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

22_23-J 18

Project Proposal Report

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IT19001708

BSc (Hons) in Information Technology

Specializing in Data Science

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DECLARATION

I declare that this is our 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 our knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgment is made int he text.

Signature: Date: 13/10/2022

Signature of the Supervisor: Date:

Signature of the Co-Supervisor: Date:

ABSTRACT

Linguistic abilities among the hearing impaired are at a very low level which causes an adverse effect on their education as reading and writing abilities are at a lower level. First language acquisition is unconscious process that is closely related with the maturation of cognitive. Until the age of five, brain plasticity of a human supports the rapid development of language and communicational cognitive. Which essentially the reason it is difficult for to acquire a second language later even though it follows the same learning process.

With the advancement of field of audiology, there are vast number of devices, surgeries that can help a hearing impaired to hear better. But wearing a device itself does not make hearing impairer's language skills better. Not acquiring a language before the cognitive development phase pass makes it almost impossible to acquire the language at a later age. Therefore, early language acquisition at the cochlear stage of life is crucial.

In order to achieve early better linguistic ability of a hearing-impaired children, they need to go through a natural language learning process that has extra support in auditory, visually.

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1. INTRODUCTION

1.1 Background and literature survey

Congenital hearing impairment reported 3 for every 1000 children globally. Only 3% of hearing-impaired children are diagnosed to have profound or severe hearing loss. In contrast, the remaining 97% are able to have a normal life with the help of suitable hearing aids, devices, or surgeries. During the past decade field of audiology advanced immensely. But wearing a hearing aid or performing surgery itself is not sufficient to make a child who has similar cognitive abilities as a hearing peer.

Cognitive development is further divided into motor(physical) development, language and communicational development, and social/emotional development. Children learn their first language primarily by imitating. In order to imitate, auditory inputs are needed where a hearing-impaired child does not have. This condition explains by the “Poverty of the stimulus argument” by Noam Chomsky. Hearing impairment has a negative impact on language acquisition. Adverse effects of language development delay reflect throughout their life [5]. Hearing-impaired children require special care and attention in order to improve their linguistic skills. Taking alternative methods and techniques is as important as early invention of hearing loss to raise a hearing-impaired child to have a normal life [4].

Brain plasticity in early childhood supports rapid language acquisition. By the age of five, a normal-hearing child essentially masters the phonological, lexical, and morpho-syntactic skills [1]. By the age of five, children naturally become fluent in their native language as they are exposed to their surroundings on a regular and frequent basis. It is crucial to learn languages during the first four, five years [2]. The misconception of hearing aid solves everything worsen the situation as parents do not put effort further and wait for the child to speak miraculously at school [4]. But researchers have found that if the linguistic development phase (first five years) is passed, it is nearly impossible to recapture [5]. Since hearing-impaired children do not get exposed to a spoken language, their vocabulary is as limited to few hundred words by the age of five, while hearing peers' vocabulary is around 20000 words. This effect heavily in their education as education is heavily biased towards verbal languages [3].

Community Child Health, Royal Children's Hospital, Australia, conducted research to identify the impact on education in relation to the age of diagnosis and severity of hearing impairment [6]. The hypothesis of this study was the age of detection of hearing impairment has a relationship with education outcomes. For this study, 132 students from 7-8 years of age participated. To measure the educational outcomes, each individual student took a three-hour assessment under the supervision of a speech pathologist and a psychologist.

The following figure explains the performance of each test (CELF, PPVT, Goldman-Fristoe, and Intelligibility) based on the different categories, severity of hearing impairment, age at diagnosis, and covariates.

Table 6 Summary of variance explained by regression models predicting language and reading measures at age 7–8 years for children with moderate, severe, and profound losses (excluding children with mild losses)

	Block 1 Covariates*			Block 2 Age at diagnosis			Block 3 Severity of hearing impairment		
	R^2 change	F	p	R^2 change	F	p	R^2 change	F	p
CELF									
Total	0.20	2.1	0.09	0.001	0.03	0.86	0.38	29.0	<0.001
Receptive	0.23	2.6	0.05	0.00	0.06	0.80	0.32	23.4	<0.001
Expressive	0.15	1.6	0.20	0.00	0.00	1.0	0.39	27.8	<0.001
PPVT	0.16	1.7	0.18	0.02	0.80	0.38	0.25	15.1	<0.001
Goldman-Fristoe†	0.05	0.46	0.77	0.003	0.12	0.73	0.14	5.8	0.02
Intelligibility†	0.13	1.4	0.27	0.005	0.19	0.67	0.11	4.9	0.03
RPT	0.26	3.0	0.03	0.01	0.56	0.46	0.13	6.8	0.01

*Covariates: non-verbal IQ, paternal occupational prestige, maternal education, family functioning (all entered as continuous variables).
†Transformed scores ($\log_e$).

