressing these ethical considerations is necessary for ensuring the responsible and ethical use of machine learning approaches in stuttering identification.

Overall, identifying stuttering at the syllable level using machine learning approaches is a challenging research problem that requires a multidisciplinary procedure. Addressing these research problems can help to improve the understanding of stuttering and guide the discovery of more successful treatments for people suffering from stuttering speech disorders.

2 OBJECTIVES

2.1 Main Objective

Provide a deep analysis of stuttering by analyzing speeches

Stuttering is a speech disorder in which the flow of speech is interrupted by involuntary repetitions and prolongations of sounds, syllables, words, or phrases as well as involuntary silent pauses or blocks in which the person who stutters is unable to produce sounds. The main objective of this component is to provide a deep analysis of stuttering by analyzing speeches. Paragraphs with various pronunciations are provided for the users to read and thereby the system analyzes collected speeches to detect the stuttering severity of the users in a detailed method. Stuttering type, stuttering phrase, and stuttering syllables are included in the deep analysis. The analyzed data are displayed in a dashboard which shows a personalized stuttering analysis to the user.

2.2 Sub Objectives

Provide paragraphs with different pronouncing types for the user to pronounce

The system should provide paragraphs with different pronouncing types for the user to read and store collected voice recordings in a highly secure database since collected voice recordings are highly private.

Pre-process the collected speeches

The collected voice recordings cannot be directly applied to the ML and CNN models because those recordings may contain noisy data which can reduce the accuracy of models. So, the collected voice recordings need to be pre-processed to convert them into a proper clean format which can be directly applied to the implemented models for training.

Identify the stuttering type

Stuttering can be mainly categorized into four types based on pronunciation. They are,

- **Repetitions** - Sound repetitions involve repeating a sound or syllable, such as "um-um-um" or "like-like-like." They are often used as filler words and can be a natural part of speech, but excessive use of sound repetitions can indicate a speech disorder.
- **Prolongations** - Sound prolongations occur when a speaker stretches out a sound, such as saying "ssssso" instead of "so." This type of disfluency can be a symptom of stuttering, anxiety, or other speech disorders.
- **Blocks** - Blocks occur when a speaker is unable to produce a sound or word, resulting in a pause or silence. This can be due to physical or psychological factors, such as difficulty coordinating the muscles used in speech or anxiety.
- **Interjections** - Interjections are words or phrases that are inserted into speech, often to express emotion or emphasis. Examples of interjections include "um," "uh," "well," "you know," and "oh." Interjections are not necessarily disfluencies, but they can be overused and interfere with communication.

The stuttering type of the user needs to be identified accurately by analyzing the collected voice recordings using ML models. Classification algorithms play a major role in the identification of stuttering types.

Generate a personalized profile and reports

A profile that includes a user-friendly dashboard should be generated based on the severity of the stuttering of the user including a detailed analysis. The dashboard should contain details related to stuttering such as stuttering type, stuttering likelihood, predictive modeling, identifying stuttering down to the syllable level, etc. The user needs to download the generated reports through the proposed “StutterAI” application when necessary.

3 SYSTEM METHODOLOGY

3.1 Requirements

3.1.1 Functional Requirements

- The application must be able to recognize voice inputs provided by the user.
- The application must provide different types of paragraphs for the user to read.
- The application must provide a detailed analysis of the stuttering state of the user through a user-friendly dashboard.
- The application must provide a personalized report for each user based on the severity of stuttering.
- The application must suggest personalized and accurate treatments for the user suffering from stuttering.
- The application must track the progress of treatments by providing vocal exercises for the user.
- Application loading time and response time need to be minimum.

3.1.2 Non-functional Requirements

- **Reliability**

  The proposed StutterAI application will be used by speech therapists to get a detailed analysis of stuttering and to treat people who are suffering from stuttering. Therefore, the reliability of the proposed StutterAI application must be very high otherwise results produced from the application will affect the stuttering people in an extremely bad way. So, the reliability of the results produced by the application needs to be validated by performing several tests with the guidance and verification of speech therapists.

- **Security**

  The proposed StutterAI application collects voice data of people and produces personalized results related to stuttering. These data should be very private so the security of the collected and generated data should be extremely high. To improve security, we planned to use many security features such as two-factor authentications, OTP verifications, human verifications, fingerprints, facial recognition, etc.

