A Web-Based Voice Enabled Mental Health Chatbot for Preliminary Assessment of Mental Illnesses

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Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the research proposal contains no material previously published or written by another person except where due reference is made in the research proposal itself.

Student signature:

Date:

Supervisor signature:

Date:

Abstract

Good mental health is characterized by a person's ability to feel, express, and manage both positive and negative emotions. This enables one to live at peace with their environment, and themselves. Although it may seem that mental illness is a recent phenomenon, evidence of its treatment can be traced back to 5000 BCE. Even so, topics surrounding mental illness are still considered a taboo especially in low- and middle- income countries. In recent years, organizations such as the United Nations, World Health Organization, International Monetary Fund, and many more have partnered to establish the 17 SDGs. Among them is SDG 3 which focuses on good health and well-being for all. Mental health is directly referred to in SDG 3, proving that the world has recognized it to be just as important as other illnesses. Unfortunately, with a rise in mental health awareness, there has been increased stigmatization against people with mental illnesses. This has made it difficult for people to seek help from friends, family, and healthcare professionals. The introduction of conversational agents to mental healthcare has been found to be a successful alternative to therapy sessions with a counsellor, more so for people who would otherwise not seek help. Chatbots also provide friends and family of mental illness patients with suggestions on how to care for them. Some of these conversational agents also provide emergency contact information and referrals to qualified health professionals. However, majority of these chatbots are not equipped with automatic speech recognition. This excludes the visually challenged and physically handicapped from utilising them, thus hindering the progression towards achieving SGD 3. The developed system seeks to solve the stated problem by implementing automatic speech recognition and speech synthesis utterance to chatbots. The system accepts user input in voice format, displays it in text, then provides a response in both voice and text format simultaneously. The project was designed using Object Oriented Analysis Design method and developed using prototyping methodology, which involved continuous testing and improvement of the system. Tools used in the project development include JavaScript programming language for the system's functionalities, and HTML (Hyper Text Markup Language) and CSS (Cascading Style Sheet) for the user interface. The IDE used was Visual Studio Code and firebase was used as the database system. BotUi was used as the chatbot's framework along with Web Speech API for speech synthesis and utterance.

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List of Abbreviations

AI Artificial Intelligence

API Application Programming Interface

ASR Automatic Speech Recognition

CBT Cognitive Behavioural Therapy

DBT Dialectical Behavioural Therapy

DNN Deep Neural Network

GUI Graphical User Interface

HCI Human Computer Interaction

IT Information Technology

ML Machine Learning

NLG Natural Language Generation

NLP Natural Language Processing

NLU Natural Language Understanding

RNN Recurrent Neural Network

SDG Sustainable Development Goal

STT Speech-to-Text

TTS Text-to-Speech

WHO World Health Organization

Chapter 1: Introduction

1.1 Background

Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (World Health Organization , 2018). As of 2017, an estimated 10.7% of the global population suffered from mental health disorders (World Health Organization, 2017). This shows that 1 in every 10 people suffers from a mental health disorder. 70% of mental health problems begin during childhood or adolescence and may go undiagnosed and untreated even into adulthood. The effects of undiagnosed and untreated mental illnesses are staggering, to both the individual and society. Mental health conditions can result in substance abuse, unemployment, poor quality of life, inappropriate incarceration, reduced life expectancy and suicide (Whiteford, 2010). This finding highlights the need for quality treatment. Mental health movements and discussions have brought to light the necessity of regarding mental disorders with the same importance and urgency as other illnesses.

Majority of the masses are now aware that mental illnesses exist and that they can be treated or managed. However, many people suffering from mental health disorders receive no treatment, more so in low- and middle-income countries (LMICs) (Demyttenaere, 2004). Apart from financial issues, there is also a limited availability of mental healthcare professionals in these countries. Globally, there exists the issue of mental illness stigmatization. This makes it difficult for people to seek help concerning mental health. Research performed by the mental health anti-stigma campaign, Time to Change, reveals that that when asked, nearly 88% of 16–24-year-olds would tell family and friends that they are ‘fine’ even when dealing with a mental health problem (Henderson, 2017).

Mental health is directly referred to in Sustainable Development Goal 3 and technology has played a major role towards achieving this goal. Chatbots or conversational agents that offer virtual therapy have been developed over the years (Abd-Alrazaq, 2019). They provide people with answers to mental health questions, tips on how to cope with a mental illness, contact information for mental health help services and some even provide a preliminary assessment for mental disorders. Some studies show that people were more inclined to communicate online with chatbots than with other people (Hill, 2015). This indicates that

there is a need to ensure that chatbots are easily accessible for use by every individual, including those with disabilities.

Figure 1. 1: The Global Sustainable Development Goals

1.2 Problem statement

Although there exists many chatbots, those focused on mental healthcare have some limitations that hinder their use. Majority of mental health conversational agents lack the implementation of voice-based communication (Torres, 2018). This limits their number of users by omitting people who are visually challenged and/or physically handicapped, slowing down the progress towards achieving SDG 3.

1.3 Aim

The aim was to develop a mental health conversational agent that makes use of both text-based and voice-based communication.

1.4 Specific Objectives

i. To investigate the evolution of chatbots in mental healthcare.
ii. To review chatbots used in mental healthcare.

iii. To design and develop a web-based mental health chatbot that employs the use of Natural Language Understanding(NLU), Automatic Speech Recognition(ASR) and speech synthesis utterance

iv. To test the developed system.

1.5 Justification

This system is important as it provides a mental health conversational agent that can be used by people who are visually or physically handicapped. It offers preliminary mental health assessment and self-help services to the user at no cost. The chatbot provides counselling services to the user regardless of their location. This contributes greatly towards achieving SDG number 3 (Whiteford, 2010) – Good health and well-being.

1.6 Scope and Limitation

The system accepts voice-based input and provides text- and voice-based responses to the user simultaneously. The system processes and understands user input then provides an appropriate and relevant response. It focuses on providing preliminary mental health self-tests, and not on counselling services. It only offers tests related to anxiety and depression. The chatbot only supports conversations related to mental healthcare, with pre-defined responses. The system only supports conversations in the English language. It is purely web-based and requires an internet connection for it to be used.

Chapter 2: Literature Review

2.1 Introduction

This chapter focuses on the history of mental illnesses and how the innovation of conversational agents has contributed towards the treatment of mental disorders. It discusses three different chatbots that are used in mental healthcare highlighting some of their limitations.

2.2 The history of mental illness

Although mental illness may seem like a recent phenomenon, references to mental illness can be found throughout history. The discovery of trephined skulls in regions that were home to ancient world cultures, is evidence that attempts to treat mental illness dates back to as early as 5000 BCE (Porter, 2002). It was believed that the mentally ill people were possessed by evil spirits and that this opening in the skull would release the evil spirits. In ancient Mesopotamia, priests treated the mentally ill through religious rituals such a s exorcisms, prayer, and incantations (Alexander, 1966).

Beliefs about the proper treatment of mental illness were altered between the 5th and 3rd centuries BCE, when the Greek physician Hippocrates denied the belief that mental illness was caused by supernatural forces, and instead proposed that it resulted from natural occurrences in the human body (Butcher, 2007). This eventually led to the establishment of asylums and treatment of mental illness by medical practitioners (MacDonald, 1981).

Since the late 1800s, medication was administered to sedate the mentally ill. However, this proved ineffective in treating the symptoms (Alexander, 1966). In 1949, pharmacology was introduced by psychiatrist Cade, J.F.J. and since then, it has been found to be one of the most successful mental illness treatment methods (Foerschner, 2009). Pharmacology is now used in the treatment of mental illness along with phycology counselling.

2.3 Conversational agents in mental healthcare

A conversational agent, commonly referred to as a chatbot, is a conversation simulating computer program (Dahiya, 2017). Interestingly, the first chatbot ever developed was in the field of mental healthcare. Joseph Weizenbaum, a Massachusetts Institute of Technology

scientist, created Eliza in 1966. It was a chatbot designed to use NLP to imitate Rogerian Psychiatrists speech patterns in psychotherapy (Donath, 2007). In 1972, an attitude-based version of Eliza named Parry, was created in Stanford University. During a Turing test, psychiatrists could only distinguish 48% of responses from Parry and a human (Jurafsky, 2015). In 1995, Richard Wallace created the artificial linguistic internet computer entity (ALICE), which become the most famous conversational agent of the 20th century. ALICE was able to chat with people more effectively due to its heuristic features. It later inspired the creation of current common chatbots such as Apple Siri, Facebook Messenger, Microsoft's Cortana, and Amazon's Alexa (Abushawar, 2015). Although there is much room for improvement in chatbots for mental health, they have been found useful in this field. Chatbots are now used for suicide prevention and cognitive-behavioural therapy (Hernandez, 2018).