Figure 1: CELF, PPVT, Goldman-Fristoe, and Intelligibility test results

Measures for another test performed int this study, were receptive and expressive language skills and receptive vocabulary (Clinical Evaluation of Language Fundamentals–Third Edition -CELF), Peabody Picture Vocabulary Test (PPVT – 3rd edition) and to measure the cognition Perceptual Organization Index (POI) of the Wechsler Intelligence Scale for Children Third Edition (WISC) was used. The cognition measuring method does not reply to the speech process but highly correlated with full-scale IQ that provides a reliable measure of a child's level of cognition regardless of the child's linguistic ability. The following graphs display the results with respect to the severity of hearing impairment.

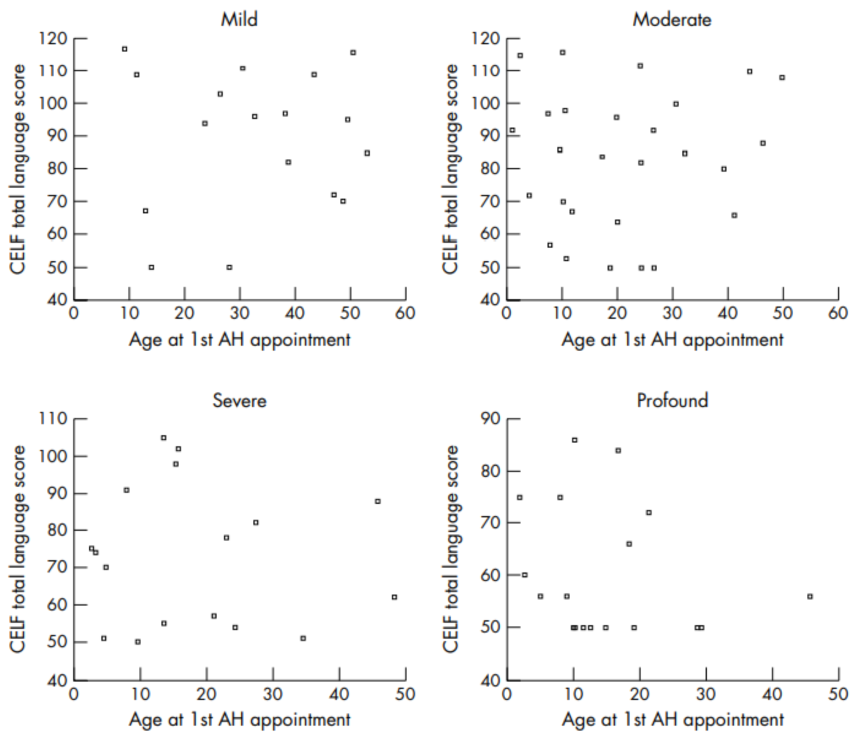

Figure 2: Intelligibility test results against the severity of hearing impairment

The above research concludes that better linguistic abilities were reported in children diagnosed with hearing impairment at early ages, regardless of the severity of the impairment. Nevertheless, early detection itself is insufficient to substantiate the long-term benefits of early detection but requires a mechanism to acquire language.

1.2 Research Gap

The book "Teaching language to hearing impaired children who have had no previous language experience" by Catherine Collins Lu, Portland State University [7] points to the importance of utilizing residual hearing to be ascertained and providing a personal experience-oriented learning environment, where similar to language acquiring process of hearing children.

The research “Web-based Teaching and Learning Methods for Deaf Students” by Tianjin University of Technology [11] is one research on improving the linguistic ability of the hearing impaired. This research proposes a network teaching and learning system to address the issues in traditional learning methods.

The Deaf network teaching and learning system emphasize taking advantage of access to the internet and multimedia. This system provides teaching materials that contain texts, videos, voices, and graphics that can be accessed through the internet. It also proposes the use of attractive characters to teach. Being a web-based learning system gives the ability of ease of access and can be used anytime, anywhere that learners can learn using this application at their ease.

The limited number of course materials and not utilizing the residual hearing can be considered major drawbacks in this system. As a pre-defined set of course materials is delivered through this system, it limits the ability to learn by exploring, which deviates from the natural learning pattern of a child. Utilization of residual hearing is crucial in order to provide a learning experience as close to the learning experience of a normal-hearing child.

The research “Applying Universal Design for Learning in Augmented Reality Education Guidance for Hearing Impaired Student” by Khon Kaen University propose an Augmented Reality based education platform. “Aurasma” is the mobile AR model proposed in this solution, and it is capable of detecting objects from the real world and translating the words into sign language in real-time. The below figure explains the flow of the proposed system.

