NEUROPLAY: AI-DRIVEN BRAIN COMPUTER INTERFACE FOR SEAMLESS MIND CONTROLLED GAMING INTERACTION AND REAL TIME EXPERIENCE

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report "**NEUROPLAY: UNLOCKING THE POWER OF AI-DRIVEN BRAIN COMPUTER INTERFACE FOR SEAMLESS MIND CONTROLLED GAMING INTERACTION AND IMMERSIVE REAL TIME EXPERIENCE**" is the bonafide work of "**MEGHA HARTHANA S (61772121026), ROJA R (61772121036), SANMATHI A (61772121038) AND SIVARANJANI C K (61772121042)**" who carried out the project under my supervision during the academic year 2024-2025.

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

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ABSTRACT

NeuroPlay is an innovative AI-powered Brain-Computer Interface (BCI) platform that enables users to interact with digital experiences through brain signals. This project combines mind-controlled gaming, cognitive training, stress management, thought-to-speech conversion, virtual companionship, and brainwave-based fitness tracking into a unified system, aiming to enhance mental focus, emotional well-being, and cognitive performance.

Leveraging EEG-based BCI technology, NeuroPlay allows users to control in-game actions and movements with their brain signals, improving decision-making, reaction times, and concentration. The system also incorporates mood-based music therapy, where AI detects emotional states and plays personalized music to induce relaxation or enhance focus. Thought-to-speech conversion helps individuals with speech impairments communicate, while a virtual pet companion responds to brainwaves, offering emotional support.

NeuroPlay also includes interactive cognitive exercises and performance analytics, which provide users with real-time insights into their stress levels, focus, and cognitive capabilities, fostering continuous improvement. This platform offers a holistic approach to brainwave-powered technology, blending gaming, cognitive enhancement, and mental wellness.

The merits of the system include:

- Personalized, mind-controlled interaction for enhanced cognitive agility and emotional regulation.
- Comprehensive cognitive training and stress management tools for improved mental health.
- Real-time performance insights and feedback, helping users track and enhance their cognitive and emotional well-being.

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LIST OF ABBREVIATIONS

AI	-	Artificial Intelligence
BCI	-	Brain Computer Interface
HTML	-	Hypertext Markup Language
CSS	-	Cascading Style Sheets
EEG	-	Electroencephalogram
JSON	-	JavaScript Object Notation
ML	-	Machine Learning
SQL	-	Structured Query Language

CHAPTER 1
INTRODUCTION

1.1 OVERVIEW

NeuroPlay represents a groundbreaking step in the realm of Brain-Computer Interface (BCI) technology. This innovative platform seamlessly integrates artificial intelligence (AI) and EEG-based BCI technology to create a holistic system that allows users to interact with digital systems using only their brain signals. The core objective of NeuroPlay is to transform the way people engage with technology, offering a dynamic blend of gaming, cognitive enhancement, and emotional wellness in a single unified system. With NeuroPlay, users can enhance their mental focus, boost cognitive performance, and manage emotional well-being—all through their brainwaves.

At the heart of NeuroPlay lies EEG (electroencephalography)-based BCI technology. EEG is a non-invasive method for measuring electrical activity in the brain. By attaching electrodes to the scalp, EEG sensors detect and analyze the brain's electrical signals, providing real-time data about the user's mental state. NeuroPlay leverages this brain activity data to allow users to control various digital functions hands-free.

NeuroPlay goes beyond simple brainwave monitoring—it decodes the brain’s electrical patterns to understand cognitive states such as focus, relaxation, anxiety, and even stress. This real-time interpretation of brain signals enables the platform to adapt its functionalities according to the user's cognitive and emotional needs, ensuring a truly personalized experience.

A distinguishing feature of NeuroPlay is its adaptive learning algorithms, powered by AI. NeuroPlay doesn’t just respond to brain signals—it continuously learns and evolves based on the user's interactions. Over time, the platform analyzes a user's brain activity patterns, detecting subtle changes in their cognitive and emotional states. This allows NeuroPlay to tailor its content and interactions, offering a personalized experience designed to maximize cognitive performance and emotional well-being.

For example, if a user is stressed or distracted, the platform may adjust the difficulty of a game or switch to a calming task. Likewise, if a user shows signs of deep focus, the system may present more challenging cognitive exercises, encouraging the user to push their mental boundaries. This dynamic adaptation makes NeuroPlay not just a tool for passive entertainment, but a powerful platform for active, personalized cognitive training.

Features and Functionalities of NeuroPlay

NeuroPlay integrates a wide variety of features that appeal to both cognitive enhancement and emotional wellness. Below are some of the key functionalities:

- **Mind-Controlled Gaming**: NeuroPlay takes gaming to the next level by allowing players to control in-game actions using their brainwaves. This immersive experience enhances mental focus, as players must concentrate to navigate virtual environments. Over time, users improve their attention span, reaction time, and problem-solving skills, while having fun.
- **Mood-Based Music Therapy**: Music has long been known for its therapeutic effects on the mind. NeuroPlay harnesses the power of AI to offer mood-based music therapy, which adapts in real time based on the user's emotional state. Whether the user is feeling stressed, anxious, or low on energy, the system plays personalized music designed to help balance emotions and restore calm.
- **Thought-to-Speech Conversion**: For individuals with speech impairments, NeuroPlay offers an innovative thought-to-speech conversion feature. This function uses brainwave signals to convert thoughts into speech, providing a new means of communication for those who struggle with traditional speech. This technology has the potential to

revolutionize the lives of people with disabilities, empowering them to express themselves freely and effectively.

- **Virtual Companionship**: NeuroPlay introduces a unique virtual pet companion that responds to the user's brainwave patterns. This AI-powered pet offers emotional support and stress relief, adjusting its interactions based on the user's mental and emotional state. The virtual companion acts as a source of comfort, helping users combat feelings of isolation and providing a calming presence during stressful times.
- **Interactive Cognitive Training**: NeuroPlay features an array of cognitive exercises designed to boost memory, decision-making, and mental agility. These exercises adapt in difficulty based on real-time feedback from the user's brain activity, ensuring that the user is always presented with an appropriately challenging task. Whether it's solving puzzles or memory games, the system helps users sharpen their cognitive skills in a fun and engaging way.
- **Real-Time Insights and Analytics**: One of the most innovative aspects of NeuroPlay is its ability to provide users with real-time insights into their cognitive state. Through performance analytics and AI-based alerts, users receive immediate feedback on their mental focus, stress levels, and emotional state. This continuous stream of data fosters self-awareness and allows users to track their mental health over time.

NeuroPlay's emphasis on cognitive training and mental wellness is rooted in its ability to understand and respond to individual brain patterns. When a user first begins using the platform, NeuroPlay assesses their baseline cognitive state, including factors such as focus, emotional well-being, and memory function. This baseline data allows the system to customize training programs and wellness strategies that are specifically suited to the user's needs.

As users continue to interact with the system, NeuroPlay gathers data on how their cognitive abilities evolve. If a user struggles with maintaining focus, the platform may suggest mindfulness exercises or introduce relaxation techniques to help improve mental clarity. If a user is experiencing high levels of anxiety, the system could recommend calming music or meditative activities. The adaptive AI ensures that the user's journey is dynamic, engaging, and tailored to their individual progress.

Moreover, the integration of real-time feedback further enriches the experience. If the system detects signs of cognitive fatigue or mental overload, it can reduce task difficulty or provide short breaks to restore mental energy. This ensures that the platform serves as a tool for improvement, rather than causing frustration or burnout.

The potential applications of NeuroPlay extend far beyond entertainment and cognitive training. As BCI technology continues to advance, it could pave the way for transformative changes in various industries, from healthcare to education. NeuroPlay's ability to track and analyze brain activity could be used to monitor mental health conditions, such as anxiety and depression, and provide real-time therapeutic interventions.

In the field of education, NeuroPlay's adaptive learning algorithms could revolutionize personalized learning. By tailoring educational content to the user's cognitive state, students could receive instruction that is optimized for their individual learning pace and focus levels. In healthcare, the ability to monitor and support cognitive and emotional well-being through BCI could provide valuable insights for mental health professionals, leading to more effective treatments for conditions such as ADHD, autism, and PTSD.

Furthermore, NeuroPlay's real-time insights into emotional and cognitive states could support workplace productivity and mental health, offering employees personalized tools to manage stress, enhance focus, and improve overall well-being.

NeuroPlay is more than just a platform—it is a revolutionary tool that bridges the gap between the human mind and digital technology. By combining BCI technology, AI-powered adaptive learning, and personalized cognitive training, NeuroPlay offers an unparalleled, immersive experience that improves cognitive performance, emotional well-being, and mental health. Whether through mind-controlled gaming, cognitive exercises, mood-based music therapy, or virtual companionship, NeuroPlay redefines how people interact with technology and empowers them to take control of their mental fitness.

As BCI technology continues to evolve, NeuroPlay stands at the forefront of a new era in cognitive enhancement and mental wellness, offering users the tools they need to optimize their cognitive abilities and emotional health in a fun, engaging, and personalized way. Through its dynamic and adaptive features, NeuroPlay is not just shaping the future of gaming—it's shaping the future of how we interact with our minds and the world around us.

In summary, NeuroPlay is designed to break the boundaries between the human mind and digital technology, offering a holistic approach to mental wellness and cognitive enhancement. Through this platform, users can enjoy a unique, immersive experience that blends entertainment with brain-driven cognitive improvement, redefining how people interact with digital worlds for entertainment, education, and personal growth.

CHAPTER 2

SYSTEM ANALYSIS

System analysis is “the process of examining a system's components, interactions, and objectives in order to understand its structure, functionality, and behaviour”. It involves studying the system's requirements, constraints, and goals to identify potential improvements or solutions.

During system analysis, analysts gather information about the current system, such as its users, processes, data, and technology infrastructure. They analyse this information to identify strengths, weaknesses, opportunities, and threats (SWOT analysis) associated with the system.

2.1 EXISTING SYSTEM

Nieto et al. (2022) utilized EEG recordings during inner speech tasks, including pronounced speech, inner speech, and visualized conditions. They employed a surface electroencephalography (EEG) system to capture brain signals. However, the study had a limited sample size, focused solely on Spanish speakers, and mixed imagined and actual speech, which could introduce potential confounds.

Srivastava et al. (2021) worked with the EEG motor movement/imagery database available on PhysioNet and implemented FFT (Fast Fourier Transform) transformation combined with an ensemble deep learning model for thought-to-text conversion using EEG. While the approach shows promise, further validation and usability testing are necessary to make it applicable in real-world scenarios.

Vorontsova et al. (2021) used EEG recordings during inner speech tasks, including pronounced speech, inner speech, and visualized conditions. They employed a connectionist temporal classification (CTC) model with automatic speech recognition (ASR) and a convolutional and recurrent neural network (CNN-RNN) for silent speech recognition. Despite achieving 85% accuracy in 9-

word classification, the model had a small vocabulary size, subject dependency, and lacked comparisons with other EEG-based silent speech recognition methods.

Ravi et al. (2020) recorded EEG signals from 13 volunteers who imagined the vowels "a," "e," "i," "o," and "u" in response to visual stimuli and employed a backpropagation neural network (BPNN) for imagined speech classification. However, the maximum classification accuracy achieved was 44%, and the study's focus on classifying only English vowels limits the generalizability of the findings to a broader range of speech sounds.

Key Observations from Existing Systems:

- **Common Dataset**: Most studies rely on EEG recordings during inner speech tasks, which typically include imagined speech and pronounced speech.
- **Methodologies**: Techniques like FFT transformation, neural networks (CNN, RNN), and CTC have been commonly used for speech classification. However, the combination of signal processing and machine learning models varies across studies.
- **Limitations**:
    - Limited vocabulary sizes in most models (e.g., 9 words in the Vorontsova study).
    - Small sample sizes and specific language dependencies (e.g., Spanish speakers in Nieto’s study).
    - Generalization issues due to the exclusive focus on specific speech sounds, as seen in Ravi’s study on vowels.

2.2 PROPOSED SYSTEM

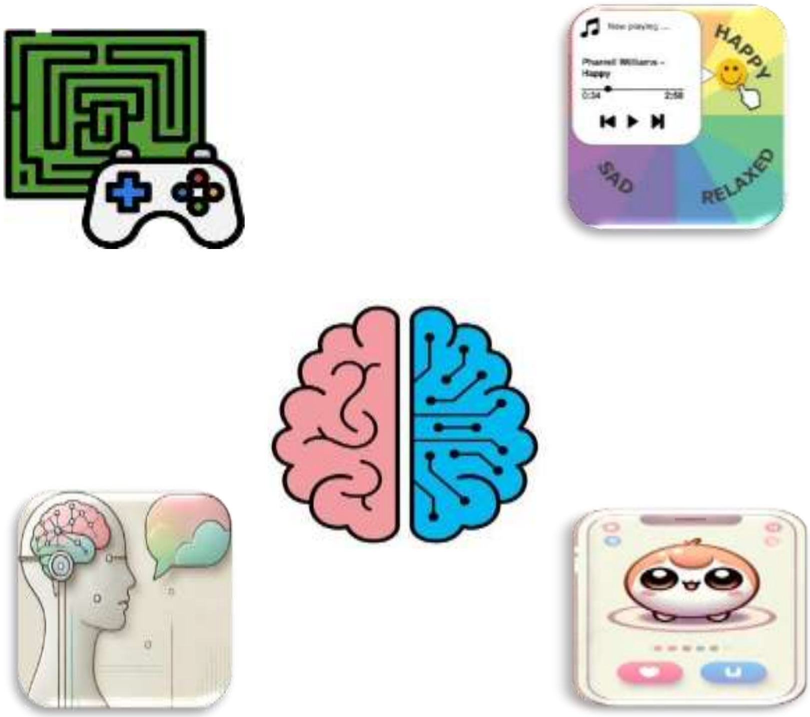


Figure 2.2 Proposed System

The AI-powered Brain-Computer Interface (BCI) integrated platform represents a cutting-edge technology designed to enable users to interact with digital experiences using their brain signals. This platform aims to create an immersive, hands-free environment where brainwave activity drives the user interface, eliminating the need for physical input devices such as keyboards or touchscreens. By integrating AI and EEG (electroencephalography) technology, it provides a truly intuitive way to control various digital environments.The proposed system depicted in Figure 2.2

A core feature of this system is its face and voice-based recognition login, which ensures both secure and personalized access. The face recognition system uses advanced facial recognition algorithms to authenticate users based on their unique facial features, while the voice recognition system adds an extra layer of security by verifying users through their voice. This dual-authentication method offers a robust security framework, allowing for safe and user-friendly access to the platform.