- **Availability**

  The application should be available 24/7 for speech therapists to get detailed analyses of stuttering patients and to suggest treatments without any disturbances. We planned to carry out several tests to verify the availability of the StutterAI application before releasing it to the public.

- **Usability**

  As the usability, need to consider how easily and efficiently a user can interact with the application to achieve their goals. The StutterAI application must be very user-friendly and easy to navigate so that the users can carry out their tasks with less time easily through the application. Providing a navigation bar with all the essential features, smooth animations, and a simpler UI enhances the usability of the proposed StutterAI application.

- **Scalability**

  Allocation and de-allocation of resources according to the demand need to be considered. The demand for the application may increase with time after releasing to the public. The high network traffic can be seen but must ensure that the application should be highly scalable to keep the application without any failures. The usage of AWS services to host the proposed StutterAI application and its components is one of the best ways to enhance scalability because all AWS services are highly scalable.

3.2 System Overview

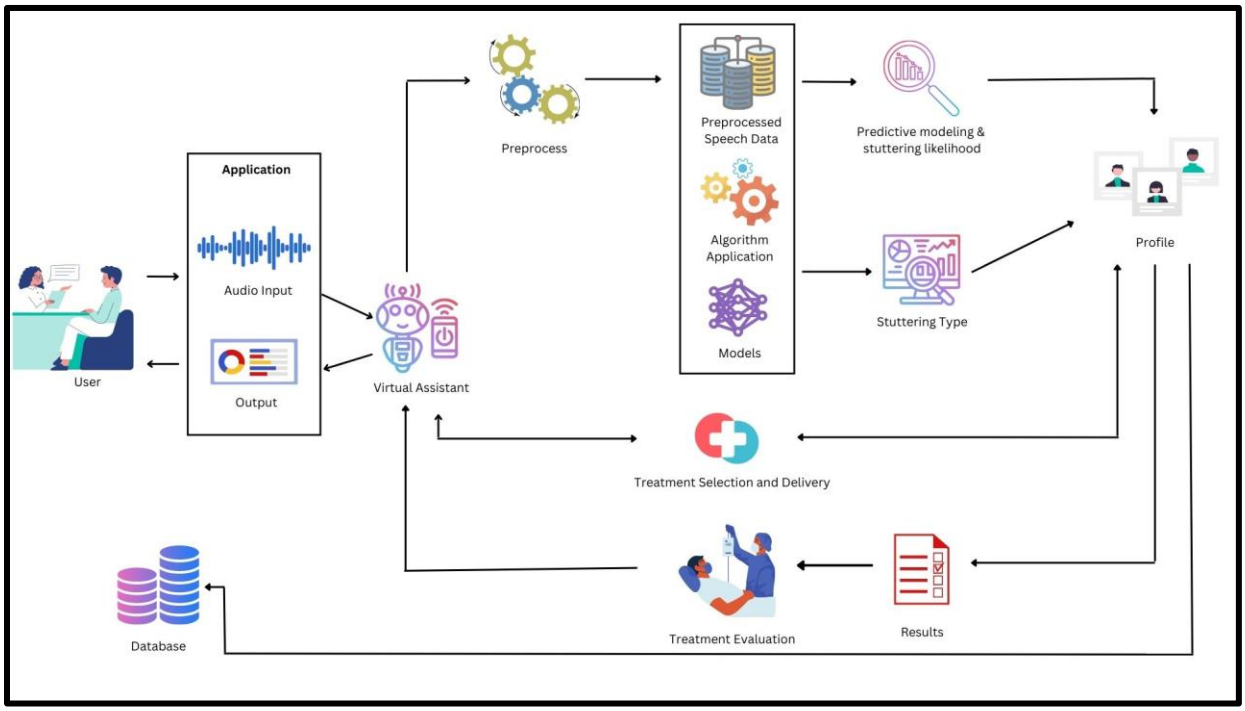

Figure 1 - System Overview Diagram

The main purpose of the proposed "StutterAI" application is to provide a deep analysis of stuttering based on the voice inputs provided by the user and suggest personalized treatments based on the severity of stuttering. The system provides users to read different paragraphs and collect voice recordings for stuttering analysis. Then the collected audio inputs are pre-processed to remove noisy data and pre-processed audio data are applied to the trained ML and CNN models to get a deep analysis of stuttering. The stuttering type, stuttering likelihood, predictive modeling, and