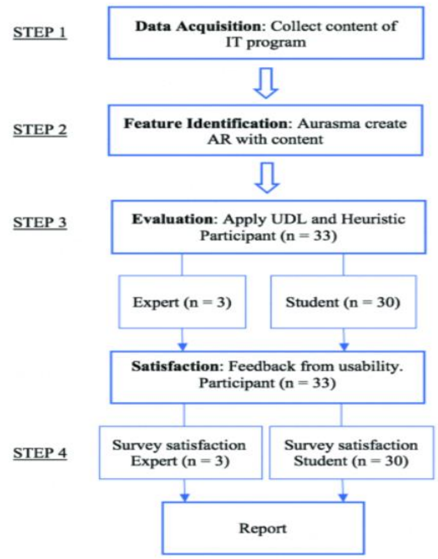

Figure 3: Source https://ieeexplore.ieee.org/document/8541294

Even though the system is capable of providing an explorative learning experience, learners will only depend on sign language. Even though there is residual hearing that can be utilized, this system does not take advantage of it. As the different nature of sign language compared to spoken languages and the limitations in sign language, it will hinder the learner's ability to acquire spoken languages, and there is a possibility of having a negative effect on the user’s reading and writing ability by only using the sign language to communicate.

1.3 Research Problem

A personal and experience-oriented environment that utilizes residual hearing in the process of language learning provides an effective language platform for hearing-impaired children. Conventional learning applications that are only limited to a pre-defined set of vocabularies and a pre-defined set of activities are unable to provide a learning environment that a child is comfortable dealing with. Bringing the learning environment into the child's own world will attract the child to the learning platform.

Normal-hearing children learn their first language by interacting with a person who is on the same ground, repetitively and frequently. The hearing-impaired children also should be provided with a similar experience by offering activities and vocabulary in relation to the child's background, culture, and environment, as well as by bringing up the residual hearing to a functional level with proper appliances. Simulation and response to the child's auditory experience are essential in the utilization of residual hearing.

The learning platform should provide materials that are suitable for the child's current state of linguistic ability and age. Words and sentences included in those activities should be at an appropriate level of difficulty to ensure a seamless learning experience. When creating teaching materials, the level of difficulty in course materials should consider both phonographic difficulty and contextual difficulty.

Preparing learning materials that are contextually similar to the words that the child has learned improves the vocabulary and helps the child to grasp the links and patterns in a language. In order to ensure repetitive and frequent use of previously learned words, new content should be presented, combining previously learned contents appropriately.

Regardless of the child's background, learning materials presented through the application should ensure the contents are appropriate for a child to learn. Context and intonation of the materials must be appropriate for a child, and in order to ensure this, content censoring should be done for every individual element presented through the application.

2. OBJECTIVE

2.1 Main Objective

The main objective of this research is to implement an experience-oriented learning platform for hearing-impaired children to learn their first language by interacting with elements of the child's world that enable an effective linguistic acquiring process. Appropriate utilization of residual hearing and different activities that replicate the natural language acquisition process to close the linguistic skill gap between hearing peers. Providing learning materials that are suitable for the level of linguistic skill enables an effortless language-learning process.

2.2 Sub objective

2.2.1 Contextually similar word generation

Generating contextually similar words and sentences to the previously learned contents in a meaningful way improves the vocabulary and helps the child to grasp the syntaxes and semantics of the language effortlessly. Providing contextually similar words and sentences helps the child to understand and link different elements that the child interacts with every day and mimics the language learning process of a hearing peer. Presenting words and sentences in a way that matches the child's interest in order to motivate the child to keep interacting with the learning platform.

2.2.2 Content filtration

Ensuring the contents presented through the application is kid-friendly is a major consideration when creating a learning platform for children. Although the learning platform is built around the child's own world, the contents presented through the application are assured to be kid-friendly regardless of the child's background. In the process of content censoring, false negative scenarios are not accepted.

3. METHODOLOGY

The main two functionalities of the proposed system are contextually similar word generation and content filtration. Similar word generation functions can generate contextually similar words that are similar to previously learned words that can be presented in a meaningful manner. Content filtration functionality ensures every content delivered through the application is suitable to present to a child.