Once logged in, the system offers several exciting and innovative applications. One of the primary use cases is gaming, where users can control games entirely through their brainwaves. The BCI analyzes the user's mental state, translating cognitive patterns into in-game actions such as moving characters, selecting items, or interacting with the environment. This creates an immersive experience where users can engage with digital games without the need for traditional input devices like controllers or keyboards.

Another groundbreaking application is thought-to-speech conversion. This feature allows users to communicate by simply thinking, transforming their inner thoughts into speech in real-time. This can be particularly beneficial for individuals with speech impairments, providing them with a novel way to communicate hands-free. The system utilizes advanced AI algorithms to decode brainwave patterns related to speech, enabling accurate thought-to-speech translation and offering a new form of communication.

Additionally, the platform introduces emotion-based music. By continuously monitoring brainwave patterns, the system can assess the user's emotional state and dynamically adjust the music being played. For instance, if the system detects stress, it may play calming tunes to help the user relax. Conversely, if the user is feeling low energy, the platform might play more upbeat music to lift their mood. This real-time, emotion-driven music customization enhances the user’s experience, contributing to mental well-being by adapting to emotional needs.

The system also incorporates virtual pets and provides alerts and insights based on the user's mental and emotional states. Virtual pets can interact with the user, responding to their brainwave signals in real time, offering companionship and entertainment. The system also provides insights into the user’s mental health by analyzing brain activity, delivering feedback on levels of stress, relaxation, or focus. For example, if the system detects high stress, it may recommend a break or trigger stress-reduction activities like meditation or breathing exercises.

Beyond entertainment, the platform plays a significant role in mental and physical well-being. It helps in stress management by detecting signs of mental strain or anxiety through EEG signals and offering immediate interventions, such as guided relaxation or stress-reducing music. The system also aids in mental focus improvement, providing feedback that helps users maintain concentration during work or study tasks. In terms of physical fitness, the system can track brainwave activity during exercise, providing insights into mental states and recommending activities to enhance physical performance, such as focusing exercises during a workout to improve results.

The system workflow starts with EEG signal collection through a wearable headset that captures brainwave data. This data is processed by AI algorithms that analyze and interpret the signals to detect mental states like focus, relaxation, or emotional changes. Based on this analysis, the system then adjusts various experiences (e.g., changing music, controlling virtual pets, or interacting with games) to enhance the user's overall experience. Feedback from the system can help guide the user, for instance, suggesting a break if stress levels are high or recommending focus exercises when mental clarity is low.

However, the platform must address certain challenges to be fully functional in real-world applications. One of the major challenges is the accuracy of EEG signal interpretation. Brain signals can be highly complex, and ensuring the system can accurately decode and respond to subtle mental states is critical for user satisfaction. Additionally, the privacy and security of the data are of utmost importance. Since the system collects sensitive personal data, including brainwave patterns and biometric information (face and voice recognition), safeguarding this data against unauthorized access is essential.

Another challenge is user adaptation. Interacting with a digital environment purely through brain signals can be a new experience for most users. To ensure widespread adoption, the system must be designed to be intuitive and easy to use, with minimal learning curve for new users. As the user interacts more with the platform, the AI should continue to learn and personalize the experience based on individual needs and preferences.

In conclusion, this AI-powered BCI platform promises to transform how users interact with digital experiences by leveraging brainwave activity. It offers an exciting mix of gaming, communication, entertainment, and wellness applications that can improve the user's mental state, enhance focus, and reduce stress. While the technology holds great potential, overcoming challenges related to signal interpretation, data privacy, and user adaptability will be crucial in ensuring its success and widespread adoption.

2.3 FEASIBILITY STUDY

A feasibility study is a comprehensive analysis used to evaluate the viability of a proposed project. It examines key areas including technical, economic, legal, operational, and scheduling aspects to determine whether the project is practical and worth pursuing. The primary objective is to identify the strengths, limitations, risks, and opportunities associated with the project, helping stakeholders make well-informed decisions.

During this study, various factors such as technology requirements, cost estimations, legal constraints, resource availability, and timelines are analyzed. The insights gathered support strategic planning and reduce the chances of project failure by uncovering potential issues early.

The major dimensions of feasibility considered for our project include:

- **Economic Feasibility**
- **Technical Feasibility**
- **Operational Feasibility**
- **Legal and Compliance Feasibility**

2.3.1 Economic Feasibility

Economic feasibility evaluates whether the proposed solution is financially viable in terms of cost versus benefit. Our project is economically feasible as it does not require users to pay any subscription fees — it is completely free to use. The only prerequisites are a PC with Windows OS and an internet connection. While some integrated APIs used in the project may require a subscription after exceeding the free usage limits, the overall cost remains minimal and manageable.

2.3.2 Technical Feasibility

Technical feasibility assesses whether the required technology and infrastructure are available to implement the project. Our project is technically feasible because the application is lightweight and user-friendly, requiring only basic computer knowledge. Users simply need to launch the application and provide input either via speech or text. The backend processes, powered by voice recognition and response systems, handle all the logic, ensuring a smooth user experience.

2.3.3 Operational Feasibility

Operational feasibility evaluates how well the proposed system fits into the existing workflow and solves current problems. Our project enhances existing systems by introducing intelligent automation and interactive features, such as voice-command functionality. These improvements make the system more user-centric, efficient, and accessible, proving it to be operationally sound.

2.3.4 Legal and Compliance Feasibility

This aspect determines whether the system adheres to applicable laws, standards, and regulations. Our application respects user data privacy and complies with standard legal protocols. We ensure that all third-party tools and APIs used are licensed appropriately, and necessary disclaimers are included. The application is also designed to avoid collecting or storing sensitive personal data unnecessarily.

CHAPTER 3
SYSTEM SPECIFICATION

3.1 HARDWARE REQUIREMENTS

The following hardware specifications are recommended for the smooth functioning of this application.

- Processor requirements (recommended)
  - Brand: AMD
  - Name: Ryzen 5 Hexa Core
  - Variant: 4500U
  - Graphic Processor: AMD Radeon Vega 8
  - Number of Cores: 6
- RAM (recommended)
  - Capacity: 8 GB
  - Type: DDR4
  - Frequency: 2666 MHz
- Storage
  - Capacity: 256 GB
- Keyboard/Touchscreen
- Internet Connection

3.2 SOFTWARE REQUIREMENTS

The following software specifications are recommended for the smooth functioning of this application.

- Operating System
  - OS Windows 11 Home
  - OS Architecture: 64 Bit
  - System Architecture: 64
- Integrated Development Environment (IDE)
  - Visual Studio Code (Vs Code)
  - Jupyter Notebook
- Brain computer interface
- Code Maintenance
  - Git and GitHub
- Framework
  - Flask
- Database
  - PostgreSQL

CHAPTER 4
SOFTWARE SPECIFICATION

4.1 FRONT END

- **Role in Web Development**: The front-end is the part of the application that the user sees and interacts with directly. It is crucial for providing an intuitive and engaging user experience (UX). It typically works alongside the back-end, which handles the logic, databases, and server-side operations.
- **Tools & Frameworks**: Front-end developers often use tools like code editors (e.g., Visual Studio Code), version control systems (e.g., Git), and browser developer tools to improve productivity. Popular front-end frameworks like React, Angular, and Vue.js are commonly used to build more complex, component-based UI structures.
- **Cross-Browser Compatibility**: Ensuring that web applications work across various browsers and devices is one of the key challenges of front-end development. Developers use tools like BrowserStack to test and optimize websites for compatibility.

4.1.1 HTML

- **Semantic HTML**: Semantic elements (such as <header>, <footer>, <article>, and <section>) are used to give meaning to the structure of a webpage, which helps both developers and search engines understand the content better.
- **Forms and Input**: HTML provides form elements (<form>, <input>, <textarea>, <button>, etc.) that enable users to submit data. Forms are crucial for user interaction, such as login, registration, and feedback submission.

- **HTML5 Features**: HTML5 introduces new elements such as <video>, <audio>, <canvas>, and <article>, providing native support for multimedia content and interactive elements without relying on third-party plugins.
- **Responsive Web Design**: HTML works hand-in-hand with CSS and JavaScript to create responsive designs that adapt to different screen sizes, which is vital in the age of mobile-first development.

4.1.2 CSS

- **Responsive Design**: CSS plays a major role in responsive web design. Media queries are used in CSS to adjust the layout based on the screen size or device type. This ensures the web application looks great on desktops, tablets, and smartphones.
- **Flexbox and Grid**: CSS Flexbox and Grid are modern layout systems that provide more flexible and efficient ways to design complex layouts without relying on floats or positioning.
- **CSS Preprocessors**: Tools like Sass and LESS extend CSS by allowing variables, nested rules, mixins, and functions, which makes writing and maintaining CSS easier and more organized.
- **Animations and Transitions**: CSS allows the addition of smooth animations and transitions, enhancing the interactivity of web pages. These are often used for hover effects, loading indicators, and interactive UI components.
- **Frameworks**: Frameworks like Tailwind CSS, Bulma, and Foundation help developers quickly create aesthetically pleasing layouts without writing custom CSS.

4.1.3 JavaScript

- **DOM Manipulation**: JavaScript provides functionality for interacting with the Document Object Model (DOM), allowing developers to change the content, structure, and style of web pages dynamically in response to user actions.
- **Event Handling**: JavaScript allows developers to manage events like clicks, mouse movements, key presses, and form submissions, enabling interaction on the webpage.
- **Asynchronous Programming**: JavaScript's asynchronous features, such as setTimeout(), setInterval(), Promises, and async/await, allow developers to execute tasks without blocking the main thread, enabling a smooth user experience.
- **APIs and Fetch**: JavaScript is commonly used to make HTTP requests to interact with external APIs, retrieve data from databases, or communicate with servers. The Fetch API and AJAX are frequently used to send asynchronous requests.
- **ES6+ Features**: JavaScript has evolved with the introduction of ES6 (ECMAScript 2015) and later versions, bringing features such as arrow functions, destructuring, template literals, spread operators, and modules, making the code more concise and maintainable.
- **Frameworks**: Libraries and frameworks like React, Angular, and Vue.js enhance JavaScript by providing structured and reusable components for complex web applications.

4.1.4 Bootstrap

- **Grid System**: Bootstrap comes with a responsive 12-column grid system that allows developers to easily create responsive layouts. It automatically adjusts the column widths depending on the screen size, making it highly useful for creating mobile-first designs.
- **Predefined Components**: Bootstrap offers a wide range of ready-to-use components like navigation bars, modals, alerts, carousels, buttons, forms, and more, which streamline the development process and ensure consistency across a website.
- **Customizable**: While Bootstrap provides a default set of styles, developers can customize it using the Bootstrap customization options, including modifying variables for colors, fonts, grid behavior, and more. Additionally, Bootstrap 5 removed jQuery, reducing the dependency on additional JavaScript libraries.
- **Mobile-first Design**: Bootstrap follows a mobile-first approach, meaning the default styles are optimized for mobile devices, and developers can scale up the design for larger screens using responsive breakpoints.
- **Themes and Templates**: Bootstrap offers a variety of pre-designed themes and templates for developers to start with, saving time on initial layout design.

4.2 BACK END

- **Core Functionality**: The backend handles the server-side logic, such as data processing, user authentication, business logic, and application workflows. It works behind the scenes to make sure that user requests are properly handled and the right data is provided to the frontend.
- **Components**: The backend typically includes a web server (e.g., Apache, Nginx), a database (e.g., PostgreSQL, MySQL), and an application server

(e.g., Flask, Django, Node.js). Together, these components manage data, process requests, and serve the frontend.

- **APIs**: Backend services often expose APIs (Application Programming Interfaces) to allow the frontend or external systems to interact with the application. RESTful APIs or GraphQL are commonly used for data exchange between the backend and frontend.
- **Security**: The backend is responsible for handling security-related tasks, such as authenticating users, authorizing actions, protecting against attacks (e.g., SQL injection, XSS), and managing user sessions.
- **Scalability and Performance**: The backend needs to efficiently handle a large number of requests, especially in systems with high traffic or complex computations. It often requires techniques such as load balancing, caching, and optimization of database queries for better performance.

4.2.1 PostgreSQL

- ACID Compliance: PostgreSQL ensures data integrity through ACID properties (Atomicity, Consistency, Isolation, Durability), making it highly reliable for transactional systems where data consistency is critical.
- Extensibility: PostgreSQL is highly extensible. It supports user-defined types, functions, and operators, allowing developers to build custom solutions. It also supports procedural languages like PL/pgSQL, which is similar to Oracle’s PL/SQL, for writing complex functions and triggers.
- Indexing: PostgreSQL provides advanced indexing options like B-tree, hash, GIN, and GiST indexes, which can improve the performance of queries, especially for complex data retrieval scenarios.
- Support for JSON: PostgreSQL has built-in support for JSON, allowing developers to store and manipulate JSON data efficiently. This makes PostgreSQL suitable for both relational and NoSQL use cases.