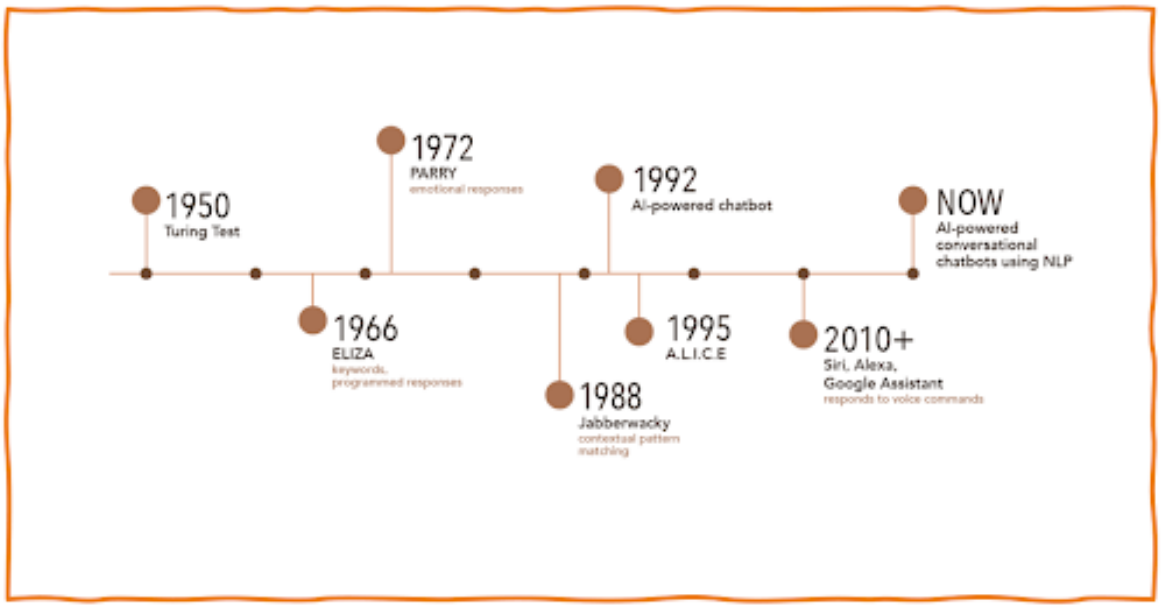


Figure 2. 1: The Evolution of Conversational Agents in Mental Healthcare

2.4 A review on similar systems

2.4.1 Wysa

Wysa, is an artificial intelligence based chatbot produced by an Indian start-up called Touchkin. It uses medically approved therapy methods such as cognitive-behavioural therapy(CBT) and dialectical-behavioural therapy(DBT) (Wysa website, 2019). Wysa has

helped many users to deal with depression, anxiety, and suicidal thoughts. Conversations with Wysa are private and encrypted. Wysa continues conversations from previous discussions with a user. This makes the conversation feel like one with a human psychologist. Wysa also offers users above the age of 18 the option of chatting with a human therapist at a fee (Kretzschmar, 2019).

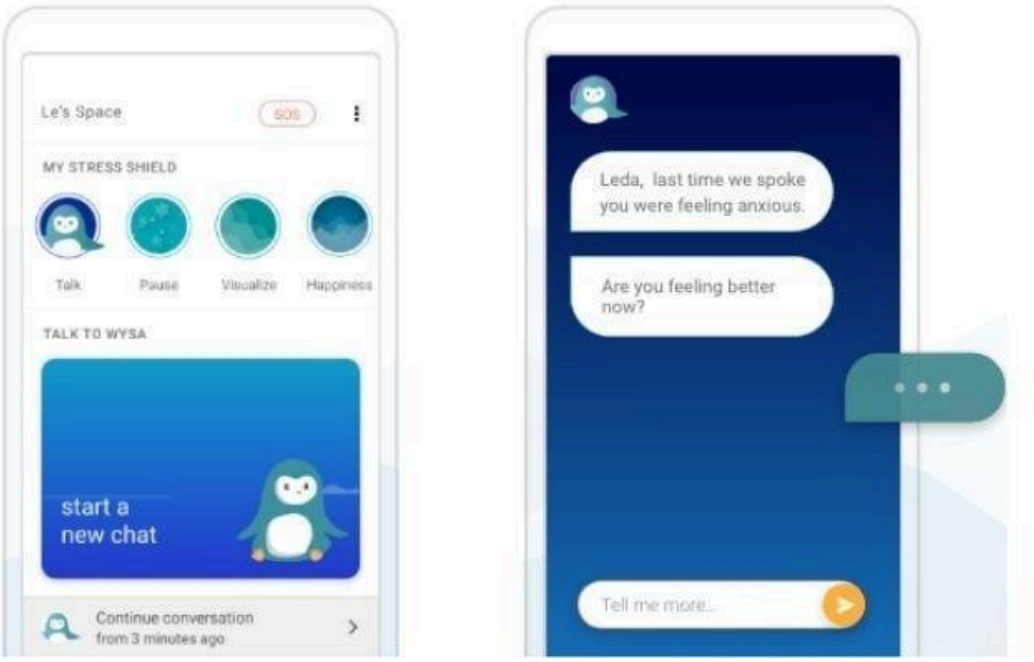


Figure 2. 2: Sample Conversation between Wysa and a User

2.4.2 Woebot

Woebot is a fully automated conversational agent developed by Woebot Labs in San Francisco (Woebot Website, 2019). It is designed to help people cope with feelings of depression and anxiety. Like Wysa, Woebot uses the principles of cognitive-behavioural therapy to treat depression. It is also used as tool to improve general mental health. Its conversations make use of emoticons making Woebot's responses look more emotional and human-like. This makes the conversation feel more relaxed, and as a result it becomes easier for the user to express their feelings to the chatbot (Kretzschmar, 2019).

Figure 2. 3: Woebot Health Logo

2.4.3 Apple Siri

Siri (Speech Interpretation and Recognition Interface) is an artificial intelligent software built into Apple's iOS and MacOS systems. It uses NLP and ASR technology, allowing users to interact with their mobile phones to perform functions such as internet searches, making calls, opening applications, setting up alarms, and more. Apple Siri able to answer all kinds of questions. If it encounters a question that it is unable to answer, it will perform a search on the internet before providing a suitable response. For this reason, Siri is used by people to seek help when they feel emotionally unstable (Bérubé, 2020). Siri makes use of humour to make its users feel comfortable.