3.1 System architecture

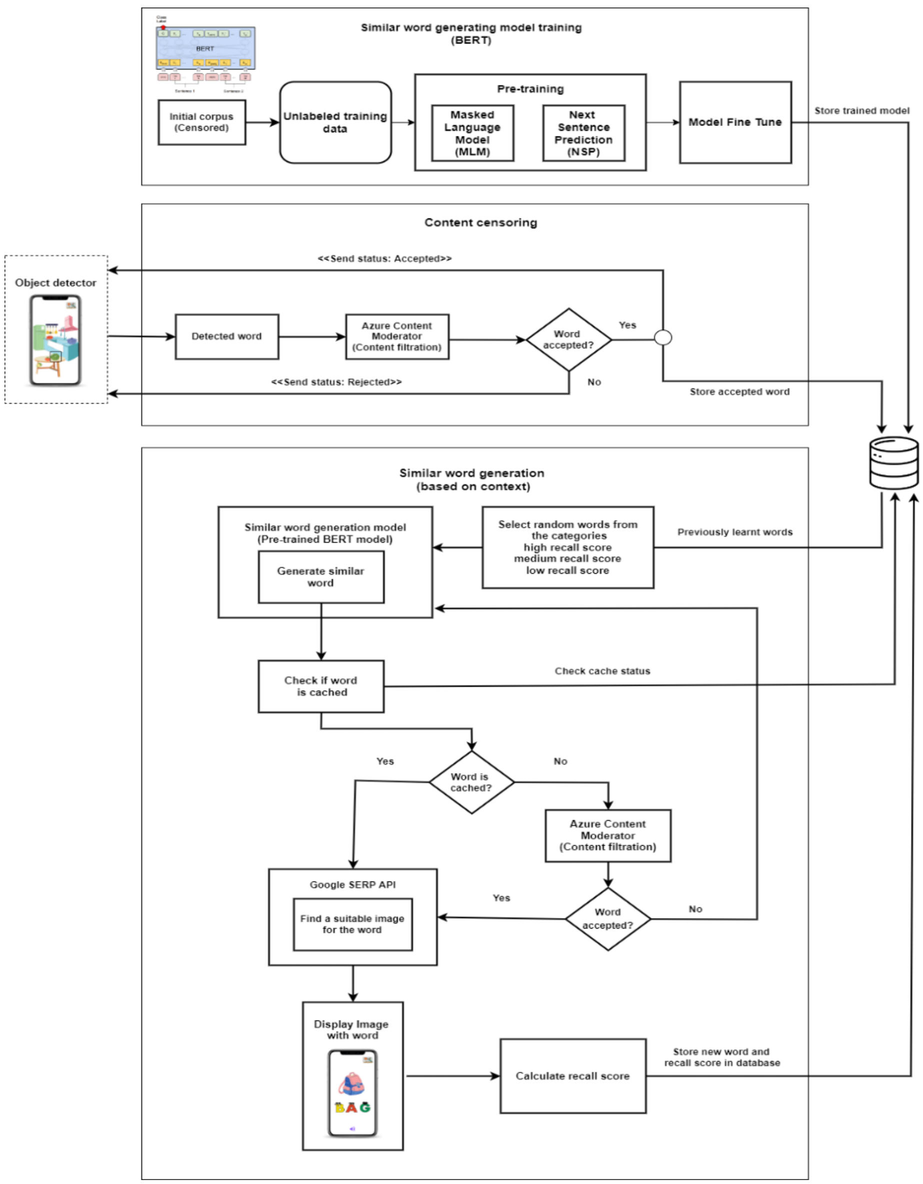

Figure 4: Individual component diagram

3.1.1 Similar Word Generation

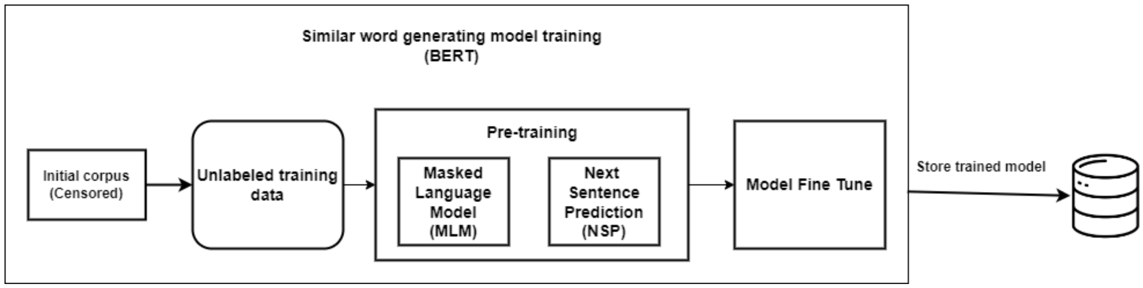

Figure 5: NLP model training

Initially, the similar word generation model is trained using unlabeled training data. The training corpus consists of contents of children's story books, whereas the tone and the contents of the training corpus should be kid friendly. As NLP model, custom trained BERT model will use as the NLP model for the proposed system.