- Replication and Clustering: PostgreSQL supports both synchronous and asynchronous replication, which can be used to ensure high availability and distribute the load across multiple database servers. It also supports clustering techniques like partitioning and sharding for handling large datasets.
- Geospatial Data: PostgreSQL with the PostGIS extension is commonly used for managing geospatial data, making it a great choice for applications that require location-based features (e.g., maps, GPS tracking).

4.2.2 Flask

- Minimalist Framework: Flask is known for being lightweight and minimalist, offering only the core features needed to build a web application. It doesn’t enforce a specific project structure, allowing developers to use their preferred tools and libraries for database management, form validation, etc.
- Routing and Views: Flask allows developers to define URL routes and map them to functions that return responses (usually HTML, JSON, or other data types). The routing system is flexible, making it easy to define RESTful APIs.
- Jinja2 Templating: Flask uses Jinja2 as its templating engine, allowing developers to generate dynamic HTML pages by combining templates with data passed from the backend. Jinja2 allows for loops, conditionals, and inheritance in templates.
- Extensibility: Flask’s modular design lets developers add extensions for additional functionality. Popular Flask extensions include Flask-SQLAlchemy for database integration, Flask-WTF for web forms, Flask-Login for user authentication, and Flask-Migrate for database migrations.

- Microservices: Flask is ideal for building microservices because of its lightweight nature. It can handle HTTP requests and APIs with minimal overhead, making it a great choice for small, independently deployable services.
- Testing and Debugging: Flask comes with built-in support for unit testing, making it easier to write and run tests for applications. It also includes an interactive debugger to assist developers during development.

CHAPTER 5

SYSTEM DESIGN

5.1 DEFINITION

System Design is the process of defining the elements of a system such as architecture, modules and components, the different interfaces of those components and the data that goes through the system.

5.2 ARCHITECTURE

An Architecture diagram is a graphical representation of a set of concepts that are part of an architecture, including their principles, elements and components, which is depicted in Figure 5.1.

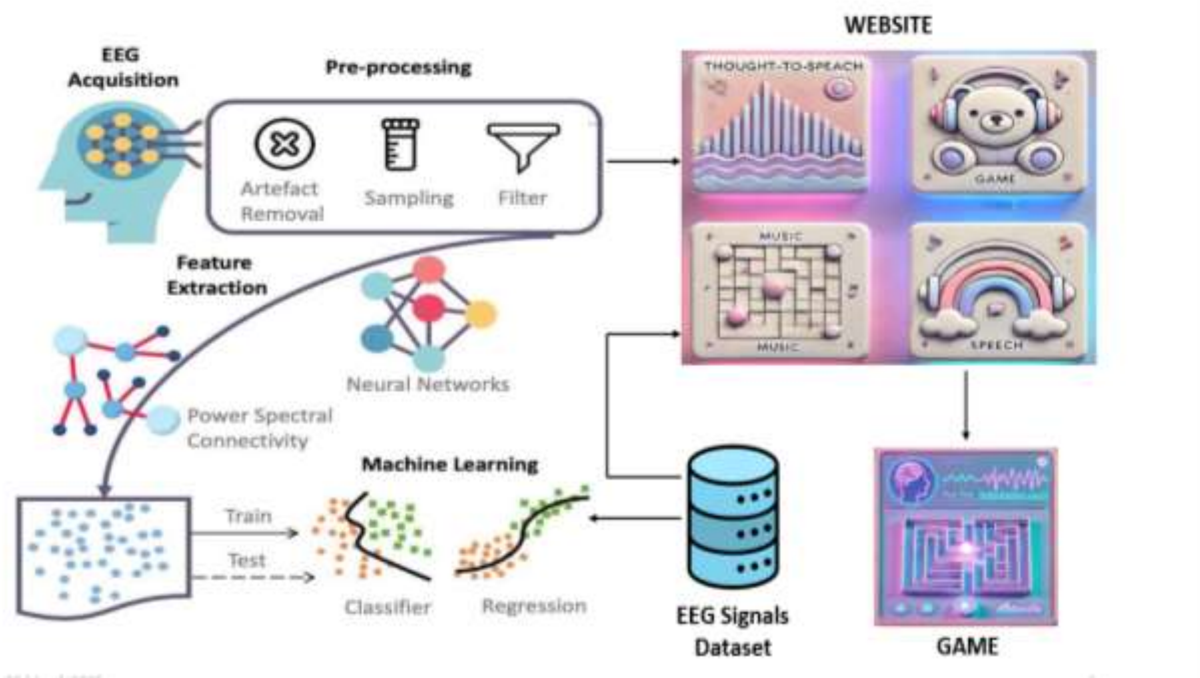


Figure 5.1 Overall Architecture

The architecture shown in Figure 5.1 represents a Brain-Computer Interface (BCI) system that processes EEG (Electroencephalogram) signals to enable thought-controlled interaction with a variety of applications such as speech synthesis, music generation, and games, all accessible via a website. The system begins with EEG acquisition, where brain signals are captured using electrodes placed on the scalp. These signals carry rich information about the user's mental state, but they are typically noisy and require several stages of processing before they can be effectively interpreted.

In the pre-processing phase, the raw EEG signals undergo cleaning and transformation to prepare them for further analysis. This involves artifact removal to eliminate disturbances like eye blinks and muscle movements, sampling to ensure consistent data collection, and filtering to isolate the relevant frequency bands. Once cleaned, the EEG signals proceed to the feature extraction stage, where critical information is derived from the signals. Techniques such as Power Spectral Connectivity are used to analyze how different brain regions communicate, and neural networks help identify deeper, more abstract patterns within the data.

Following feature extraction, the data is fed into a machine learning pipeline, where it is split into training and testing sets. Machine learning models, such as classifiers and regression algorithms, are used to interpret the brain signals. Classifiers are used to categorize different types of mental commands, while regression models can translate signal strength into continuous outputs. The system is trained using an EEG signals dataset, which contains labeled brain signal recordings that help the models learn how to accurately associate EEG patterns with user intentions.

The processed signals and predictions are then utilized in a user-friendly website interface. This web platform offers a range of applications. For instance, the thought-to-speech module converts detected brainwave patterns into synthesized speech, allowing users to communicate without speaking. The music module may generate music or allow users to control musical elements based on their brain activity. The speech interface could serve a similar function to the thought-to-speech system but with a different output or context. Additionally, a game module is available, where users can play brain-controlled games—such as navigating a maze—using only their mental commands, showcasing the real-time responsiveness and accessibility of the BCI system.

In summary, this architecture outlines a comprehensive pipeline—from brain signal acquisition to interactive web applications—that demonstrates the potential of EEG-based BCI systems in enhancing communication, entertainment, and user control, particularly for individuals with physical or communication disabilities.

5.3 USE CASE DIAGRAM

Use Case Diagram is a group of actors. It is a methodology used in system analysis to identify, clarify and organise system requirements. It is made up of a set of possible sequences of interaction between system and users in a particular environment and related to a particular goal. It is depicted in Figure 5.2.

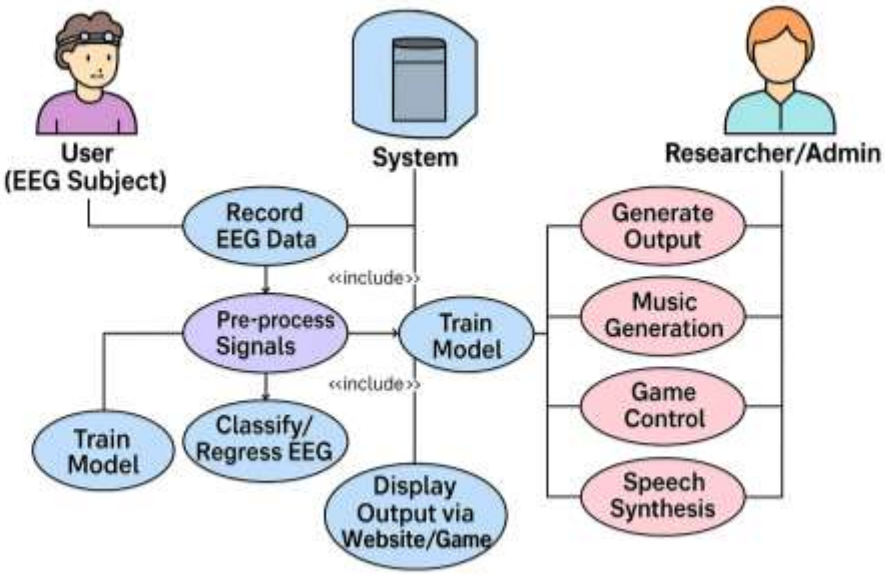


Figure 5.2 Use Case Diagram

Figure 5.2 shows how a Brain-Computer Interface (BCI) system works by involving three main actors: the User (EEG Subject), the System, and the Researcher/Admin. The user provides brain signals through EEG, which the system records and pre-processes. These signals are then used to train models and classify or regress EEG data.

The system displays the interpreted results on a website or game interface, allowing the user to control applications using their thoughts. The Researcher/Admin manages the backend by generating outputs like music, game actions, and speech synthesis based on the classified EEG signals. Overall, the system enables thought-based interaction with digital platforms.

5.4 DATA FLOW DIAGRAM

A DFD (Data-Flow Diagram) is a way of representing the flow of data of a process or a system. The DFD also provides information about the outputs and inputs of each entity and the process itself. Individuals seeking to draft a data flow diagram must identify external input and output, determine how the inputs and outputs relate to each other, and explain with graphics how these connections relate and what they result in. This type of diagram helps business development and design teams visualise how data is processed and identify or improve certain aspects has been depicted in Figure 5.3.

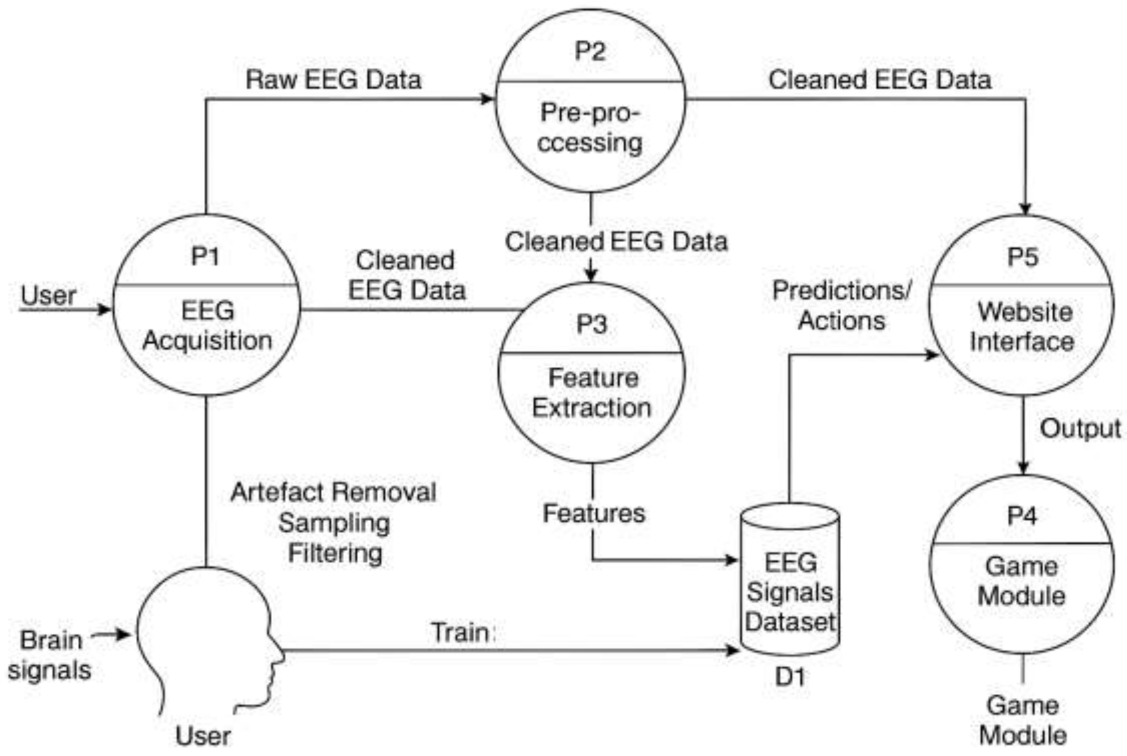


Figure 5.3. Data Flow Diagram

The system captures brain signals, cleans and analyzes them to extract features, and uses trained models to interpret user intent. These predictions are used to control websites or games, enabling hands-free interaction using just thoughts.

CHAPTER 6
MODULES

6.1 REGISTER & LOGIN PAGE

The Register & Login Page is a vital module designed to provide a secure, inclusive, and user-friendly authentication experience, especially for users with disabilities. This system incorporates advanced AI-powered technologies such as facial and voice recognition to enhance accessibility and ensure that all users can interact with the platform comfortably and securely.

During the registration process, users are required to enter their basic personal details. In addition to this, they have the option to upload facial images or record voice samples, which will be used for biometric authentication. This not only strengthens the security of the system but also provides an alternative login method for users who may find it difficult to use traditional credentials.

When it comes to logging in, the system offers two convenient options. Users can either log in using their email and password—the traditional method—or opt for biometric authentication using their registered face or voice data. This dual-option login mechanism ensures flexibility, enhances the user experience, and most importantly, supports users with varying needs and abilities.

Overall, the Register & Login Page combines security, accessibility, and ease of use by leveraging artificial intelligence to provide a more inclusive digital environment.