identifying stuttering down to the syllable level are included in the analysis. Based on the results of the analysis, a personalized profile for each user is created with a user-friendly dashboard. The patients can view their stuttering state through that dashboard. The results of the analysis are stored in a secure database. Also "StutterAI" application is capable of suggesting accurate treatments for four stuttering types based on the obtained stuttering results by analyzing the audio inputs. The speech therapists can review and apply those treatments directly to the stuttering patient and also the patient can track the progress of treatments by performing vocal tests available in the application. Based on the test results, the application again suggests necessary treatments for the stuttering patient. This treatment evaluation process can be performed till the patient gets cured.

3.3 Component Overview

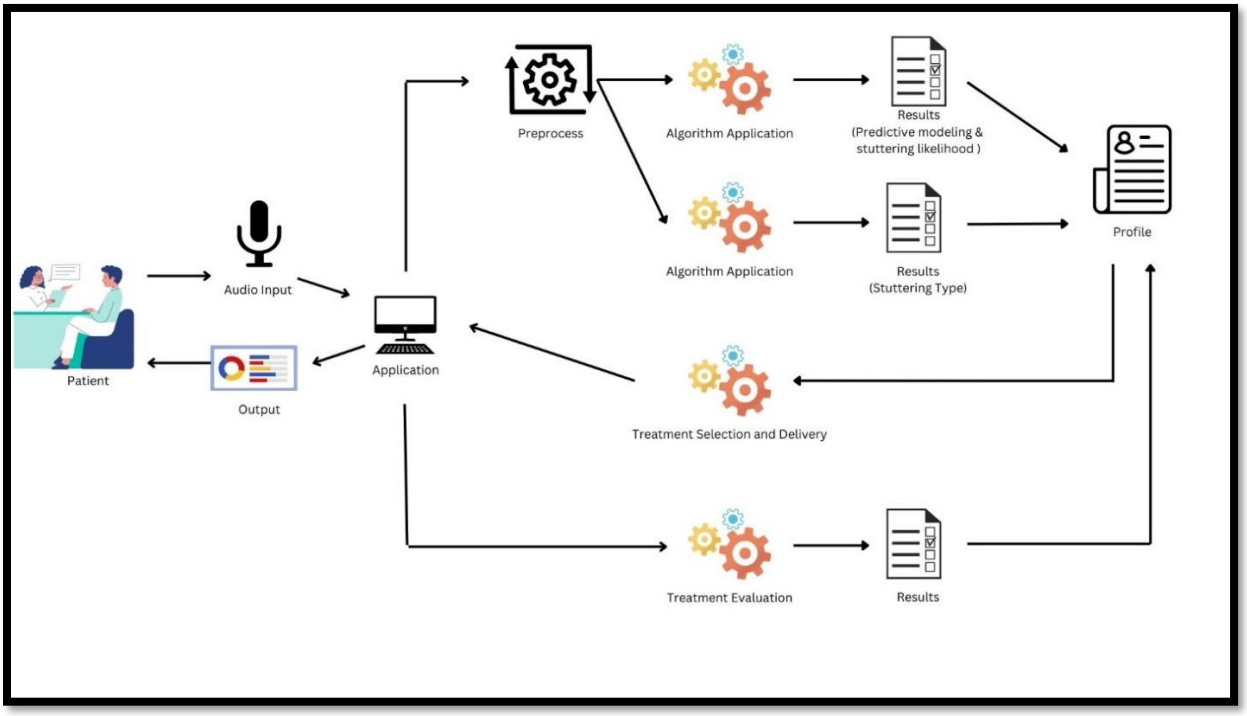

Figure 2 - Individual Component Diagram

The main purpose of this research component is to identify the stuttering type, stuttering phrase, and stuttering syllable accurately. The novelty of this component is detecting the stuttering down to the syllable level. The system provides users to read different paragraphs and collect voice recordings for stuttering analysis. Then the collected audio inputs are pre-processed to remove noisy data and pre-processed audio data are applied to the trained ML and CNN models to get a deep analysis of stuttering. Stuttering type, stuttering phrase, and stuttering syllables are included in the deep analysis in a more detailed way. The results are stored in a secure database. Based on the results obtained, a personalized user profile for each user is generated. The results are shown in a user-friendly dashboard from which the user can understand the severity of stuttering. The doctors can use those results in the dashboard to suggest specific treatments for stuttering patients.