BERT is an open-source, state-of-the-art NLP model developed by Google AI. BERT (Bidirectional Encoder Representations from Transformers) enables bidirectional learning from text with the use of transformers that has the ability to achieve a high level of accuracy, outperforming the previous state of art NLP models [8]. The following figure shows the comparison of NPL model performances on SQuAD (Stanford Question Answering Dataset)

Rank	Model	EM	F1
1 [Oct 05, 2018]	**BERT (ensemble)** Google AI Language **arrive.org/abs/180.04805**	**87.433**	**93.16**
-	**Human Performance** Stanford University (Rajpurkar et al. '16)	82.304	91.221
2 [Sep 09, 2018]	**nlnet (ensemble)** Microsoft Research Asia	85.356	91.202
3 [Jul 11, 2018]	**QANet (ensemble)** Google Brain & SMU	84.454	90.490

Figure 6: comparison of NPL model performances on SQuAD

The training process of the BERT NLP model further divides into two tasks as MLM (Masked Language Model) and NSP (Next Sentence Prediction). In MLM, some percentage of input tokens are masked, and those masked tokens will be predicted. Final masked tokens are fed into an output SoftMax over the vocabulary. NSP is capable of understanding the relationship between two sentences. The NSP training process involves pre-training of a binarized next-sentence prediction task that can be generated from any monolingual text.

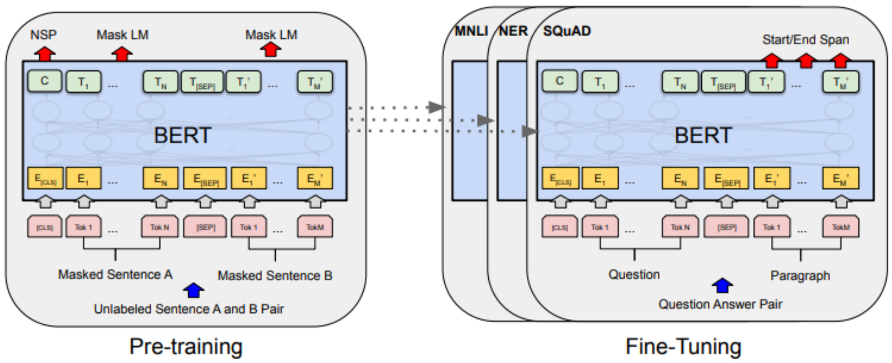

Figure 7: Pretraining process of BERT algorithm
Source: https://huggingface.co/blog/bert-101

In the application, similar word generation is done at the previously learned words that are stored in the database. Objects scanned through the object detection component and the similar words generated before are considered as the previously learned contents. When the user clicks the function that generates similar words, the system extracts four previously learned words based on the recall score high, medium, and low in the ratio of 1:1:2. Similar words will be generated on those selected words and will send for the censoring process.

In the censoring process, it will first check the local cache in order to find whether they are already stored in the cache. The purpose of having a local cache is to minimize the time taken for content filtration as Azure Content Moderator (content filtration model) is deployed in the cloud. If the word cannot be found in the local cache, it will send to Azure Content Moderator and get the accepted or rejected status. If the word is accepted, it will proceed to the image generation process, and if the word is rejected word will be sent back to the word generation model to regenerate a similar word.

Suitable images for generated words are extracted using the Google SerpApi Service. SerpApi Service is an API endpoint that allows scraping results via the Google search engine easily. For the application of the proposed system, image results from the SerpApi Service will be used. Since SerpApi Service contains advanced filters for contents, such as adult content filtering and domain filtering, it is not necessary to perform further filtration through the application.

UI of the similar word generation component will display the word and the image as a game that the child can interact with. The recall score will be calculated based on the child's interaction and performance in the game. The generated word and the calculated recall score will send to the database to be stored.