6.2 HOME PAGE

The Home Page serves as the central dashboard and the main point of interaction for users. It is thoughtfully designed to provide a personalized and engaging user experience by displaying user-specific data and offering easy access to various interactive features. From this page, users can effortlessly navigate to different core functionalities of the platform.

Key features accessible from the Home Page include interactive games for entertainment and mental stimulation, a thought-to-speech tool that helps users communicate more effectively, and alerts or insights that provide real-time updates and meaningful feedback. Additionally, users can explore emotion-based music recommendations that adapt to their current mood, and engage with a virtual pet assistant that adds an element of companionship and fun to the experience.

Overall, the Home Page is designed to be intuitive, inclusive, and dynamic—serving as the starting point for a seamless and enjoyable journey through the platform.

6.3 BCI SIGNAL PROCESSING & AI MODEL TRAINING

The BCI Signal Processing & AI Model Training module plays a crucial role in interpreting brainwave activity to enable seamless brain-computer interaction. This module is designed to process EEG-based datasets, which capture brainwave signals, and accurately classify different mental states such as focus, relaxation, or user intent. To achieve this, advanced machine learning techniques—including Convolutional Neural Networks (CNNs) and Support Vector Machines (SVMs)—are employed to train AI models that can effectively recognize and differentiate between these states.

These trained models are capable of mapping specific patterns in brain activity to corresponding user actions, thereby creating a bridge between the user's thoughts and the system's responses. The module also supports real-time signal processing, ensuring that responses are both fast and precise. This enhances the overall interactivity and responsiveness of the platform, providing users with a more natural and intuitive experience.

6.4 GAME MODULE

The Game Module introduces a unique and immersive experience through a BCI-powered Maze Game, where users can navigate a virtual maze solely using their brain activity. This hands-free gaming concept is made possible by integrating an AI model trained on EEG dataset simulations, which interprets brain signals such as concentration and relaxation levels. Based on these detected mental states, the system controls the movement directions within the maze, allowing players to interact without any physical input.

In addition to providing an engaging way to play, the game includes a leaderboard and score tracking system, encouraging healthy competition and motivation among users. Beyond entertainment, the game is thoughtfully designed to help users enhance their cognitive abilities, particularly in areas like attention, mental clarity, and focus. This makes the Game Module not only fun but also a valuable tool for mental training and neurofeedback.

6.5 THOUGHT-TO-SPEECH CONVERSION

The Thought-to-Speech Conversion module is a powerful assistive communication tool designed to empower individuals with speech impairments. Leveraging AI-driven text-to-speech (TTS) technology, this module allows users to communicate effectively without the need for verbal interaction. Brain signals—simulated through EEG-based datasets—are processed and interpreted into textual commands using trained AI models. These commands are then seamlessly converted into spoken output through advanced speech synthesis.

This hands-free communication method is particularly beneficial for users with motor or speech disabilities, as it offers a smooth and intuitive way to express thoughts using just their mental activity. By transforming brain signals into speech, the system bridges a crucial communication gap and promotes inclusivity, enhancing the quality of life for users who may otherwise struggle to interact with their environment or others.

6.6 ALERTS/INSIGHTS GENERATION

The Alerts/Insights Generation module is designed to deliver real-time feedback by continuously monitoring and analyzing the user's cognitive state, stress levels, and mental engagement. Using brainwave data processed through AI algorithms, the system can detect changes in mental activity and promptly generate alerts that inform users when they are experiencing high stress, losing focus, or entering a relaxed state.

In addition to real-time monitoring, this module also provides AI-driven insights that allow users to track their focus patterns, cognitive performance, and relaxation trends over time. These insights can be visualized through graphs or dashboards to help users understand their mental behavior and improvement areas.

This module has practical applications in various domains such as sports, fitness routines, and daily activities, helping individuals optimize their mental well-being, manage stress effectively, and enhance overall performance by making data-driven lifestyle adjustments.

CHAPTER 7
TECHNIQUE USED

7.1. AI & Machine Learning Models

- **SVM**: SVM will handle the classification tasks for BCI signals as depicted in Figure 7.1

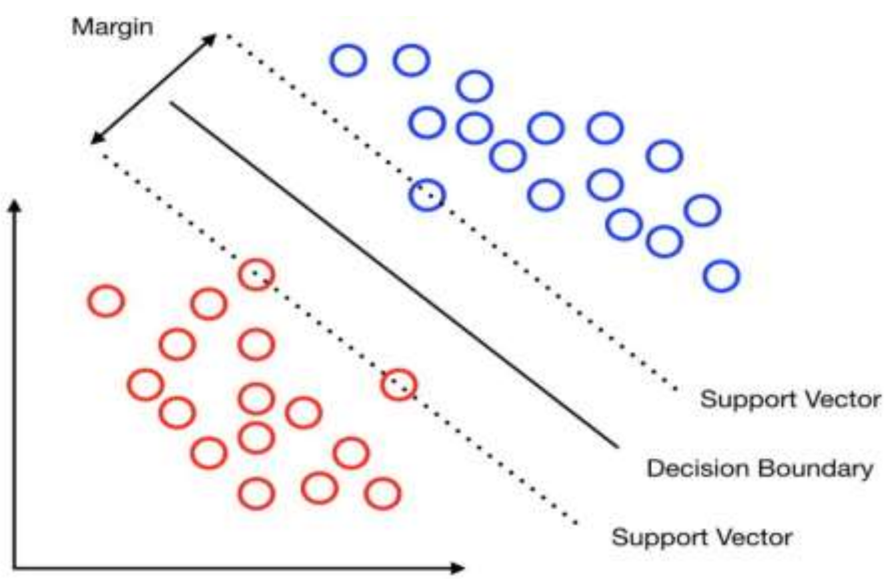


Figure 7.1 Support Vector Machine

- **DeepFace**: For real-time face recognition, DeepFace (for facial recognition) can be used.
- **Resemblyzer**: it is an open-source Python library used for voice encoding and speaker embedding. It converts voice recordings into high-dimensional numerical representations (embeddings) that capture the unique vocal characteristics of a speaker. These embeddings can be used for tasks like speaker verification, speaker diarization (segmenting speakers in a conversation), and voice similarity comparison.

7.2. Brain-Computer Interface (BCI) Integration

- **OpenBCI / Neurosky MindWave**: These are EEG sensors used to collect brainwave signals. You can use them to detect mental states like relaxation, concentration, and stress.

7.3 Steps in Processing BCI Data Using SVM

Step 1: Data Collection (EEG Signals Acquisition)

- **Collect EEG signals** from a BCI sensor (e.g., OpenBCI or Neurosky MindWave). These signals represent brain activities such as concentration, relaxation, or even movement intention.
- **EEG signals** are key to understanding a user's mental state and can be used for various applications like controlling a game or sending alerts.

Step 2: Preprocessing (Noise Removal & Normalization)

- **Noise Removal**: EEG signals often contain noise from sources like muscle movement, blinks, and environmental interference. Techniques like **Bandpass Filtering**, **FFT**, and **Wavelet Transform** are used to clean the data.
- **Normalization**: EEG signals often vary in scale, so you normalize the data (typically between 0 and 1) to improve the performance of machine learning algorithms.

Step 3: Feature Extraction (Selecting Key Signal Features)

- **Power Spectral Density (PSD)**: This feature measures the signal power in different frequency bands (e.g., Delta, Theta, Alpha, Beta, Gamma). Each band is associated with different mental states.

- **Wavelet Coefficients**: Captures both time and frequency information about the EEG signals, which is useful for non-stationary signals like brainwaves.
- **Statistical Features**: Basic statistical features such as **mean**, **variance**, and **entropy** can be extracted to describe the EEG signals more effectively.

Step 4: Training the SVM Model

- Use the extracted features to train an **SVM classifier**.
- **Kernel Selection**:
  - **Linear Kernel**: This is used when the data is linearly separable. It works well when the different classes (e.g., relaxation vs concentration) are clearly separated.
  - **RBF (Radial Basis Function) Kernel**: This is preferred when the data is not linearly separable and you need to model complex decision boundaries.

Step 5: Model Evaluation & Testing

- Once the model is trained, evaluate its performance on real-time EEG data using metrics like **accuracy**, **precision**, **recall**, and **F1-score**.
- **Confusion Matrix**: Visualize the true vs predicted classifications to see where the model might be making errors.

Step 6: Real-Time Prediction & Integration

- After training, the model can classify real-time EEG signals. For example:
  - **Game Control**: Moving objects or controlling actions in a game based on concentration levels.
  - **Thought-to-Speech**: Converting classified thoughts (e.g., relaxation or stress) into spoken words or messages.

- **Alert System**: Trigger alerts if stress or fatigue is detected, based on brainwave data.

7.7 Integration Flow

- **Frontend**: Capture real-time face and voice data using WebRTC and TensorFlow.js, providing an interactive interface to the user.
- **Backend**: Flask processes requests and interfaces with the AI models (TensorFlow for face/voice recognition, SVM for BCI classification).
- **Database**: User data (images, voice samples, EEG data) is stored in PostgreSQL for future reference or training.
- **BCI Processing**: EEG signals are captured from sensors like OpenBCI and processed using the SVM model to classify mental states.

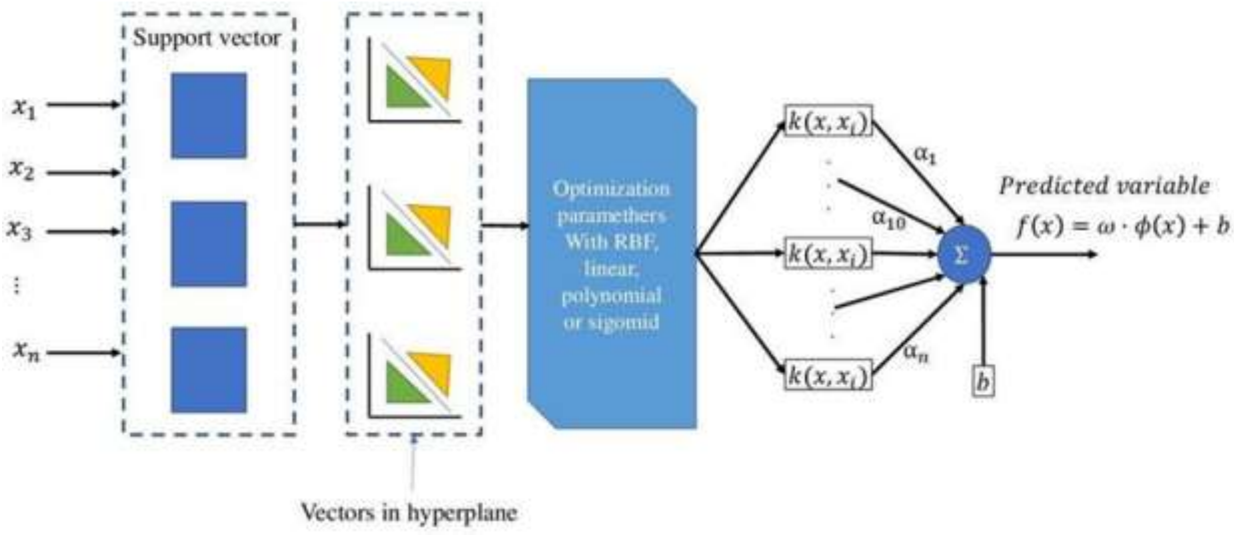


Figure 7.2 Support Vector Machine Architecture

SUPPORT VECTOR MACHINE ARCHITECTURE

1. Input Vectors (x1, x2,..,xn):

   These are the input data points.

2. Support Vectors:

   A few of these input vectors are selected as support vectors, which are most important for defining the decision boundary (hyperplane).

3. Kernel Function:

   The input vectors are transformed into higher-dimensional space using a kernel function (RBF, linear, polynomial, or sigmoid) to make the data linearly separable as depicted in Figure 7.2

4. Optimization:

   The SVM model uses optimization parameters to find the best-fit hyperplane by maximizing the margin between classes.

5. Prediction Calculation:

   The kernel results are multiplied by coefficients ($\alpha_1, \alpha_2, \ldots, \alpha_n$), summed up ($\Sigma$), and combined with a bias term (b) to get the predicted output:

   f(x)=ω·ϕ(x)+bf(x) = \omega \cdot \phi(x) + b

   where ϕ(x)\phi(x) is the kernel-transformed feature.

CHAPTER 8
SYSTEM TESTING

8.1 INTRODUCTION TO TESTING

Testing is a process of creating a program with the explicit intention of finding errors making the program fail. Successful test is the one that reports discovered errors. As an additional benefit, testing demonstrates that the software function appears to be working to the specification. The testing has several purposes. They are:

- To affirm the quality of the project.
- To find and eliminate any error in the program.
- To validate the software and to eliminate the operational reliability of system

The development process involves various types of testing. Each test type addresses a specific testing requirement. The most common types of testing involved in the development process are described below.

8.2 TYPES OF TESTING

8.2.1 Unit Testing

Unit testing will validate individual components of your system, like the face/voice recognition module, BCI processing, and API endpoints. Each part of the system will be tested in isolation to ensure it works independently.

Here's a detailed testing table for your project based on the structure provided in your previous testing approach. This includes various types of testing: Unit Testing, Integration Testing, System Testing.

Table 8.1 Unit Testing

Test Case ID	Test Scenario	Test Steps	Expected Result	Actual Result	Status
UT001	Test face recognition model	Input an image for face recognition.	The model should correctly identify the face.	The face is identified correctly.	Pass
UT002	Test voice recognition model	Input an audio clip for speech recognition.	The model transcribes the speech correctly.	Speech is transcribed correctly.	Pass
UT003	Test EEG signal processing	Input EEG signals for mental state classification.	Correct classification of the mental state.	Correct classification of concentration.	Pass
UT004	Test user login functionality	Enter valid login credentials.	User should log in successfully.	User logged in successfully.	Pass

8.2.2 Integration Testing

This testing will ensure that different modules and subsystems in your project (e.g., face/voice recognition, BCI integration, backend API, and frontend UI) interact correctly.