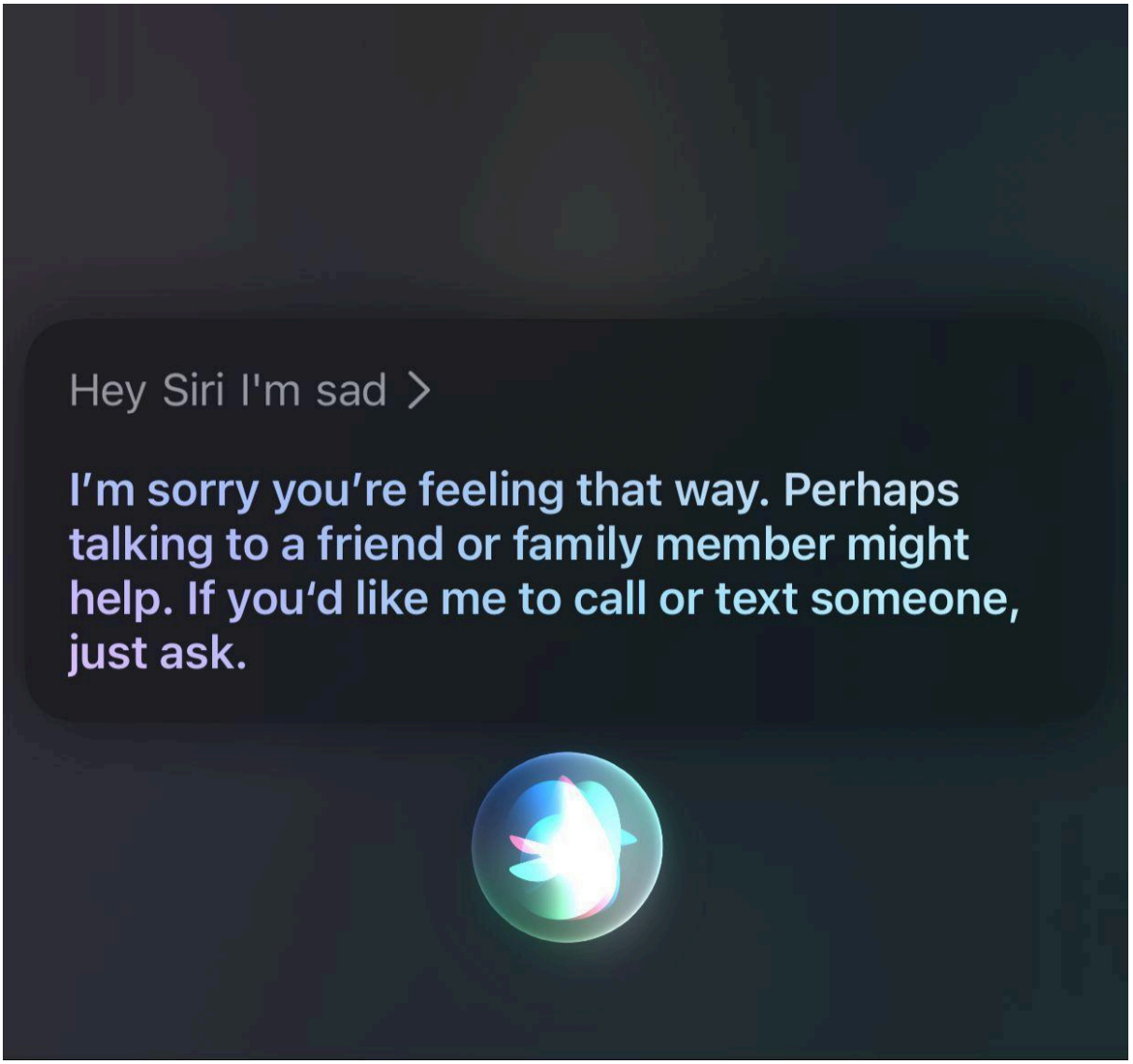


Figure 2. 4: Siri's Response to a User

2.5 Limitations of the reviewed systems

Woebot only accepts text-based user input. Its responses are also purely text-based. This is inconvenient for users with visual impairment (Kretzschmar, 2019).

Wysa has same limitation as Woebot, where it only accepts input in form of words. Furthermore, Wysa makes use of prefilled answers and guided journeys making it feel more like an interactive quiz or game than a mental healthcare chatbot (Hernandez, 2018).

There are few weaknesses existed in Apple Siri. It can only be deployed on devices that run on Apple's MacOS and iOS. This limits the number of potential users. Siri is not designed to specifically deal with a user's mental health concerns. When asked questions that it does not

have an answer to, it performs an internet search and gives links to related content as a response (Kretzschmar, 2019).

2.6 Proposed System

2.6.1 Solutions to gaps in reviewed systems

The proposed system was intended to offer solutions to these limitations. It was developed to accept voice-based input from the user, processes the information, then provides a response both in text and voice form. This makes it possible for people with visual or physical impairment to use the system. The system is web-based creating access to anyone with an internet connection.

2.6.2 Comparison between the developed and reviewed systems

The table below provides a summary on the features of the developed system and the reviewed systems.

Table 2.1: Comparison between Existing Chatbots and the Developed System

System name	Wysa	Woebot	Siri	Developed system (Joybot)
Text-based conversations	Yes	Yes	Yes	Yes
Voice-based conversations	No	No	Yes	Yes
Supported platforms	Cross-platform apps	Cross-platform apps	iOS and MacOS only	Web Application
Answers specific pre-defined questions	Yes	Yes	No	Yes
Designed for mental healthcare	Yes	Yes	No	Yes
Completely free	No	No	Yes	Yes

2.7 Conceptual framework

The developed chatbot receives the input from the user in voice format. The input is then converted to text using Speech-to-Text (STT) technology before being processed. The converted input is then processed. After this, the selected response in text form is converted into voice form using Text-to-Speech (TTS) technology. The chatbot then displays the output to the user in both text and voice form.

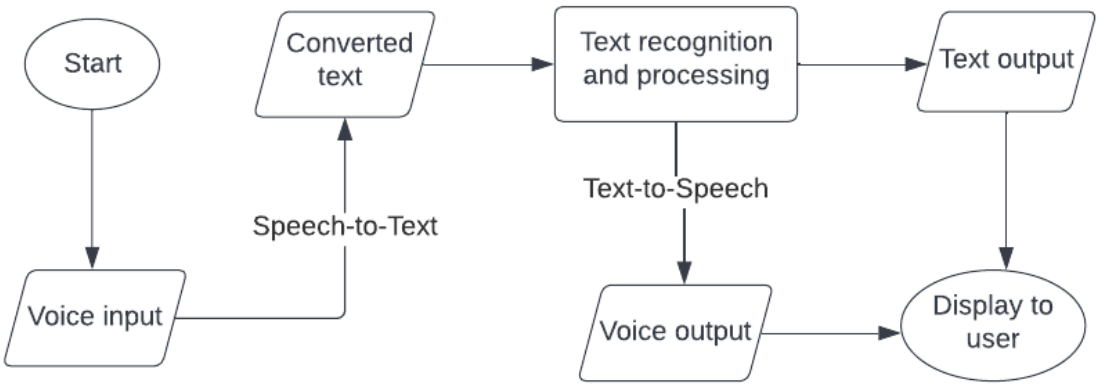


Figure 2. 5: Conceptual Framework of the Developed System

Chapter 3: Methodology

3.1 Introduction

This chapter describes the reliability and validity of the methods chosen to develop the system. It covers the methodology that was used for the developed system, the requirements of the system, the system modules, and the tools and techniques that were be used to develop the system.

3.2 System development methodology

The system was developed using the prototyping model. The model is an iterative, trial and error method, in which a prototype is built, tested, and reworked before achieving the final system. The methodology made troubleshooting and problem detection simple because it involved continuous testing throughout the development phase.

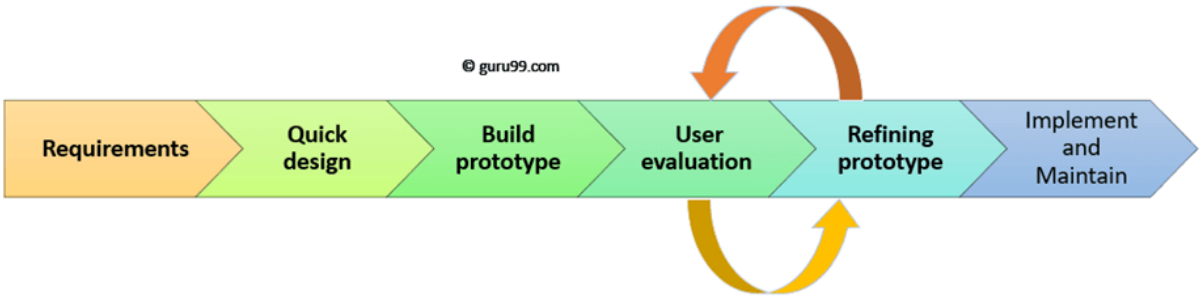


Figure 3. 1: Prototyping Model

3.2.1 Requirements analysis

The project aim was to create a free and easily accessible mental healthcare system, which can be used by the visually or physically impaired. This would facilitate mental healthcare to a larger population and contribute towards achieving SDG 3. The requirements analysis focused on gathering the chatbot's functional and non-functional requirements. They were gathered via research papers, analysis of similar existing models, questionnaire, and articles and journals on chatbots.

3.2.2 Quick design

The chatbot made use of the Structured System Analysis Design(SSAD) method. The system design made use of analysis and design diagrams. These diagrams promoted a better understanding of the project, resulting in efficient implementation of the system. They include:

i. Context diagram – This diagram outlines how external entities interact with the system.
ii. Level 0 data flow diagram – This diagram shows a representation of the whole system as a single process.
iii. Level 1 data flow diagram – This is an exploded view of the context diagram. It expands on each of the main sub-processes which constitute the entire system.
iv. Entity relationship diagram - This is a visual representation of the relationship between users, events, and objects within a system.
v. Wireframes - This is a representation of an interface that enables the user to interact with the system by use of icons and pointers.