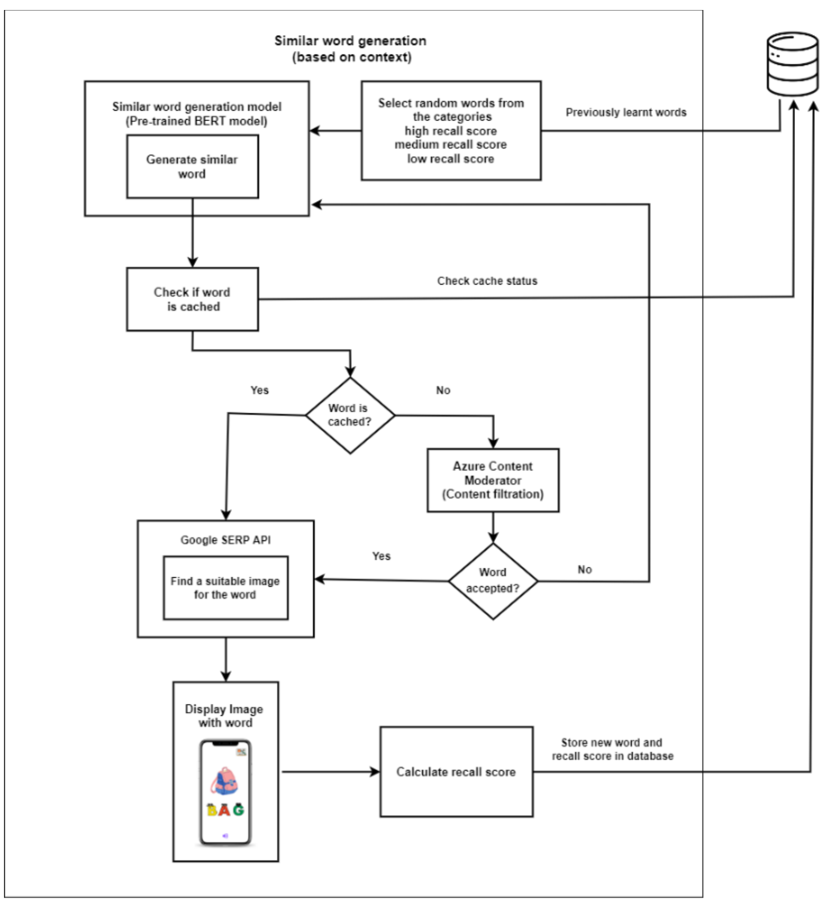

Figure 8: Similar word generation process

3.1.2 Content Censoring

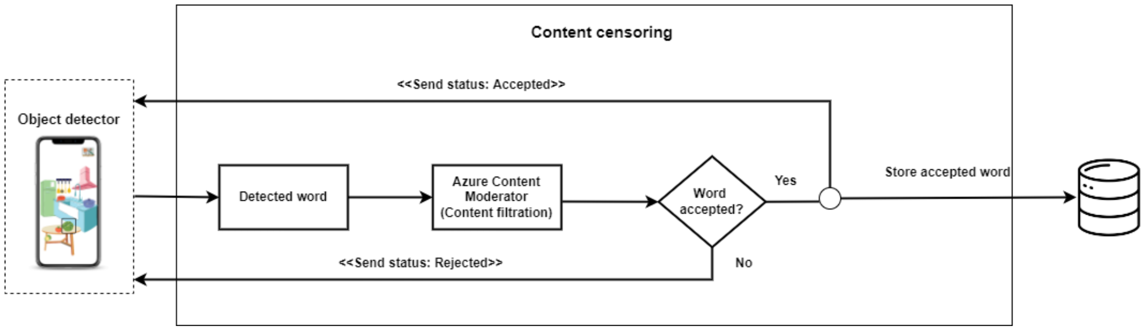

Figure 9: Content censoring

Content censoring is another functionality that will be implemented in the proposed system. For that, Azure Content Moderator is an AI powered moderation service offered in Azure Cognitive Services, which is capable of filtering potentially offensive and undesirable content from text images and videos. Text filtration service from Azure Content Moderator will be used for this application [10].

The object detection component sends the detected word to the content censoring component. In there, the word will be sent to the Azure Content Moderator service and get the content moderation insights as a JSON. Based on the classification label and classification score, acceptance of the word will be decided. The accepted or rejected status will send back to the object detection component, and if the word is accepted, it will be stored in the database as a learned word.

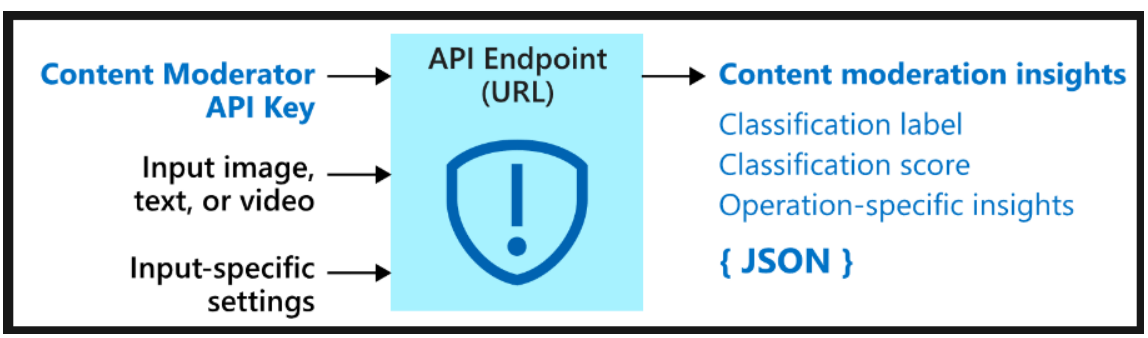

Figure 10: Azure Content Moderator

3.2 Technology selection

Table 1: Technologies and techniques use in the proposed system

Technologies	Python, TensorFlow Hugging Face, React Native, Django
Techniques	Masked Language Model, Next Sentence Prediction
API Services	Azure Content Moderator, Google SerpApi Service
Algorithms	BERT
Cloud services	Azure
Database	MongoDB
Other tools	Unity, Pycharm

3.3 Implementation

Implementation of the software solution will follow SDLC (Software Development Life Cycle) in order to achieve quality and consistent software product. In order to respond to the changing requirements, the Agile methodology will be followed as the project management approach.