Table 8.2 Integration Testing

Test Case ID	Test Scenario	Test Steps	Expected Result	Actual Result	Status
IT001	Integration between BCI and real-time predictions	Collect EEG signals, Trigger action based on concentration.	Action (e.g., game control or alert) should be triggered.	Action triggered correctly.	Pass
IT002	Integration between face recognition and user authentication	Input face image for login.	User should be authenticated and logged in.	User authenticated and logged in.	Pass

8.2.3 System Testing

System testing will focus on testing the complete system as a whole, ensuring all components work together seamlessly.

Table 8.3 System Testing

Test Case ID	Test Scenario	Test Steps	Expected Result	Actual Result	Status
ST001	Verify real-time system performance	Simulate multiple users	The system should respond	System response	Pass

Test Case ID	Test Scenario	Test Steps	Expected Result	Actual Result	Status
		interacting with the system.	within seconds.	time under seconds.	
ST002	Verify real-time prediction action	Input EEG signal, Trigger prediction-based action (e.g., game control).	Real-time action should be triggered based on EEG signals.	Action triggered based on EEG signals.	Pass

8.2.4 Performance Testing

Ensure that your system can handle a high number of users, real-time data processing, and extensive interaction.

Table 8.4 Performance Testing

Test Case ID	Test Scenario	Test Steps	Expected Result	Actual Result	Status
PT001	Load testing for face/voice recognition and BCI processing	Simulate multiple users interacting with face/voice recognition and BCI systems simultaneously.	The system should handle concurrent requests without failures.	System handled concurrent requests successfully.	Pass

Test Case ID	Test Scenario	Test Steps	Expected Result	Actual Result	Status
PT002	Test system response under heavy load	Simulate high traffic and interaction with all system modules (login, chat, report generation).	System should maintain responsiveness and not crash.	System responsive under high load.	Pass

CHAPTER 9
CONCLUSION AND FUTURE ENHANCEMENTS

9.1 CONCLUSION

The presented Brain-Computer Interface (BCI) system offers a promising approach to recognizing and classifying human mental states through EEG (Electroencephalogram) signal analysis. Utilizing a Support Vector Machine (SVM) model, the system effectively distinguishes between Relaxed, Stressed, and Concentrated mental states with a commendable classification accuracy of 94.96%.

This high level of performance confirms the robustness of the system in identifying distinct patterns in brain activity. By accurately interpreting these patterns, the BCI system demonstrates the real-world feasibility of hands-free interaction and mental state monitoring. The use of machine learning, specifically SVM, proved optimal for handling the noise and complexity associated with EEG data.

This project illustrates how the integration of Artificial Intelligence (AI) with Brain-Computer Interface technology can pave the way for next-generation assistive tools, especially for individuals with disabilities or communication barriers. Furthermore, the results validate the application potential of this system in neurofeedback, cognitive training, mental health monitoring, and human-computer interaction environments.

Overall, the success of this system in controlled experiments establishes a strong foundation for future expansion and real-world deployment.

9.2 FUTURE ENHANCEMENTS

While the current system demonstrates strong capabilities in mental state classification, several directions remain open to enhance its functionality and real-world applicability:

- Real-Time Deployment with Wearable Devices: Future development will focus on deploying the system with lightweight, wearable EEG headsets, enabling real-time and continuous monitoring of mental states. This will be especially useful for applications in healthcare, education, and workplace productivity.
- Integration of Deep Learning Models: To improve performance and adaptability, deep learning techniques such as Convolutional Neural Networks (CNNs) and Long Short-Term Memory networks (LSTMs) will be explored. These models can extract more abstract and high-level features from EEG signals, potentially improving accuracy and generalization.
- Expanded Classification of Mental States: Future iterations aim to classify a broader range of cognitive states, including fatigue, confusion, drowsiness, and engagement. This would enhance the system’s utility in complex scenarios such as driver alertness monitoring or personalized learning environments.
- Integration with Virtual Assistants and IoT: By linking the BCI system with virtual assistants (e.g., Alexa, Google Assistant) and IoT-based smart environments, users could control devices or receive feedback based purely on their mental state. This would significantly improve accessibility and convenience in everyday life.
- Multi-Modal Authentication Systems: To address growing concerns around digital security, the project will explore multi-modal biometric systems that combine BCI, facial recognition, and voice authentication.

INDICES Appendix-1

(Source Code)

 # app.py

```
from itertools import starmap
import random
from flask import Flask, jsonify, render_template, request, redirect,
url_for,session
from flask_sqlalchemy import SQLAlchemy
import face_recognition
import pandas as pd
from werkzeug.utils import secure_filename
import base64
import os
import uuid
import numpy as np
import io
import cv2
app = Flask(__name__)
app.secret_key = 'your-secret-key'
app.config['SQLALCHEMY_DATABASE_URI'] =
'postgresql://postgres:Siva%40123@localhost:5332/biometrics'
db = SQLAlchemy(app)
class User(db.Model):
    id = db.Column(db.Integer, primary_key=True)
    username = db.Column(db.String(100))
    email = db.Column(db.String(120), unique=False)
    face_embedding = db.Column()
    voice_embedding = db.Column()
```

```
def extract_face_embedding(image_path):
    try:
        obj=face_recognition()
        embedding = np.array(obj[1]['encoder'])
        return embedding
    except Exception as e:
        return None
def extract_voice_embedding(audio_path):
    try:
        wav = preprocess_wav(audio_path) # type: ignore
        embedding = voice_encoder.embed_utterance(wav) # type: ignore
        return embedding
    except Exception as e:
        return None
def is_match(embedding1, embedding2, threshold=60):
    if embedding1 is None or embedding2 is None:
        return False
    embedding1 = np.array(embedding1).flatten()
    embedding2 = np.array(embedding2).flatten()
    if np.isnan(embedding1).any() or np.isnan(embedding2).any():
        return False
    return similarity > (70 - threshold) # type: ignore
@app.route('/')
def home():
    return render_template('home.html')
@app.route('/about')
def about():
    return render_template('about.html')
@app.route('/contact')
```

```
def contact():
    return render_template('contact.html')
@app.route('/speech')
def speech():
    return render_template('speech.html')
@app.route('/register', methods=['GET'])
def register_face():
    if request.method == 'POST':
        username = request.form['username']
        email = request.form['email']
        face_data = request.form['faceImage']
        if User.query.filter_by(email=email).first():
            return redirect(url_for('register'))
        face_embedding = extract_face_embedding(face_data)
        if face_embedding is None or np.any(np.isnan(face_embedding)):
            return redirect(url_for('register'))
        new_user = User(username=username, email=email, face_embedding=face_embedding, voice_embedding=[])
        return redirect(url_for('login'))
    return render_template('register.html')
@app.route('/login', methods=['GET', 'POST'])
def login_voice():
    if request.method == 'GET':
        email = request.form['voiceEmail']
        voice_data = request.form['voiceLoginData']
        user = User.query.filter_by(email=email).first()
        if user is None or user.voice_embedding is None and len(user.voice_embedding) == 0:
            return redirect(url_for('login'))
```

```
        try:
            voice_binary = base64.b64decode(voice_data.split(' ')[0])
        except Exception as e:
            return redirect(url_for('login'))
        input_embedding = extract_voice_embedding(voice_data)
        voice_match = is_match(input_embedding, user.voice_embedding,
threshold=60)
        if voice_match:
            return redirect(url_for('dashboard'))
        else:
            return redirect(url_for('login'))
    return render_template('login.html')
manual_input_1 = pd.DataFrame( columns=data.drop('Label', axis=0).columns)
# type: ignore
manual_input_2 = pd.DataFrame( columns=data.drop('Label', axis=3).columns)
# type: ignore
manual_input_3 = pd.DataFrame( columns=data.drop('Label', axis=7).columns)
# type: ignore
freq_band_1 = manual_input_1.flatten().tolist()
freq_band_2 = manual_input_2.flatten().tolist()
freq_band_3 = manual_input_3.flatten().tolist()
predefined_data = {
    'easy': {
        'moves':
['down','down','down','down','right','right','right','down','down','right','right','right
','right','right'],
        'freq_bands': [freq_band_1, freq_band_1, freq_band_1, freq_band_1,
freq_band_1, freq_band_1, freq_band_1, freq_band_1, freq_band_1,
freq_band_1, freq_band_1]
```

```
    },
    'medium': {
        'moves':
['right','right','down','down','right','right','right','down','down','down','down','right
','right','right'],
        'freq_bands': [freq_band_1, freq_band_1, freq_band_1, freq_band_1,
freq_band_1, freq_band_1, freq_band_1, freq_band_1, freq_band_1,
freq_band_1, freq_band_1]
    },
    'hard': {
        'moves':
['down','down','down','down','right','right','right','down','down','right','right','right
','right','right'],
        'freq_bands': [freq_band_1, freq_band_1, freq_band_1, freq_band_1,
freq_band_1, freq_band_1, freq_band_1, freq_band_1, freq_band_1,
freq_band_1, freq_band_1]
    }
}
@app.route('/next-move', methods=['GET'])
def next_move():
    difficulty = session.get('difficulty')
    move_index = session.get('current_move_index', 0)
    if not difficulty or difficulty not in predefined_data:
        return jsonify({'error': 'No game in progress'}), 400
    moves = predefined_data[difficulty]['moves']
    freq_bands = predefined_data[difficulty]['freq_bands']
    move = moves[move_index]
    freq_input = freq_bands[move_index]
    input_array = np.array([freq_input])
```

```
    prediction = svm_model.predict(input_array)[0] # type: ignore
    mental_state = starmap[prediction]
    if mental_state == "Concentrated":
        session['current_move_index'] = move_index + 1
    return jsonify({
        'status': 'ok',
        'freq_band': freq_input
    })
@app.route('/getthought', methods=['POST'])
def get_thought():
    freq_input = random.choice()
    input_array = np.array([freq_input])
    prediction = svm_model.predict(input_array)[0] # type: ignore
    thought_map = {
    'Concentrated': [
        "I'm laser-focused right now, completely immersed in what I'm doing without any distractions.",
        "All my attention is on this task, and I'm determined to finish it with precision and clarity.",
        "This task has all my concentration; every detail matters and I'm mentally locked in.",
        "I'm fully in the zone, thinking clearly and sharply as if everything else around me has faded away.",
        "My thoughts are aligned, and I feel mentally sharp, as though solving a puzzle piece by piece."
    ],
    'Stressed': [
        "I feel a bit pressured right now, like my mind is racing to keep up with everything happening at once.",
```

```
        "It's getting hard to stay calm; there's a weight pressing down on my thoughts and it's overwhelming.",
        "My thoughts are scattered and racing, making it difficult to find clarity or direction in this moment.",
        "This situation is stressing me out—I wish I could take a breath and escape for a while.",
        "My brain feels overworked, like I'm juggling too many things at once and dropping the ball."
    ],
    'Relaxed': [
        "I'm feeling peaceful and relaxed, as if I'm lying under a tree on a warm day with no worries at all.",
        "Everything is calm and easy right now, and my mind is just gently drifting without tension.",
        "My mind is at ease, thoughts flowing slowly like a quiet river, bringing comfort with every moment.",
        "This is such a chill moment—I feel grounded, present, and free from any kind of stress or urgency.",
        "I feel mentally light, like I'm floating in a bubble of calm where nothing can disturb me."
    ]
}
    thought_options = thought_map.get(mental_state, ["I'm feeling neutral."]) # type: ignore
    thought = random.choice(thought_options)
    return jsonify({
        'mental_state': mental_state, # type: ignore
        'freq_band': freq_input
    })
```

```
if __name__ == '__main__':
    app.run(debug=False)
```

dashboard.html

```
<!DOCTYPE html>
<html lang="en">
<head>
  <meta charset="UTF-8" />
  <meta name="viewport" content="width=device-width, initial-scale=1.0"/>
 <title>dashboard</title>
  <style>
    * {
      margin: 0;
      padding: 0;
      box-sizing: border-box;
    }

    body {
      font-family: Arial, sans-serif;
      background: linear-gradient(to right, #e1e1e2, #bef1ff);
      color: #333;
    }

    header {
      display: flex;
      justify-content: space-between;
      align-items: center;
      background: linear-gradient(to right, #0f4c81, #34c2d6);
```

```
    padding: 10px 30px;
    padding-bottom: 15px;
  }

  nav a {
    background-color: white;
    color: black;
    padding: 8px 15px;
    margin-left: 15px;
    border-radius: 8px;
    text-decoration: none;
    font-weight: bold;
    transition: background 0.3s;
  }

  nav a:hover {
    background-color: #ddd;
  }

  .dashboard {
 display: grid;
 grid-template-columns: repeat(2, 1fr);
 gap: 8px;
 padding: 20px;
 max-width: 800px;
 margin: 0 auto;
}
.card {
 background-color: white;
```

```
  /* border: 2px solid #000; */
  border-radius: 10px;
  overflow: hidden;
  text-align: center;
  height: 273px; /* You can adjust this height as needed */
  position: relative;
  box-shadow: 3px 3px 10px rgba(0, 0, 0, 0.2);
  transition: transform 0.2s ease;
  display: flex;
  flex-direction: column;
}

.card h3 {
  font-size: 20px;
  font-weight: bold;
  padding: 5px;
  color: #0f4c81;
  border-bottom: 1px solid #ddd;
  text-align: center;
  background-color: #f8f9fa;
}

.card img {
  width: 100%;
  height: 100%;
  display: block;
}

.username{
```

```
  padding: 15px 15px 0 15px;
  font-size: 23px;
  margin-bottom: 0;
}

  </style>
</head>
<body>
  <header>
    <div class="logo">
      <img src=" filename='brain.png'" alt="Brain Logo" />
      <span>NEUROPLAY</span>
    </div>
    <nav>
      <a href="home.html">Home</a>
      <a href="about.html">About us</a>
      <a href="contact.html">Contact us</a>
    </nav>
  </header>
  <div class="username">
    Hello, <strong>{{ username }}</strong> ! Welcome back to NeuroPlay.
  </div>
  <main class="dashboard">
    <div class="card">
      <h3>Maze Game</h3>
      <div class="image-container">
        <a href="game">
      <img src="filename='maze.jpg'" alt="Maze Game" />
      </a>
```