3.2.3 Build prototype

In this phase, the system was developed by implementing the requirements and with reference to the design diagrams. The chatbot was developed using JavaScript programming language, BotUi interface and the web speech API. The first step was building the user and admin interfaces. Next was to build the chatbot by implementing speech recognition, speech synthesis and speech utterance.

3.2.4 User evaluation

In this phase, users interacted with the system and provided feedback on its speed, usability, and functionality. Users suggested that the speech rate should be increased, and that the hamburger should be changed to a navigation bar for easier navigation.

3.2.5 Refining prototype

Changes based on user recommendation at the evaluation phase were implemented here. They included modifying the user interface and adjusting the rate, pitch and speed of the voice output.

3.2.6 Deployment and maintenance

Once launched, the system is deployed on the web. This ensures ease of access by the users. Maintenance will involve making necessary changes as required by the system to improve its usability by the end user.

3.3 Deliverables

The system consists of five modules. They include the Natural Language Understanding(NLU) module, ASR module, state machine module, dialogue Natural Language Generation(NLG) module and reports module.

3.3.1 NLU module

This module is responsible for obtaining intents, identifying entities, and interpreting the conversation text.

3.3.2 ASR module

This module is responsible for converting voice-based input to text format.

3.3.3 State machine module

This module is responsible for maintaining the conversation state. This is achieved by the use of Recurrent Neural Networks(RNN).

3.3.4 Dialogue NLG module

This module is used to get the response from the state machine and relay it to the user. It handles the user interface.

3.3.5 Reports module

This module is responsible for generating reports for the administrator.

3.4 System design tools

The following tools were used for the development of the system

i. Integrated Development Environment - Visual Studio Code was used as the development environment for the system. It natively supports many programming and markup languages, and functions can be added by users via plugins.
ii. Database - Firebase was used to host the system's database. It is an open-source database management system developed by google. The database was used for data processing, data storage, and report generation.
iii. Repository: GitHub was used to back up the code for this project so as to mitigate against loss of progress.
iv. Runtime environment - Node.js was used to build, run and execute the application.
v. Bot module - BotUi and Newbot Framework were used to design the user interface, and to import libraries used for development of the bot.
vi. Application Programming Interface - The web speech API used was speech synthesis utterance, which is capable of converting voice to text, and speech to text.
vii. Programming Languages - HTML, CSS and JavaScript programming languages were used. Since the system is web based, the development process made use of web scripting languages to develop the solution.

Chapter 4: System Analysis and Design

4.1 Introduction

This chapter provides a list of all the functional and non-functional requirements that were identified for this system. It also highlights the approaches that were taken in the process of gathering the requirements during the system analysis phase. The chapter includes the system architecture and design diagrams, which facilitated smooth development of the system.

4.2 Requirements gathering

Research papers on similar existing systems were used to obtain insights on user needs and experiences. Volunteers used and tested similar systems and provided feedback and recommendations on how to improve them. This was also done to analyse the usability and effectiveness of existing systems. Articles and journals, and manuals of these systems were used to provide further understanding on how the systems worked and provide further insight on possible improvements to existing systems.

4.3 System requirements

4.3.1 Functional requirements

The following are the functional requirements that were gathered for the development of the system.

i. The chatbot should respond to predefined user input.
ii. It should accept user input in voice form and display it in text format.
iii. The system should provide output to the user in both text and voice format simultaneously.
iv. The chatbot should accept input and provide output in the English Language only.
v. The system should generate reports on the most frequent test taken weekly, and the ratio between percentages of the tested mental illnesses.
vi. The system should support predefined information related to mental healthcare.

vii. The system should allow clients to create accounts, sign in, and sign out.

4.3.2 Non-functional requirements

The following were gathered to improve user experience and system functionality.

i. Utility - The chatbot should have NLP functions to analyse the context of a conversation. It will therefore be able to identify the intent of a question and provide an accurate answer.
ii. Accessibility - The system should be deployed on the web making it easily accessible to a user regardless of the location or time. However, an internet connection is necessary for this.
iii. Security - All sensitive data should be encrypted.
iv. Manageability - The system should have a simple GUI to enhance Human Computer Interaction(HCI).
v. Reliability - The chatbot should have a fast response time.

4.4 System architecture

A user interacts with the chatbot via an electronic device connected to the web. User query is processed in the NLU layer, where intents are classified, and entities are recognized. The intents and entities are then used to fetch a response from the knowledge base of the model. The response is processed by the NLG layer and a response is relayed to the user.