3.3.1 Requirement Gathering

After the initial background research, a discussion with doctors in the ENT unit of Lady Ridgeway Hospital for Children was conducted to gather information on the medical background of the hearing impairment. After that, the School for the Deaf, Ratmalana, and the Centre for Education of Hearing-Impaired Children (CEHIC) reached out to understand currently how the education system is structured for hearing-impaired children. Interviews with audiology experts from Wickramarachchi Hearing Care Center were helpful in understanding the advancement of technological capabilities in hearing aids and devices and how they can be utilized to maximize the use of residual hearing of hearing-impaired children.

3.3.2 Feasibility Study

Technical feasibility study and planning were conducted to determine the feasibility of the proposed system and identify the knowledge gap of the team members and areas that needed to be improved in order to successfully deliver a quality software solution within the given timeframe.

A schedule feasibility assessment was conducted to plan and evaluate the feasibility of delivering a complete software solution concerning the given time frame and the technical capabilities of the team members.

The economic feasibility study was helpful in understanding the feasibility of the usage of the tools and technologies proposed for the system concerning budget constraints.

3.3.3 Design

The proposed system was designed considering the outcomes of technical, schedule, and economic feasibility studies. Use case diagrams, overall system architecture diagrams, and individual component diagrams are some of the diagrams used in order to illustrate the system's functionality.

3.3.4 Implementation and Integration

As discussed in the methodology section, implementation of the proposed system will follow,

- Custom training of the BERT algorithm as the NLP model
- Implementation of the similar word generation model using a custom-trained model
- Integration of the Azure Content Moderator with the NLP model

- Development of interactive games to present content generated from the similar word generation
- Integration of the game with the NLP model
- Integration of the Azure Content Moderator with object detection component.

3.3.5 Testing

Testing of the performance of the NLP model and the content censoring will be conducted in this phase in order to ensure the delivery of meaningful similar word generation and ensure the kid-friendliness of the contents presented through the application.

3.4 Commercialization

The proposed system supports eliminating the adverse effects of the linguistic skills gap in hearing-impaired children. The application will be available for user through the Google Play Store and Apple App Store. A freemium model will be used as a main revenue stream of the proposed system where sum of the advanced features will only be available for users that buy a monthly subscription.

Discussion with Wickramarachchi hearing care center is being processed on potential partnership on introducing a subscription-based payment model to their customers.

4. PROJECT REQUIREMENTS

4.1 Functional Requirements

1. System should be able generate contextually similar new words based on the previously learned contents.
2. System should be able to extract relevant images for the generated words.
3. System should be able to present the generated contents in a meaningful manner.
4. All the contents presented through the application must be kid friendly.
5. Content filtration must not allow any false negatives.

4.2 Non-functional Requirements

1. User-friendliness – Since the proposed system is an education tool for kid's, system UI must be attractive yet simple in design.

2. Integrity – System must only present the accurate contents.

3. Compatibility – System should be compatible with major mobile operating systems and should be able to run the application without any performance issues on majority of the mobile devices that are currently used in the community.

4. Reliability – All of the different functionalities of the system should be able to smoothly run on mobile devices without causing errors.

4.3 User Requirements

1. Parents – Parents use this application to give their hearing-impaired child a natural language learning experience that addresses the obstacles that preventing the child having a natural language learning experience.

2. Educators – Educators use this application to improve the quality of education provide from their institutes by encouraging children to learn by their own experiences.

4.4 System requirements

When system requirements are met the deployed system can properly operate on both client side and the server side. Smart phones that are compatible with following OS are able to run the proposed system