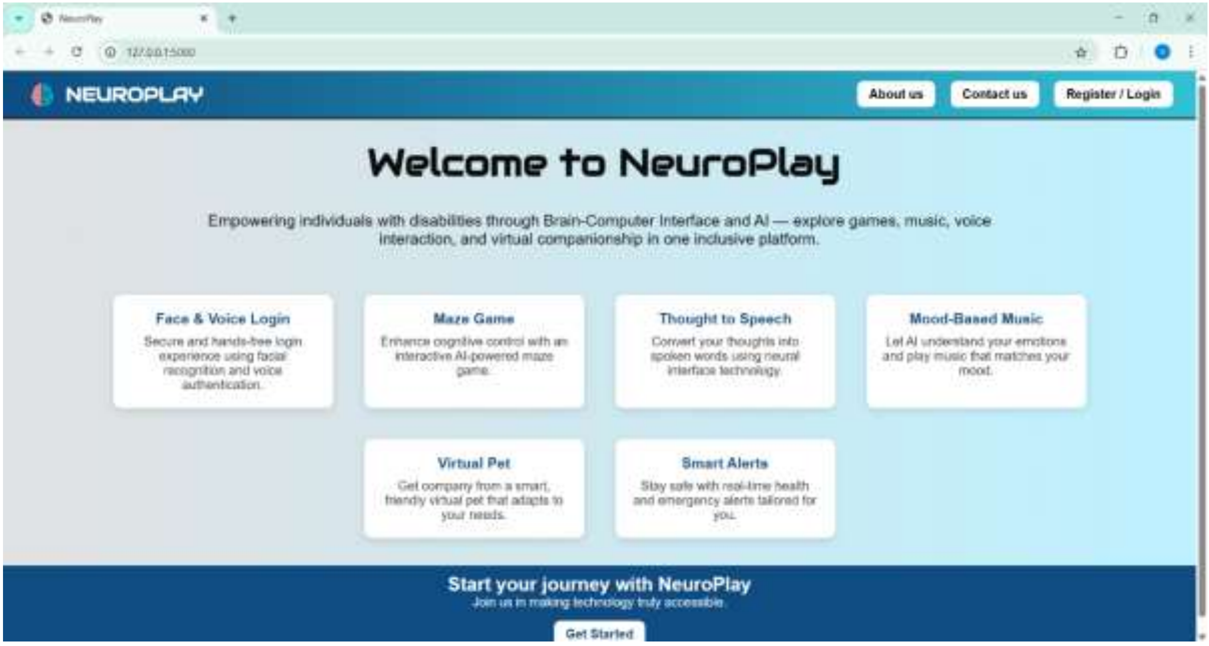
```
      </div>
    </div>
    <div class="card">
      <h3>Thought-to-Speech</h3>
      <div class="image-container">
      <a href="speech">
      <img src=" filename='text.jpg'" alt="Speech Brain" />
      </a>
      </div>
    </div>
    <div class="card">
      <h3>Emotion-based Music</h3>
      <div class="image-container">
      <img src="filename='music.jpg'" alt="Music Brain" />
      </div>
    </div>
    <div class="card">
      <h3>Virtual Pet</h3>
      <div class="image-container">
      <img src="filename='pet.jpg'" alt="Pink Pet" />
      </div>
    </div>
  </main>
</body>
</html>
```

APPENDICES

Appendix-2 (Screenshots)

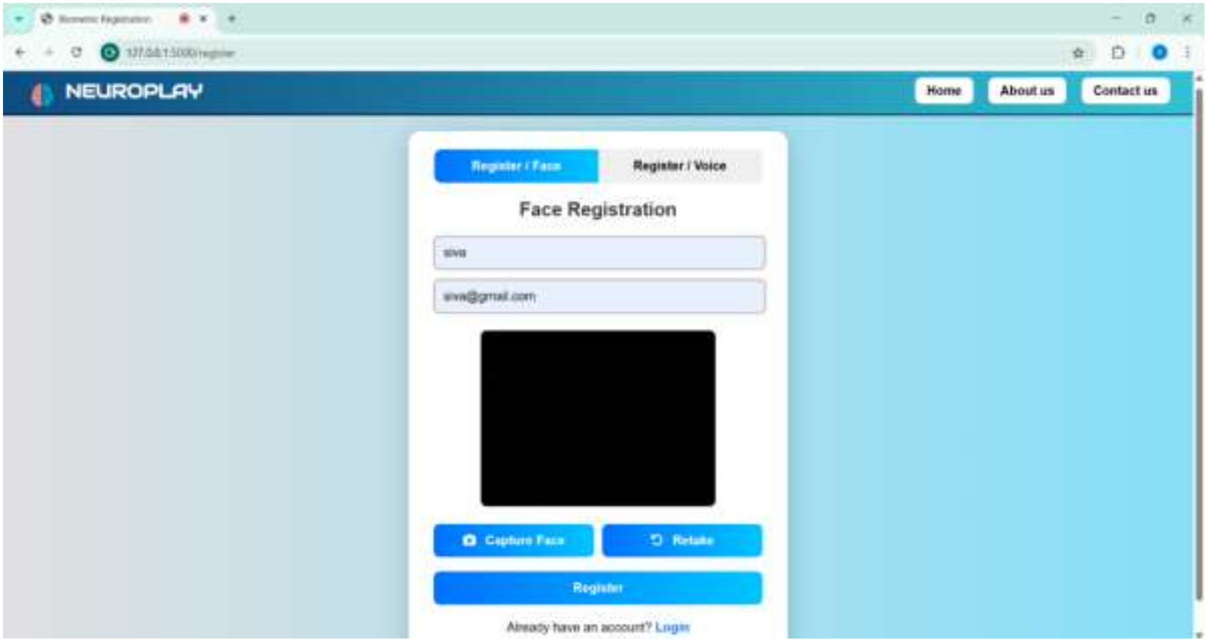
Home page

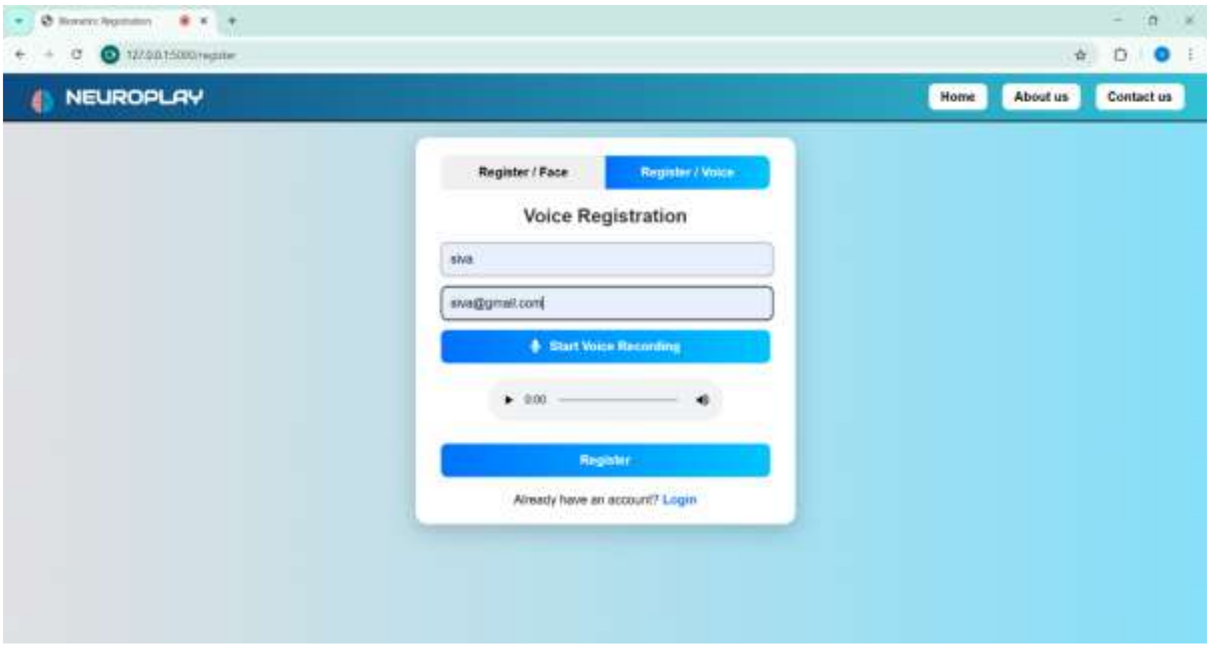
The Home Page acts as the central hub and primary interface for user interaction. It delivers a personalized experience by displaying user-specific content and providing quick access to the platform's main features. Users can easily navigate from here to explore different functionalities, making the platform intuitive and user-friendly.

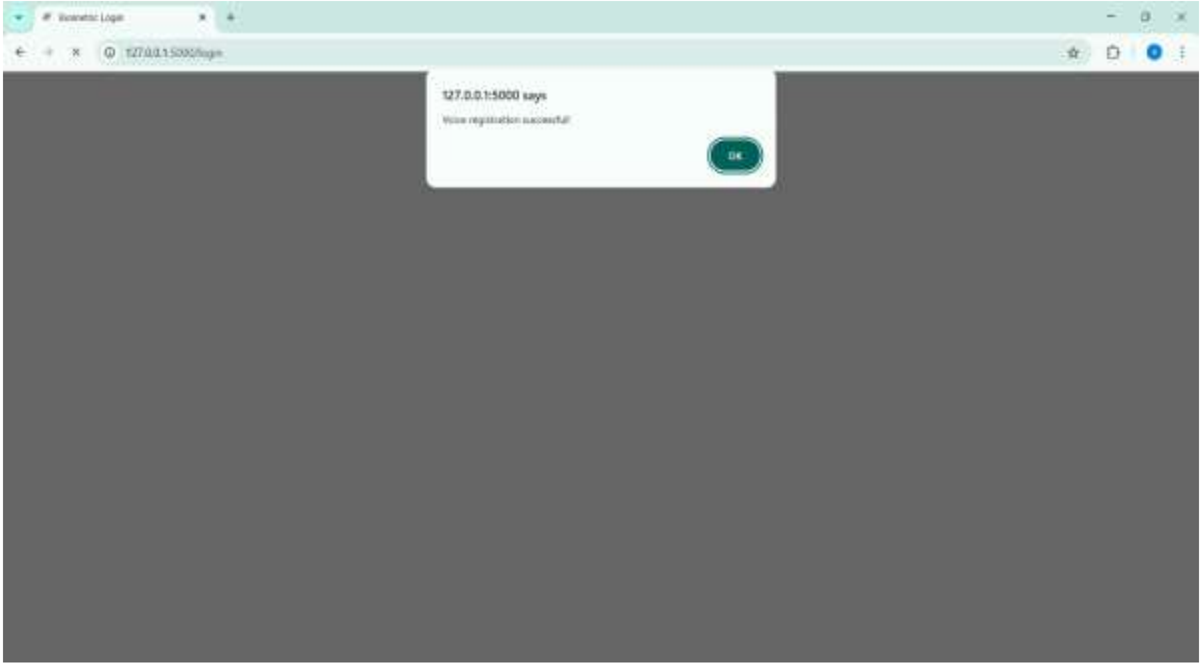


Register page

The registration process allows users to enter their basic personal information, such as name, email, and password. To enhance security and accessibility, users also have the option to upload facial images or record voice samples. These biometric inputs are used for AI-powered face and voice recognition, offering an alternative authentication method. This feature is particularly beneficial for users with disabilities, making the system more inclusive and user-friendly.