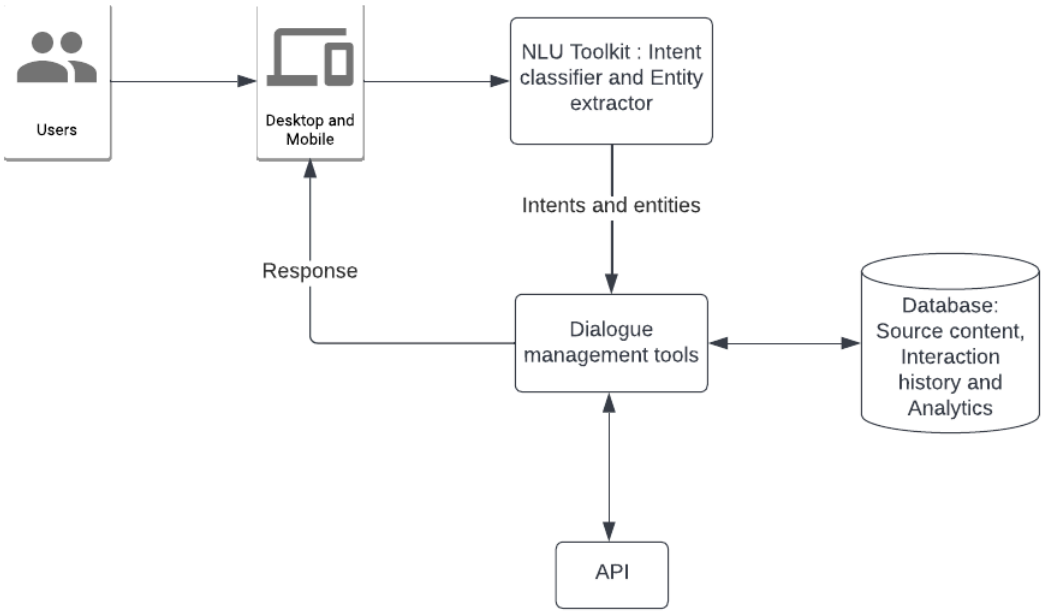


Figure 4. 1: System Architecture for the Developed System

4.5 Analysis and design diagrams

4.5.1 Context diagram

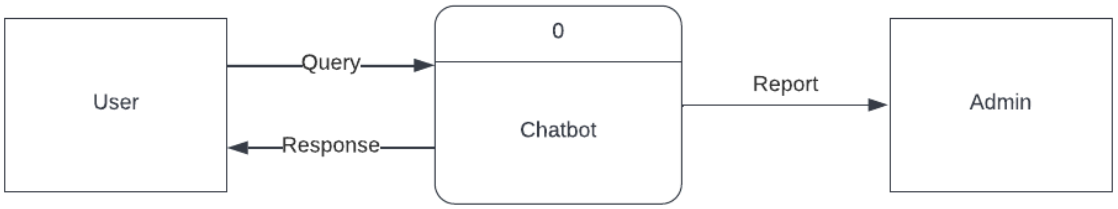


Figure 4. 2: Context Diagram for the Developed System

4.5.2 Level 0 Data Flow Diagram

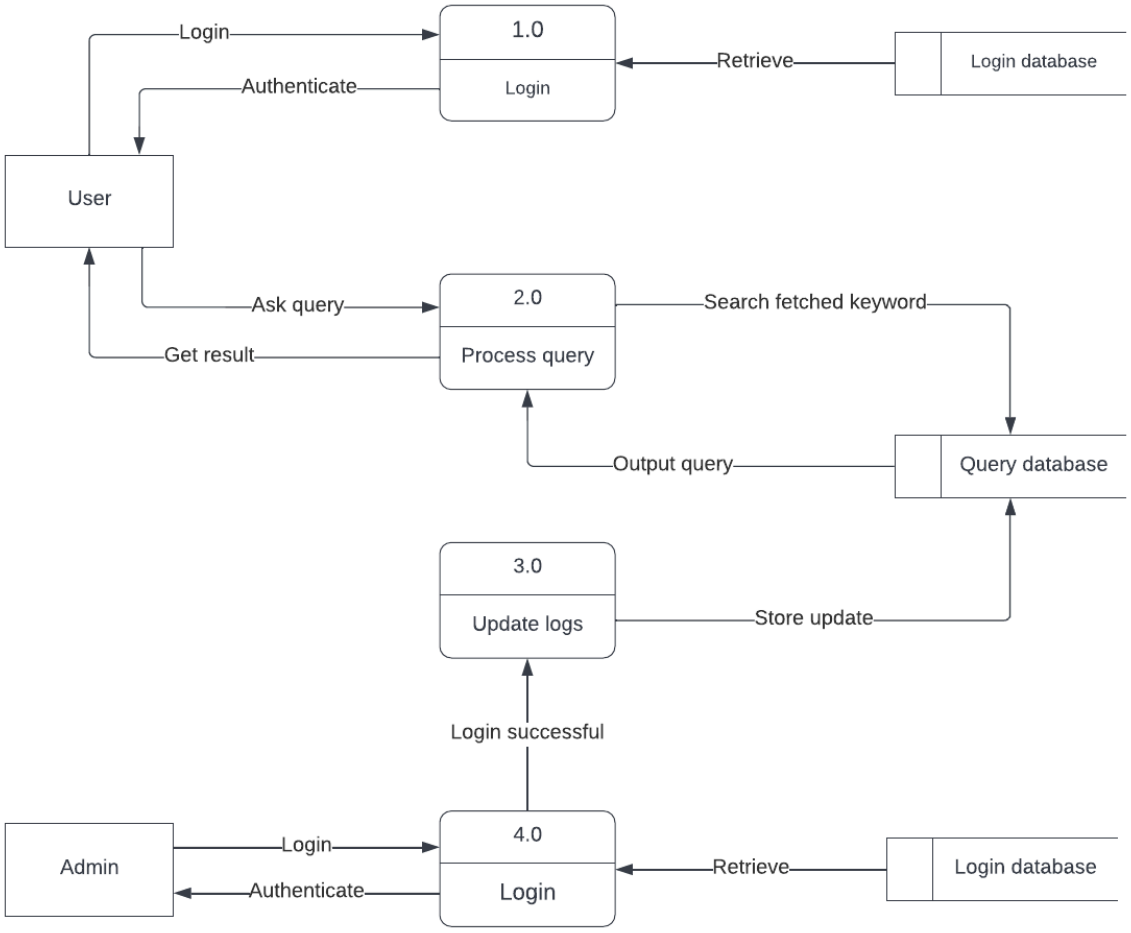


Figure 4. 3: Level 0 DFD of the Developed System

4.5.3 Level 1 Data Flow Diagram

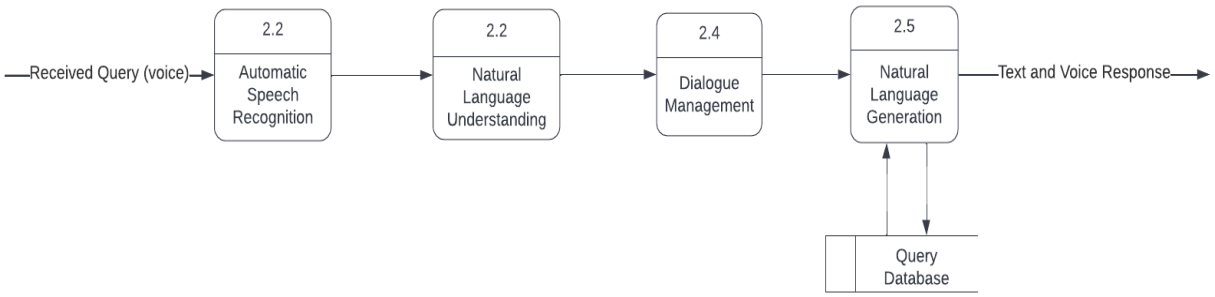


Figure 4. 4: Level 1 DFD for the Developed System

4.5.4 Entity Relationship Diagram

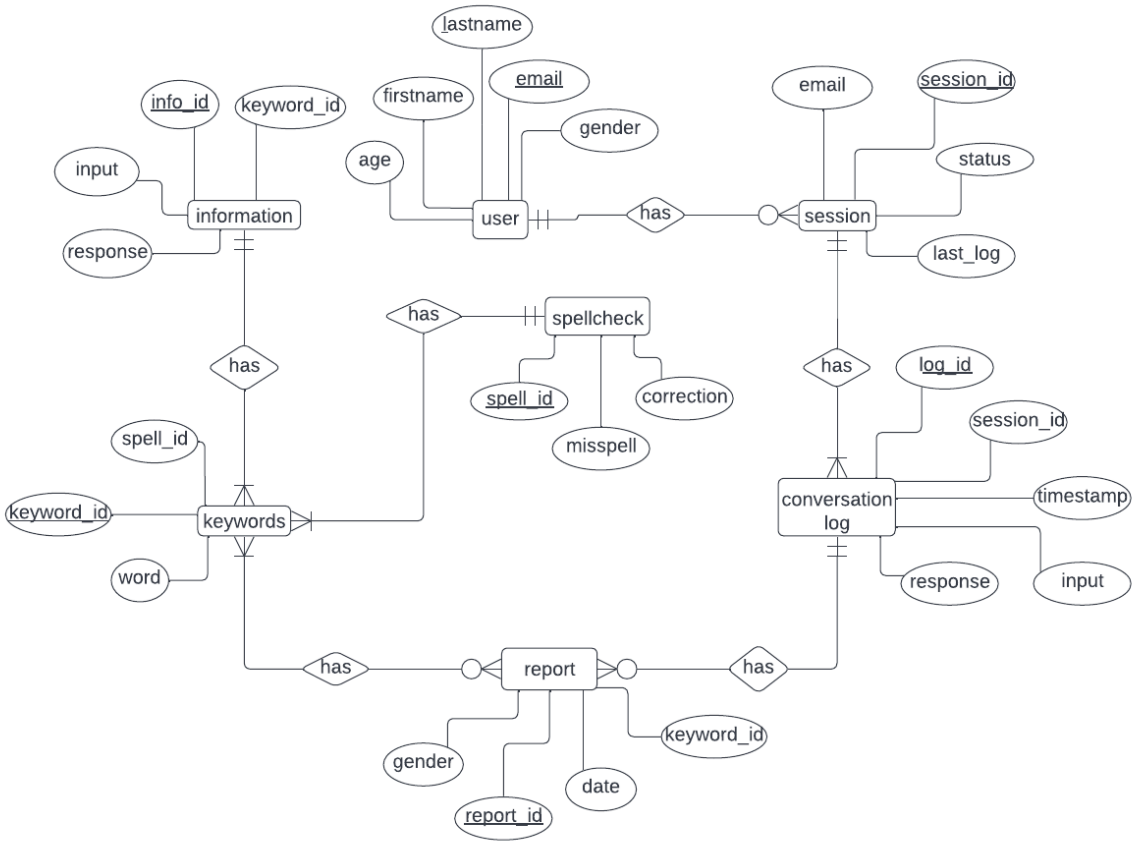


Figure 4. 5: ERD for the Developed System

Chapter 5: System Implementation and Testing

5.1 Introduction

This chapter describes how the system was developed, that is; both the user interface and the backend of the system. Furthermore, it explains how the system was tested to ensure that it fulfilled the specified requirements.

5.2 Implementation

The system was developed using methodologies described in Chapter 3, with reference to the design diagrams and requirements mentioned in Chapter 4 of this document. Below are diagrams of the user interface and code snippets of the development process.