4 DESCRIPTION OF PERSONAL AND FACILITIES

Personal Support:

- Supervisors with expertise in both ML and NLP to give guidance and feedback on the research, implementation, and evaluation.
- Speech therapists with experience in stuttering diagnosis and treatment to provide expert opinions on the effectiveness of the proposed ML-based stuttering detection and treatment approach.
- Research team members with programming skills and experience in ML to assist with data collection, model development, and analysis.

Facilities:

- A high-performance computing system with GPU capabilities to train and test ML models for speech analysis and classification in real-time.
- Access to the "Sep-28k" and "Libristutter" datasets, as well as any other speech datasets that may be required to increase the diversity and size of the training data.
- ML platform for data management, processing, and analysis of the collected speech datasets.

5 BUDGET AND BUDGET JUSTIFICATION

Component	**Est. Amount in USD**	**Est. Amount in LKR**
Internet Connectivity Charges	9.4	3000.00
Charges for tools used for research. (Cloud Services, Grammarly, Mendeley, etc.)	31.37	10,000.00
Traveling fees for consultation sessions and data collecting (Medcon pvt ltd)	2.15	700.00
Technical Consultation Charges (External technical information session)	13.9	4,500.00
Cloud Platforms (AWS, GCP, Dialogflow, Microsoft Bot Framework, Amazon Lex)	40.00	13,000.00
Total	96.82	31,200.00

6 COMMERCIALIZATION ASPECT OF THE PROJECT

Stuttering is experienced by 1% of the world's population, which is about 8 million people. So, it is a massive amount and large market that we could capitalize on. As mentioned previously, there are various difficulties and challenges in obtaining the treatments in the traditional way, which is through a speech therapist.

So, we are planning to give a solution to the patients such that they can overcome these difficulties. We have introduced several subscriptions as follows,

- **Monthly Subscription – Rs.300**
- **Annual Subscription – Rs.2400**
- **Children Orphanages – Free**

We are hoping to give the diagnosis of stuttering free of charge. But, to obtain treatments, the patients would have to sign up for a subscription plan. This would be an efficient and cost-effective solution for the patient and encourage the patients to obtain treatments since it reduces the challenges of obtaining the treatments through a speech therapist and on the other hand, we will be able to generate a good revenue.

7 CONCLUSION

The machine learning-based stuttering identification research that is being proposed could have a big impact on the industry. The "StutterAI" application being presented has the ability to improve the lives of those who stammer by creating a real-time and efficient alternative technique to the currently available stuttering identification methods. The results of this study could influence the creation of a useful and approachable instrument that can help in the early detection and treatment of stuttering with the collection of speech samples from users. Overall, this study has the potential to significantly advance the detection of stuttering and enhance the quality of life for people who experience this communication issue.