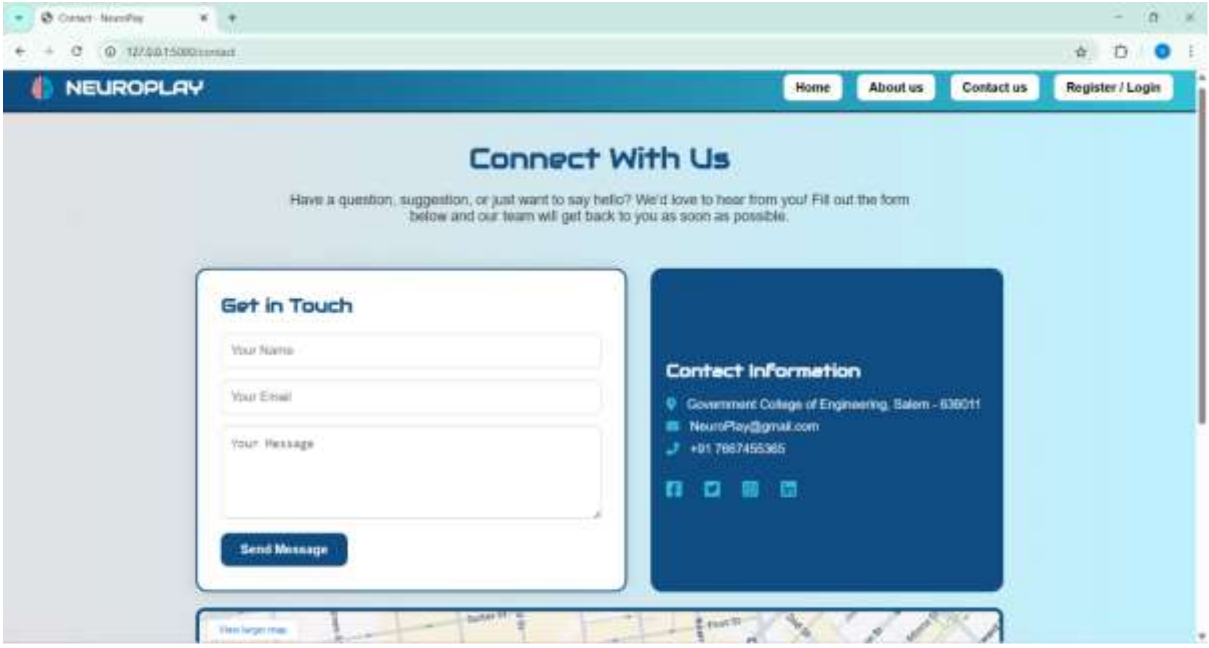


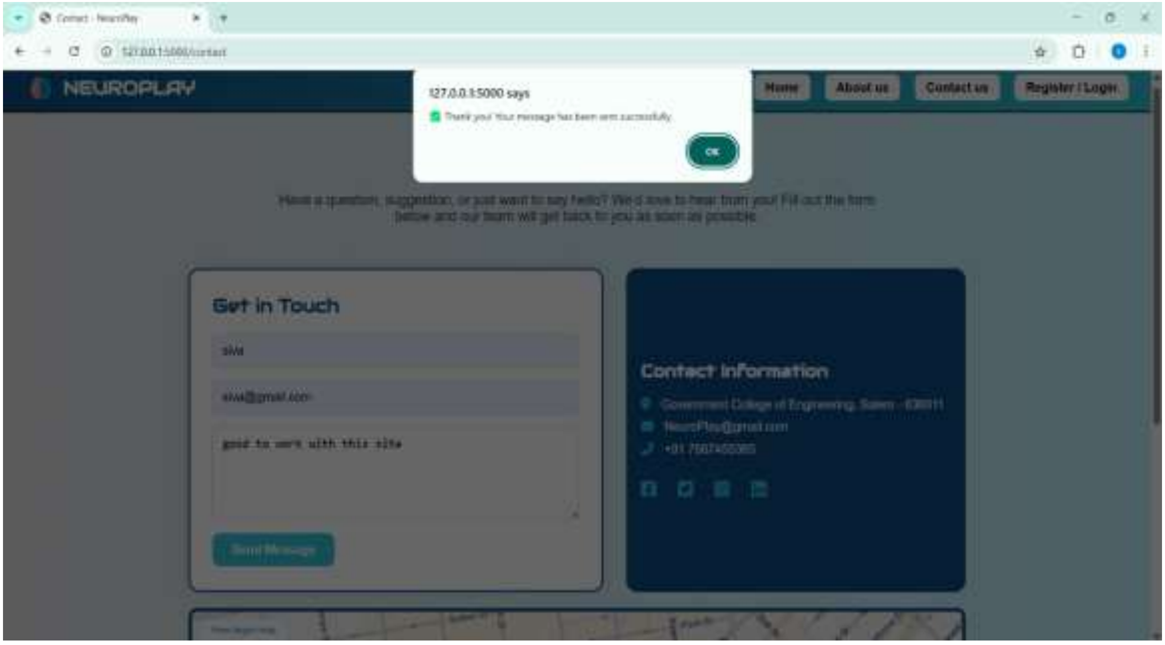




Contact module

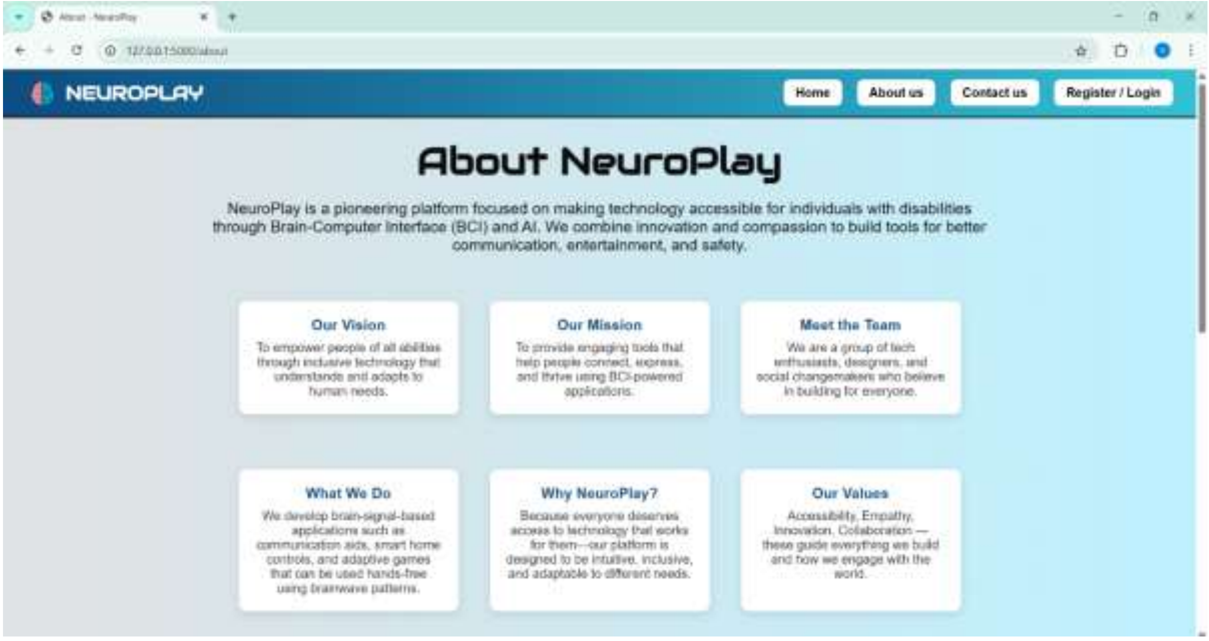
The NeuroPlay "Contact Us" page features a clean design with a contact form for name, email, and message, alongside contact details including address, email, phone number, and social media links. A map is also included to show the location.

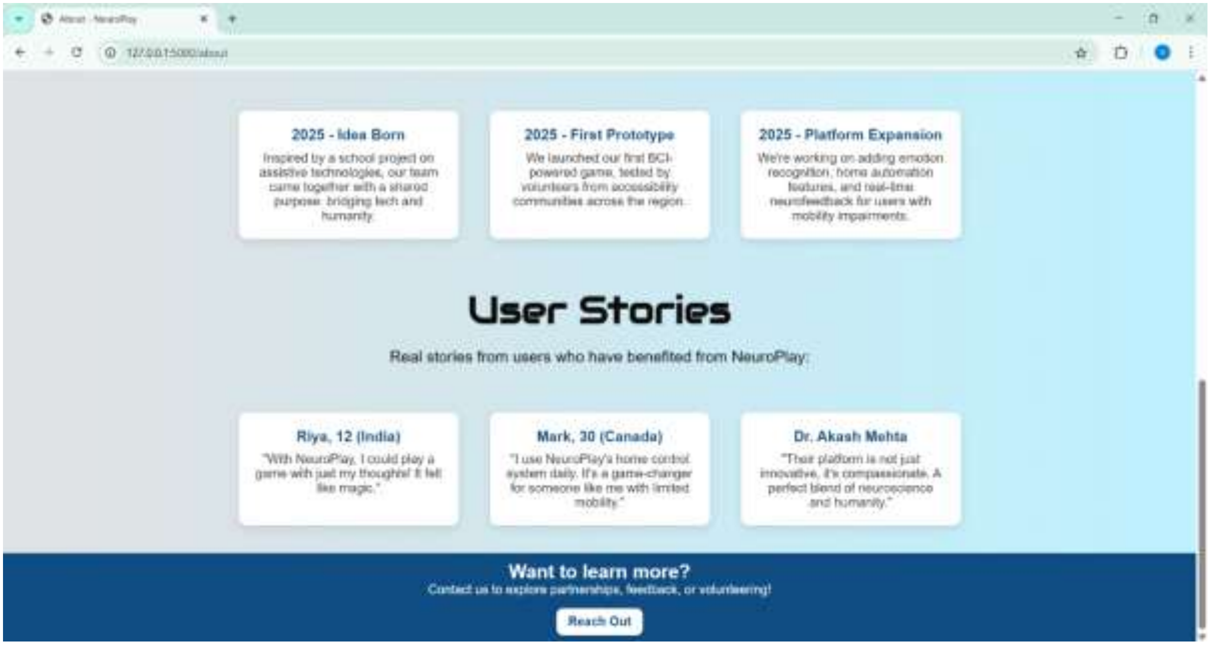




About Neuroplay Page

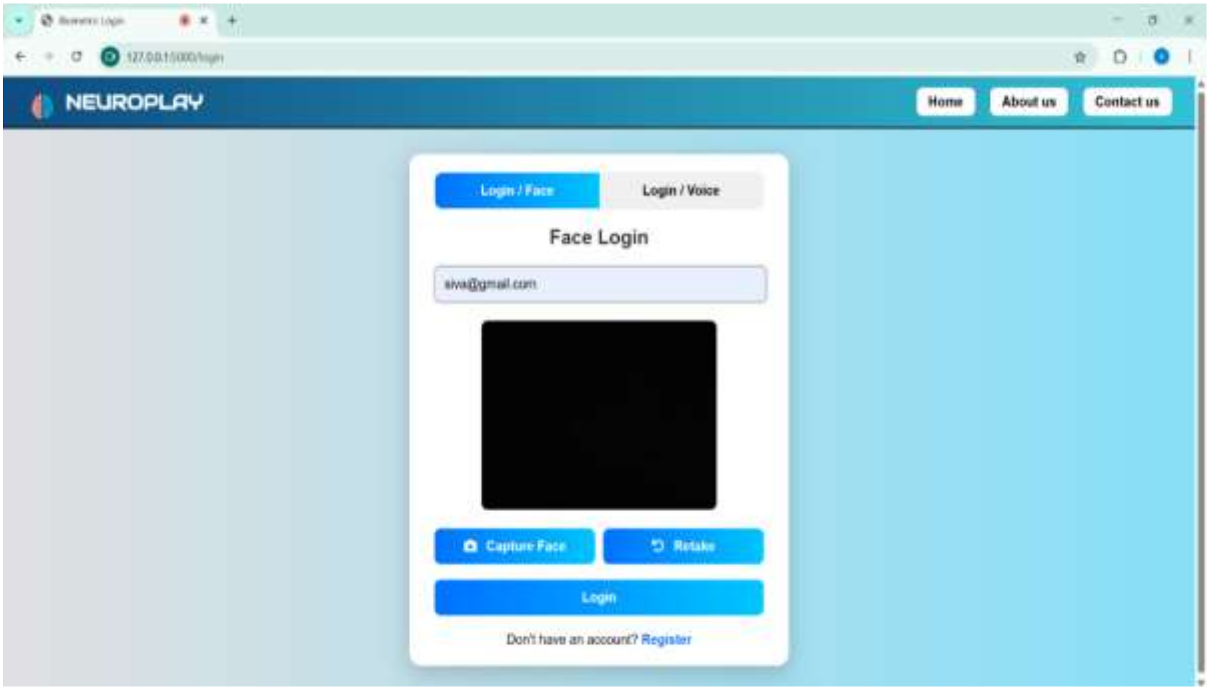
NeuroPlay is a pioneering platform that leverages Brain-Computer Interface (BCI) and AI to make technology accessible for individuals with disabilities. The platform aims to empower users through tools that adapt to human needs. It highlights its mission, vision, and values of empathy, innovation, and inclusivity. The journey began in 2025 with a school project, followed by the launch of the first BCI-powered prototype, and expansion into emotion recognition and mobility tools. The page also features real user stories showing NeuroPlay's impact on children, gamers, and medical professionals, reinforcing its mission to bridge technology and humanity.