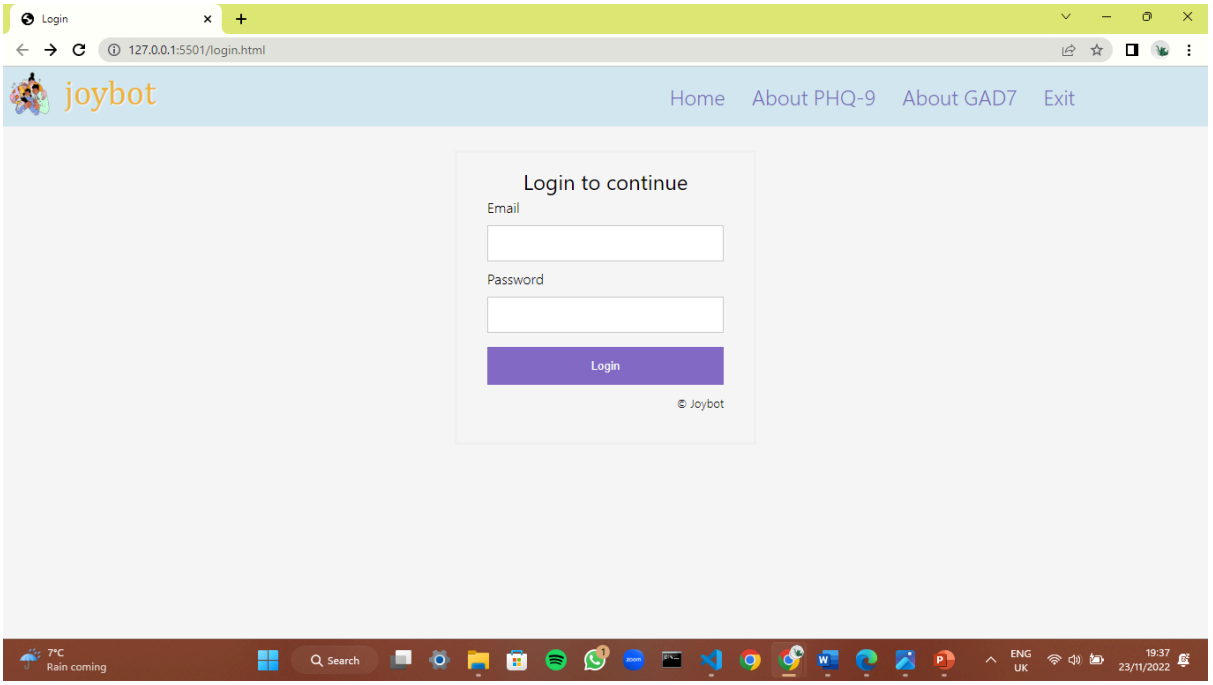


Figure 5. 1: User Login page

Once a user has logged in, they are redirected to the home page. The home page has a nav bar which is used to navigate throughout the website.

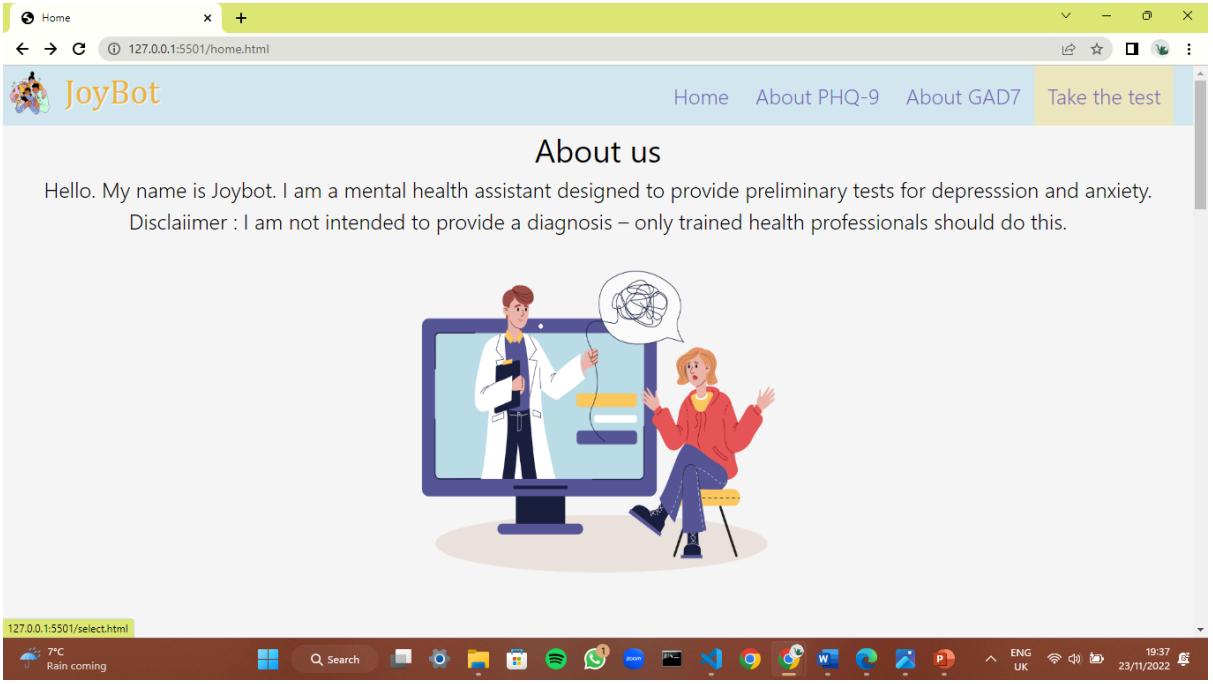


Figure 5. 2: : User Home Page

On clicking the "Take the test" button, the user is redirected to the "Select test" page to choose the test they wish to take. Selecting a test launches the chat interface.