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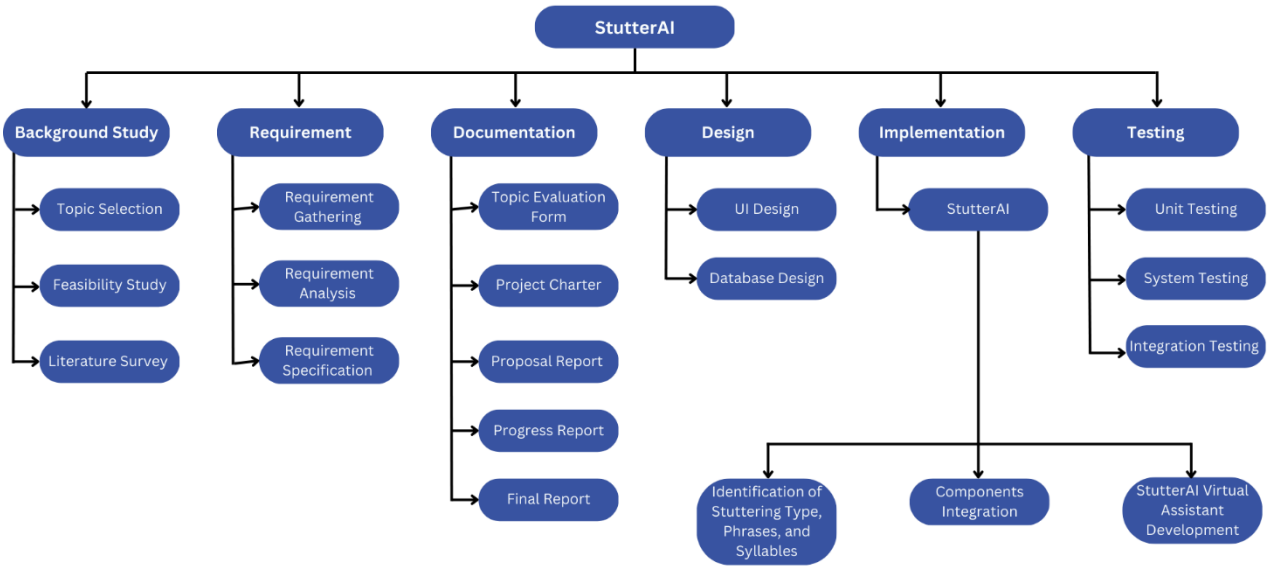
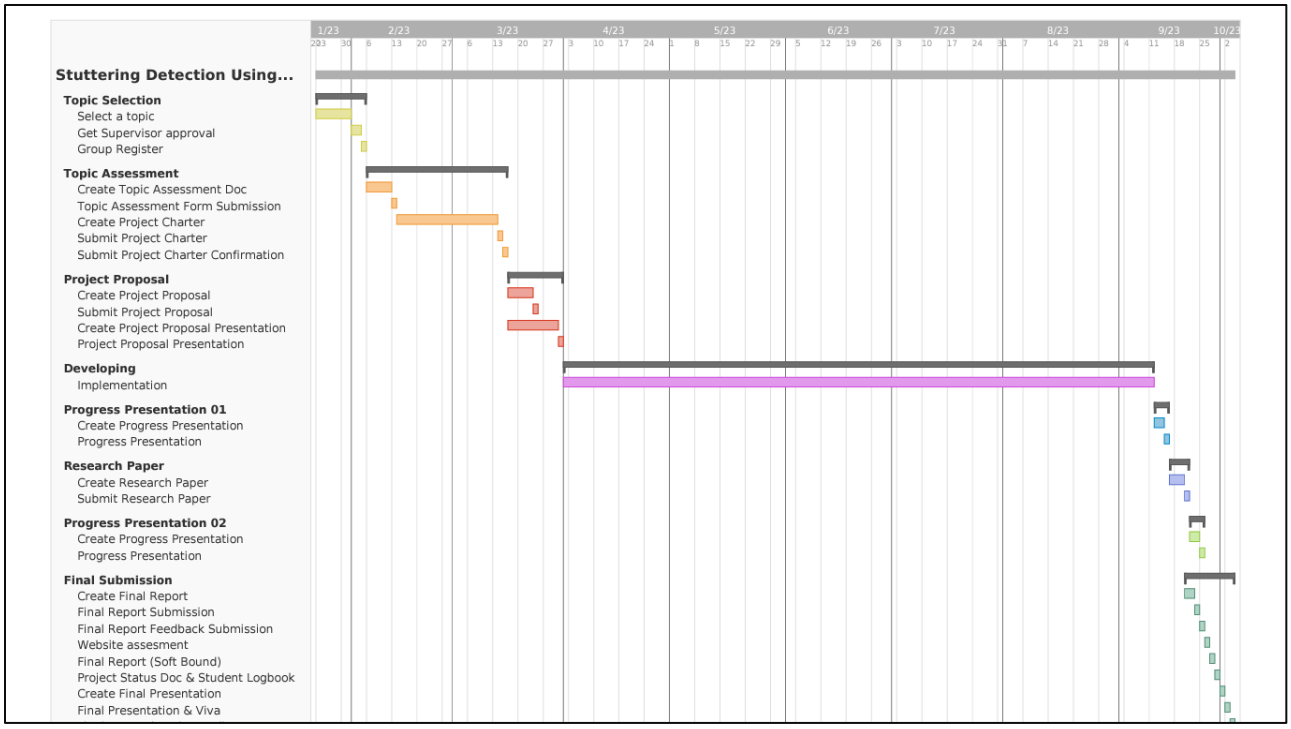
APPENDICES

Appendix 1 - Application Logo



Appendix 2 - Work Breakdown Chart



Appendix 3 - Gantt Chart