Android mobile phone – Android OS version 7 or above

Apple IOS – Released after 2016

4.5 Work Breakdown Structure

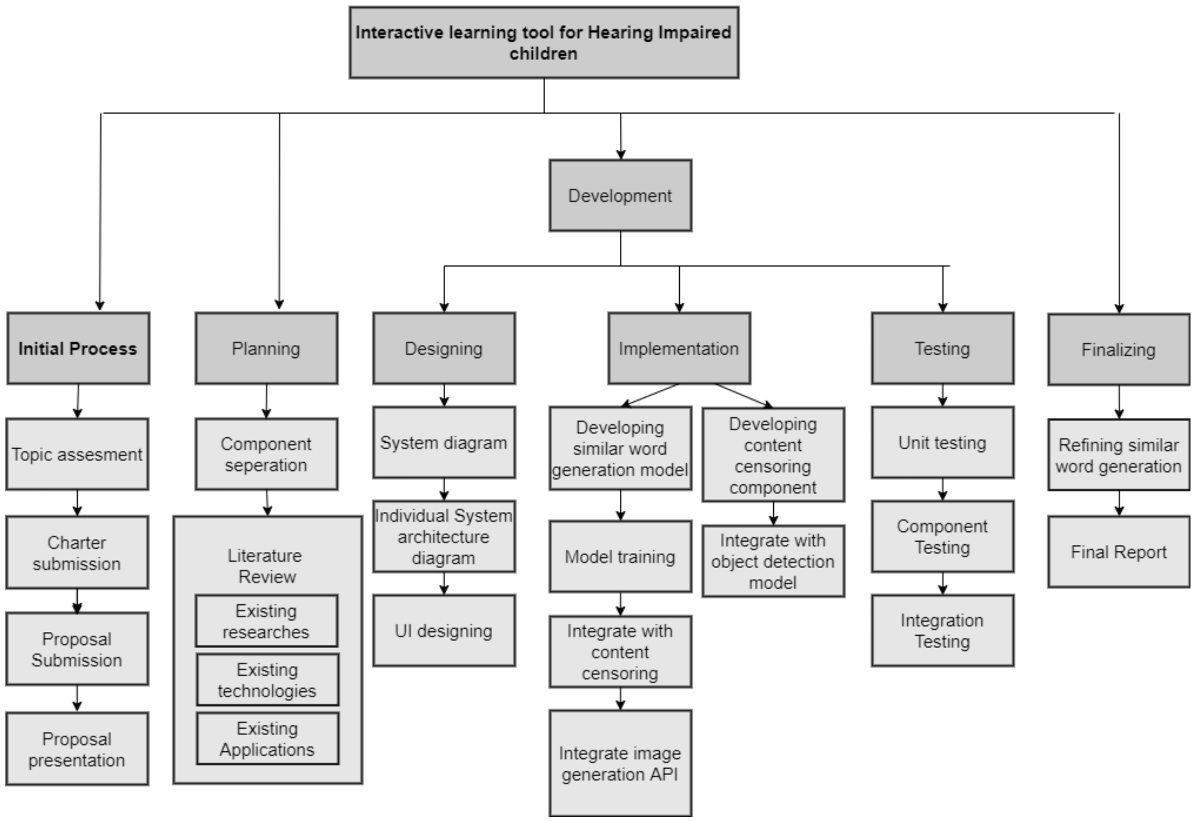

Figure 11: WBS

4.6 Gantt Chart

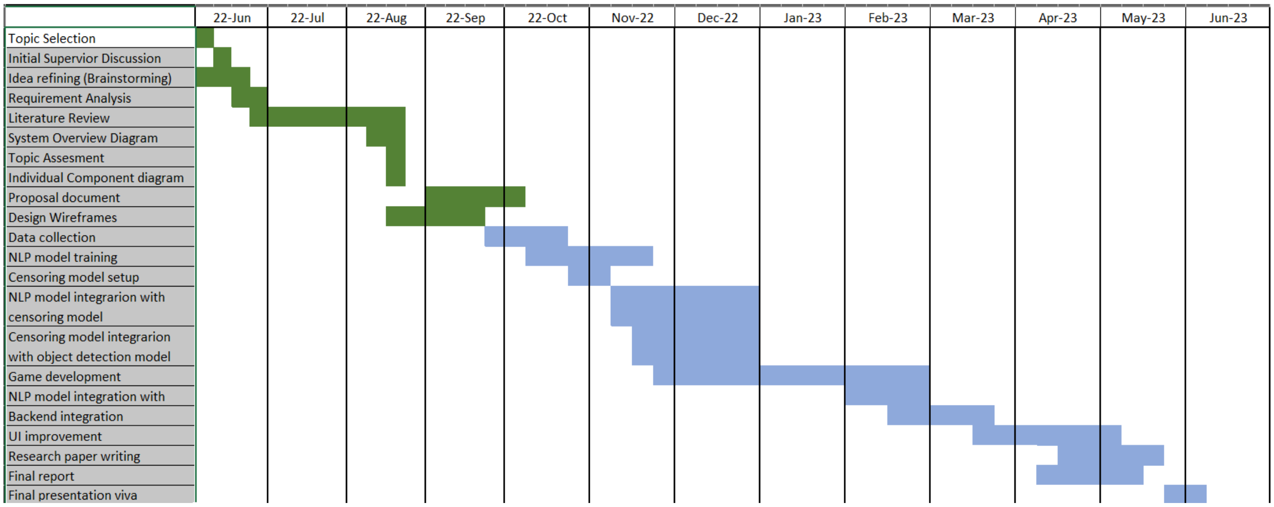

Figure 12: Gantt chart

4.7 Wireframes

Figure 13: Gantt chart

4.8 Budget and Justification

Table 2: Table of expenses related to proposed system

Requirement	Payment type	Estimated cost
Azure Content Moderator Service	Every extra transaction per second $1 per transaction (0-1M transactions)	$40 /month
Google SerpAPI	5,000 searches / month	$50 / month
Hosting Cost(Azure)	$0.075/hour	$50/ month
Google Play Store	One time payment	$25
Apple App Store	Annual fee	$99

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6. APPENDIX

Appendix 1: Plagiarism Report