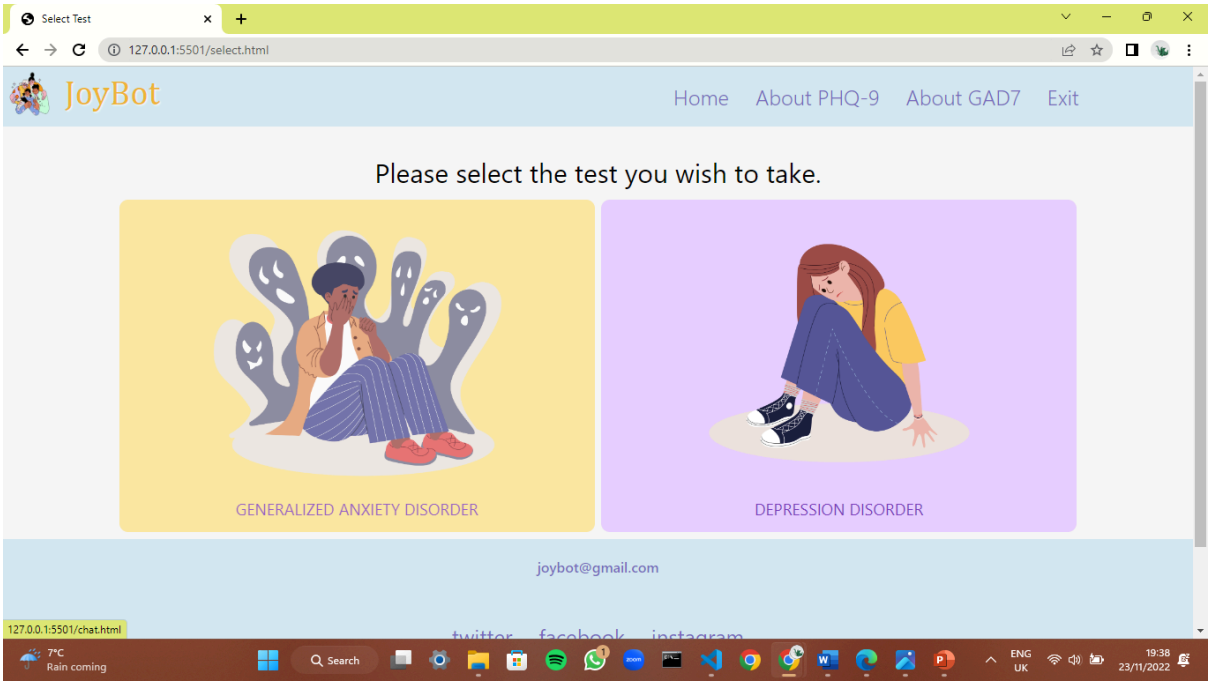


Figure 5. 3: Test selection

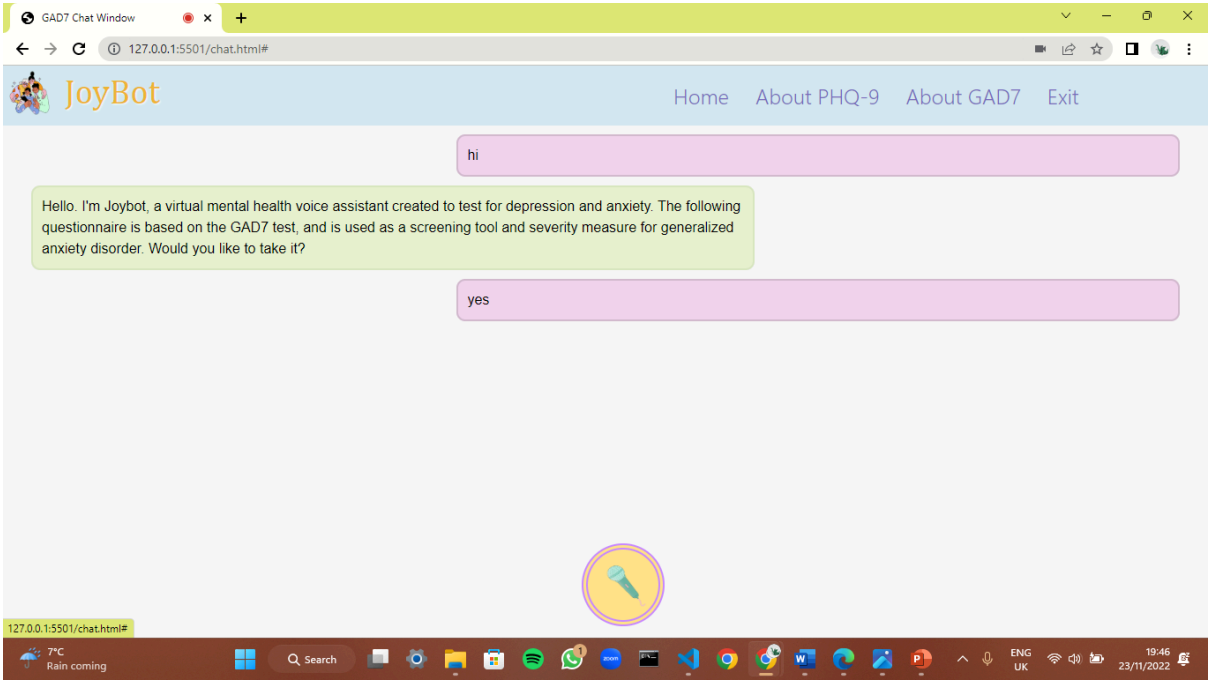


Figure 5. 4: Voice Bot Chat Interface (Red dot on tab shows recording in progress)

The voice prompt "Yes" opens the requested questionnaire. The bot reads out the question and choices to the user. The user can either select a choice by clicking a button, or by reading out one of the options given by the system. Once all questions have been answered, the test score is provided to the user and a recommendation is given to them based on the score.

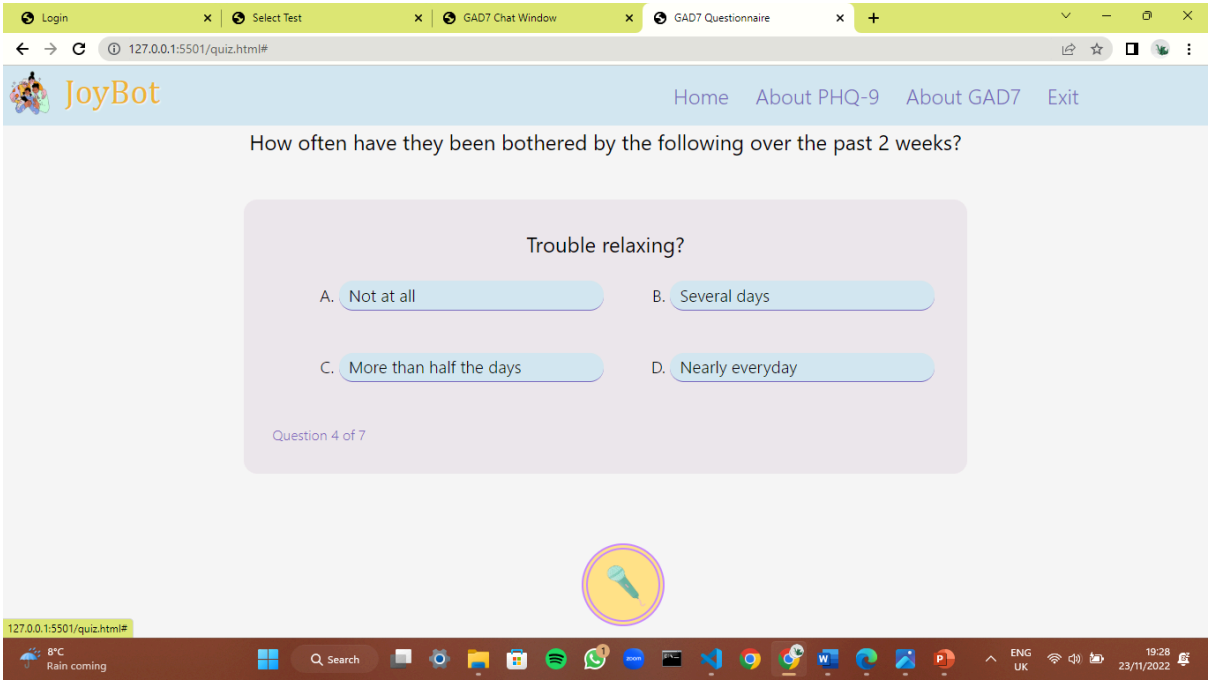
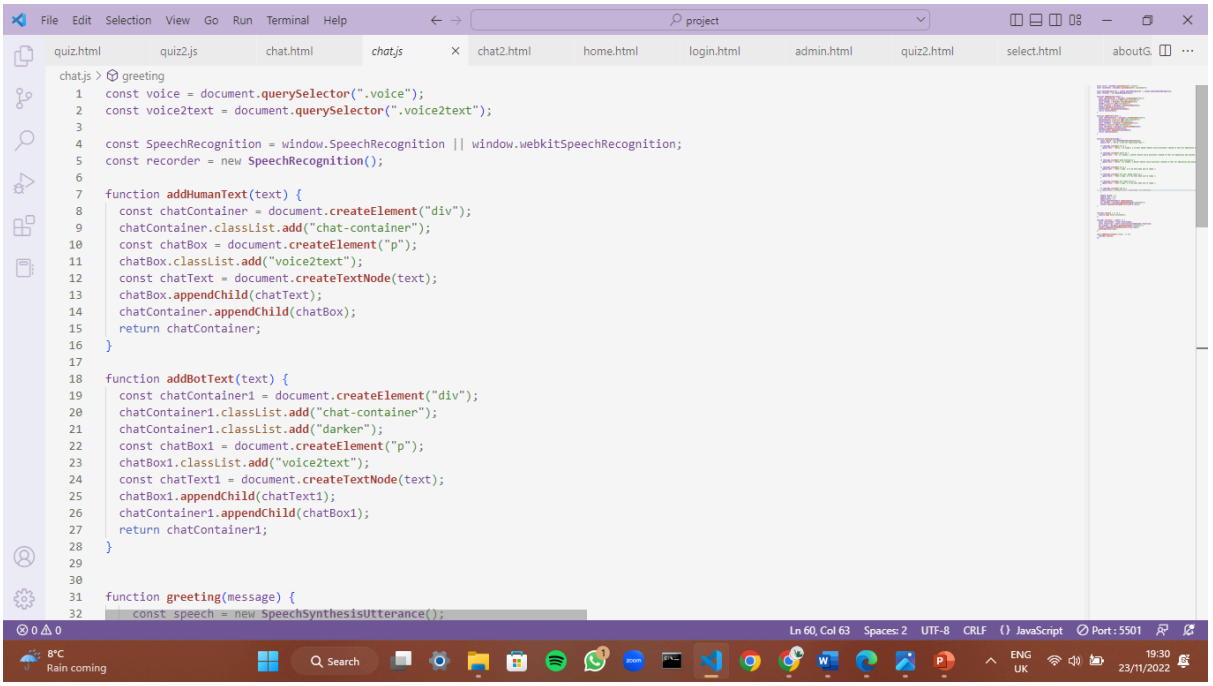


Figure 5. 5: Voice-Enabled Anxiety Disorder Test

Below are the code snippets used to enable the speech recognition, speech synthesis and speech utterance features.



```
const voice = document.querySelector(".voice");
const voice2text = document.querySelector(".voice2text");

const SpeechRecognition = window.SpeechRecognition || window.webkitSpeechRecognition;
const recorder = new SpeechRecognition();

function addHumanText(text) {
  const chatContainer = document.createElement("div");
  chatContainer.classList.add("chat-container");
  const chatBox = document.createElement("p");
  chatBox.classList.add("voice2text");
  const chatText = document.createTextNode(text);
  chatBox.appendChild(chatText);
  chatContainer.appendChild(chatBox);
  return chatContainer;
}

function addBotText(text) {
  const chatContainer1 = document.createElement("div");
  chatContainer1.classList.add("chat-container");
  chatContainer1.classList.add("darker");
  const chatBox1 = document.createElement("p");
  chatBox1.classList.add("voice2text");
  const chatText1 = document.createTextNode(text);
  chatBox1.appendChild(chatText1);
  chatContainer1.appendChild(chatBox1);
  return chatContainer1;
}


function greeting(message) {
  const speech = new SpeechSynthesisUtterance();
```

Figure 5. 6: Defining User Input and Bot Response using Web Speech API

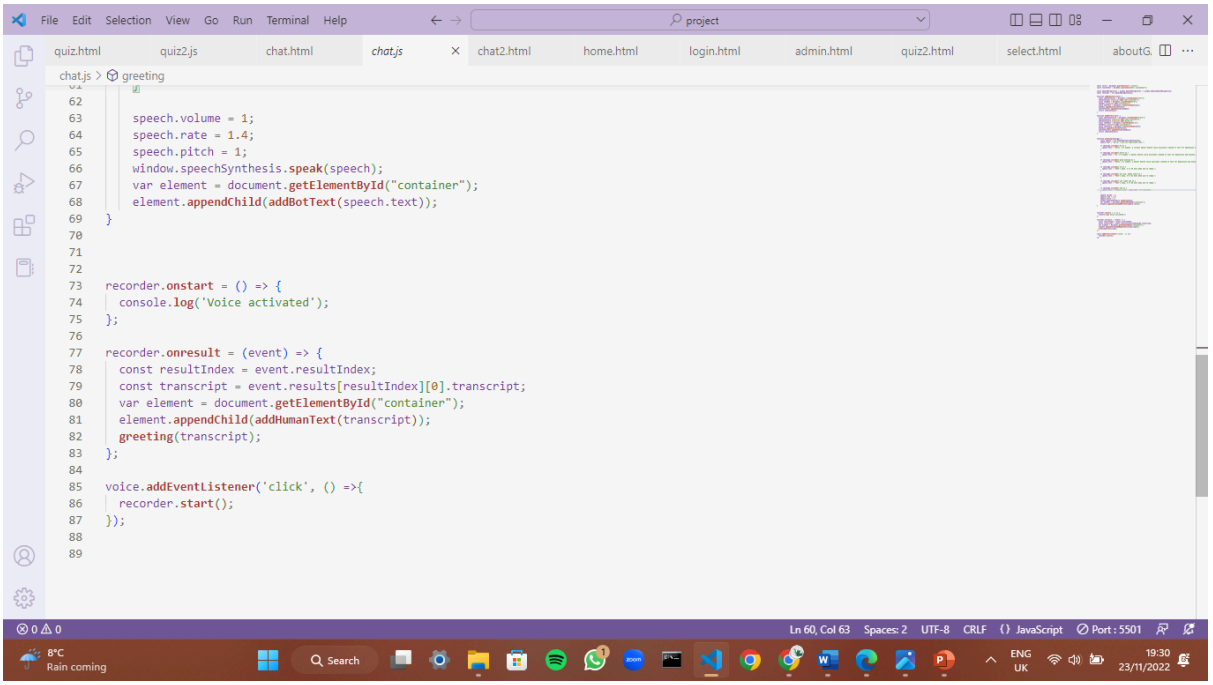


Figure 5. 7: Speech Synthesis Initialization

5.3 Testing

The following tests were carried out to check whether all requirements had been met.

Table 5.1: Tests Performed

Test No.	Related requirement	Inspect element	Test data	Priority	Pass/Fail
1	User registration	Does the system allow user to create an account and save it to database	Email: test@gmail.com Gender: Other Age: 30 Password: *******	High	Pass
2	User authentication	Does the system allow user to login and logout	Email: test@gmail.com Password: *******	High	Pass
3	Security	Does the system hash user password when keyed in and in the database	Email: test@gmail.com Password: *******	High	Pass

4	Utility	Does the system accept voice input Does the system provide response in voice and text	Email: test@gmail.com Password: *******	High	Pass
5	Access	Does the system allow the admin to view the database and reports	Email: admin@gmail.com Password: ******** Email: admin1@gmail.com Password: ******* Email: admin2@gmail.com Password: *********	Medium	Fail

Chapter 6: **Conclusions, Recommendations and Future Works**

6.1 Conclusion

This system was designed with the aim of providing preliminary mental healthcare to people with visual and physical disabilities. The system has achieved this through the implementation of automatic speech recognition, speech synthesis and speech utterance. The system has undergone testing to ensure that the requirements are met.

6.2 Recommendations

The Web Speech API that supports the system is fairly new, and only works in specific web environments. As of now, the system should be accessed via chrome and Microsoft edge only so as to ensure optimal functionality.

6.3 Future works

The system was designed to provide mental healthcare to people, including those with disabilities. The primary function, preliminary testing for mental illnesses (depression and anxiety), was achieved. However, due to the limited time frame, implementation of a virtual therapist within the chatbot could not be accomplished. Future works advancing on this project may implement the forementioned functionality.

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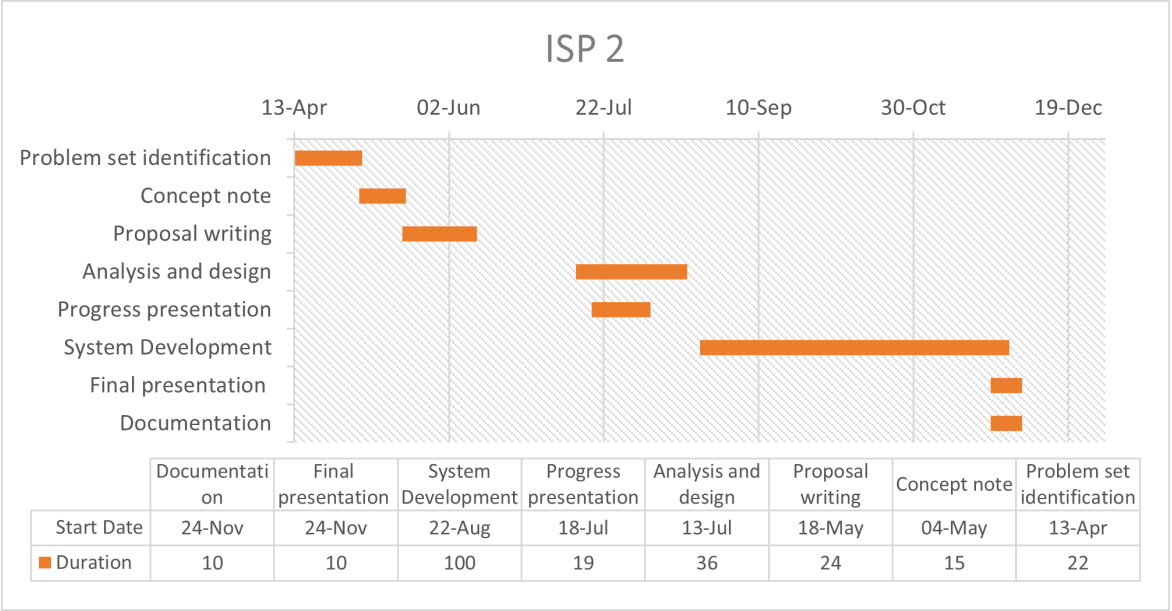
Gantt Chart



	Documentation	Final presentation	System Development	Progress presentation	Analysis and design	Proposal writing	Concept note	Problem set identification
Start Date	24-Nov	24-Nov	22-Aug	18-Jul	13-Jul	18-May	04-May	13-Apr
Duration	10	10	100	19	36	24	15	22