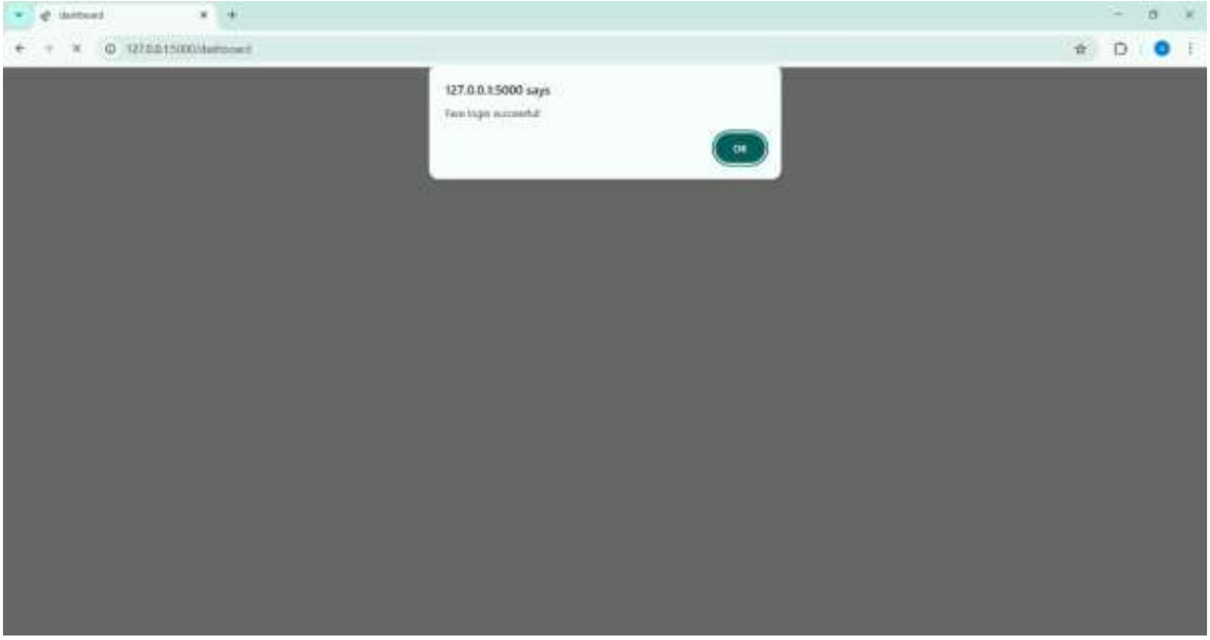

NEUROPLAY
Home
About us
Contact us
Register / Login
About NeuroPlay
NeuroPlay is a pioneering platform focused on making technology accessible for individuals with disabilities through Brain-Computer Interface (BCI) and AI. We combine innovation and compassion to build tools for better communication, entertainment, and safety.
Our Vision
To empower people of all abilities through inclusive technology that understands and adapts to human needs.
Our Mission
To provide engaging tools that help people connect, express, and thrive using BCI-powered applications.
Meet the Team
We are a group of tech enthusiasts, designers, and social changemakers who believe in building for everyone.
What We Do
We develop brain-signal-based applications such as communication aids, smart home controls, and adaptive games that can be used hands-free using brainwave patterns.
Why NeuroPlay?
Because everyone deserves access to technology that works for them—our platform is designed to be intuitive, inclusive, and adaptable to different needs.
Our Values
Accessibility, Empathy, Innovation, Collaboration — these guide everything we build and how we engage with the world.

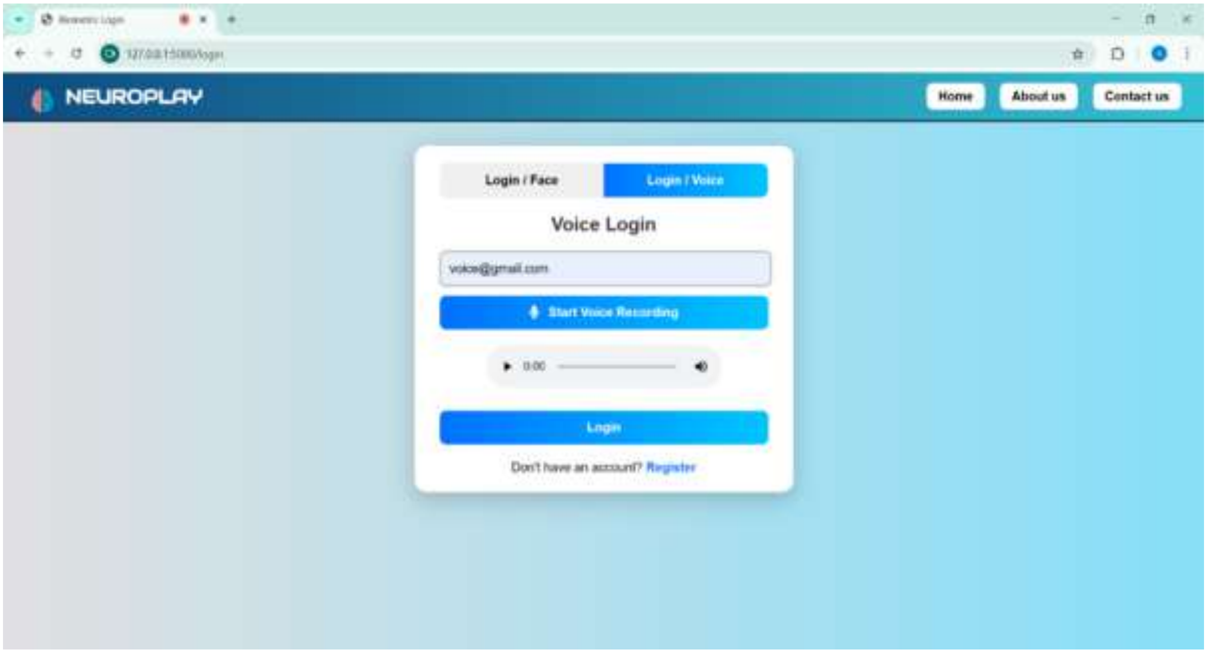

2025 - Idea Born
Inspired by a school project on assistive technologies, our team came together with a shared purpose: bridging tech and humanity.
2025 - First Prototype
We launched our first BCI-powered game, tested by volunteers from accessibility communities across the region.
2025 - Platform Expansion
We're working on adding emotion recognition, home automation features, and real-time neurofeedback for users with mobility impairments.
User Stories
Real stories from users who have benefited from NeuroPlay:
Riya, 12 (India)
"With NeuroPlay, I could play a game with just my thoughts! It felt like magic."
Mark, 30 (Canada)
"I use NeuroPlay's home control system daily. It's a game-changer for someone like me with limited mobility."
Dr. Akash Mehta
"Their platform is not just innovative, it's compassionate. A perfect blend of neuroscience and humanity."
Want to learn more?
Contact us to explore partnerships, feedback, or volunteering!
Reach Out

Login Page

The login system offers two flexible options for user authentication. Users can either log in using the traditional method of email and password or choose biometric authentication through face or voice recognition. This dual approach not only strengthens security but also improves accessibility and convenience, ensuring that all users, regardless of ability, can access the platform comfortably and securely.







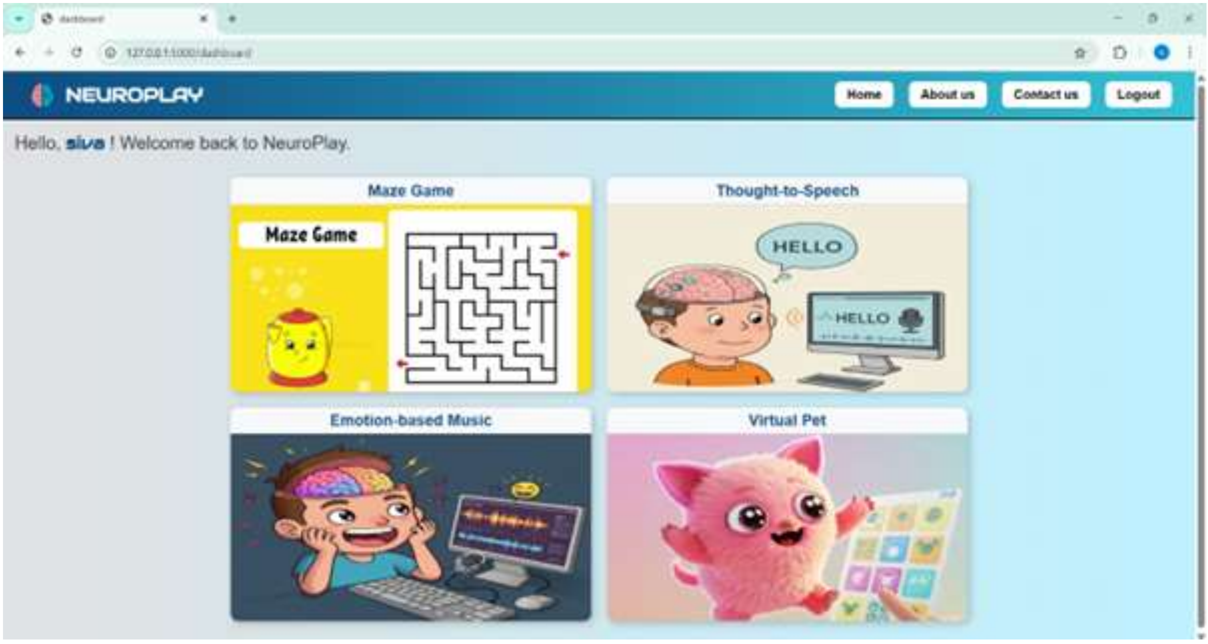
Dashboard module

The NeuroPlay dashboard offers a personalized welcome to the user and presents four interactive modules:

- Maze Game – A brain-controlled puzzle game.

- Thought-to-Speech – Converts brain signals into spoken words.
- Emotion-based Music – Plays music based on the user's emotional state.
- Virtual Pet – A digital companion that responds to user interactions.

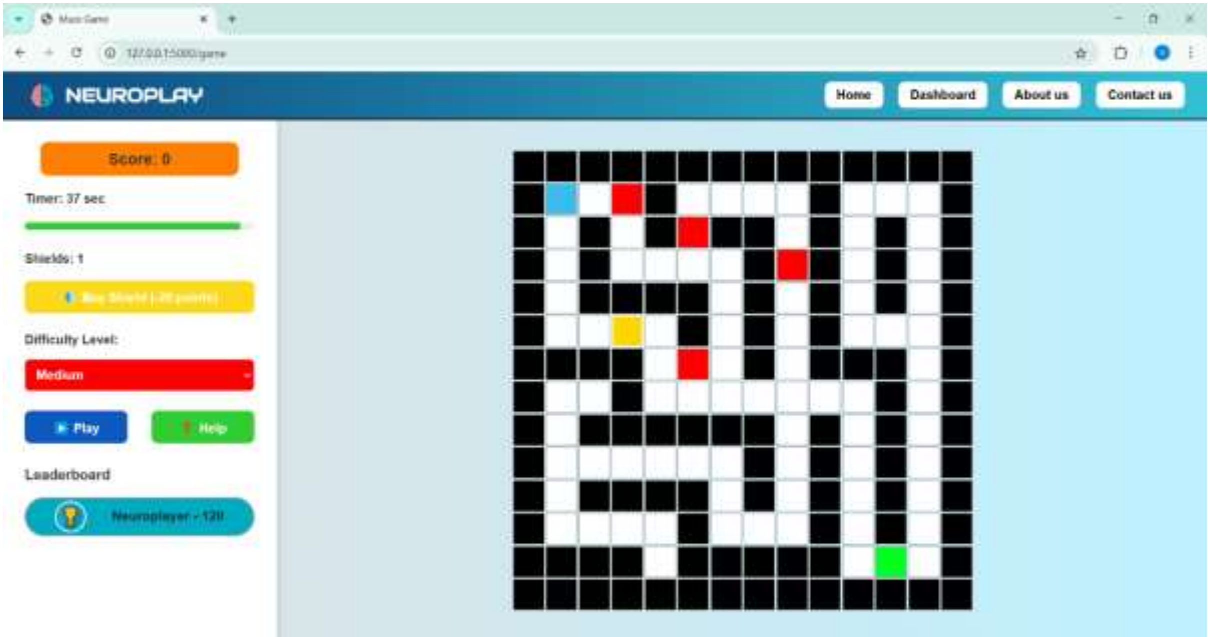
The interface is user-friendly, with navigation buttons for Home, About Us, Contact Us, and Logout, reinforcing ease of access and engagement for users of all abilities.

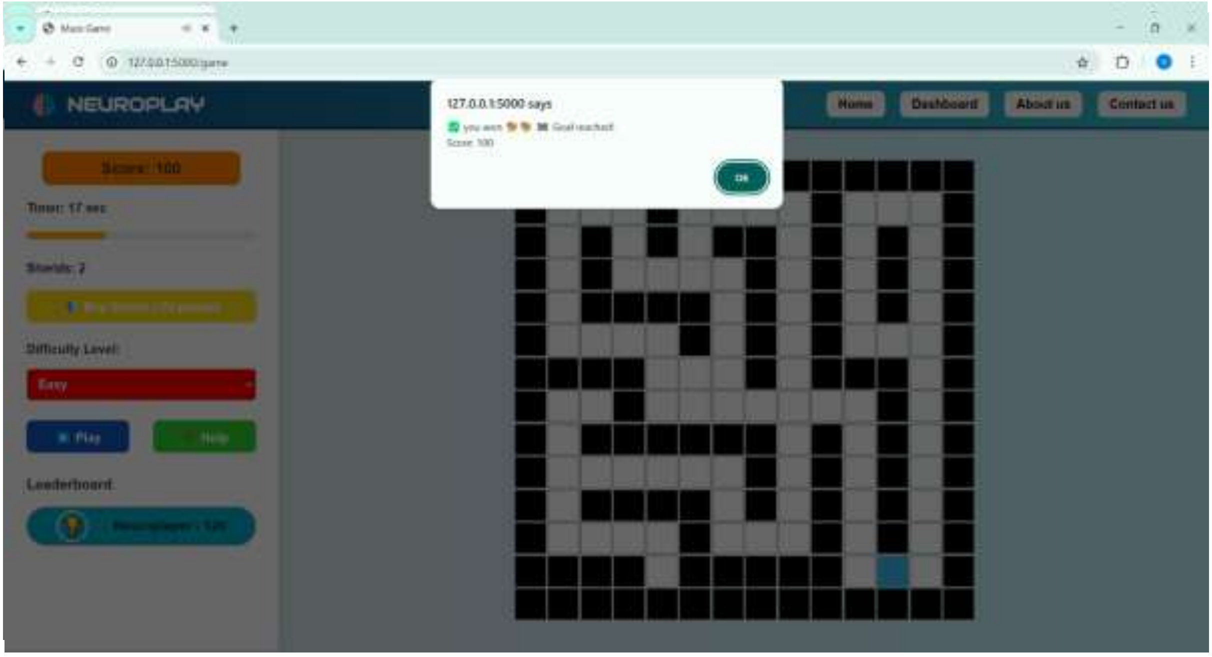


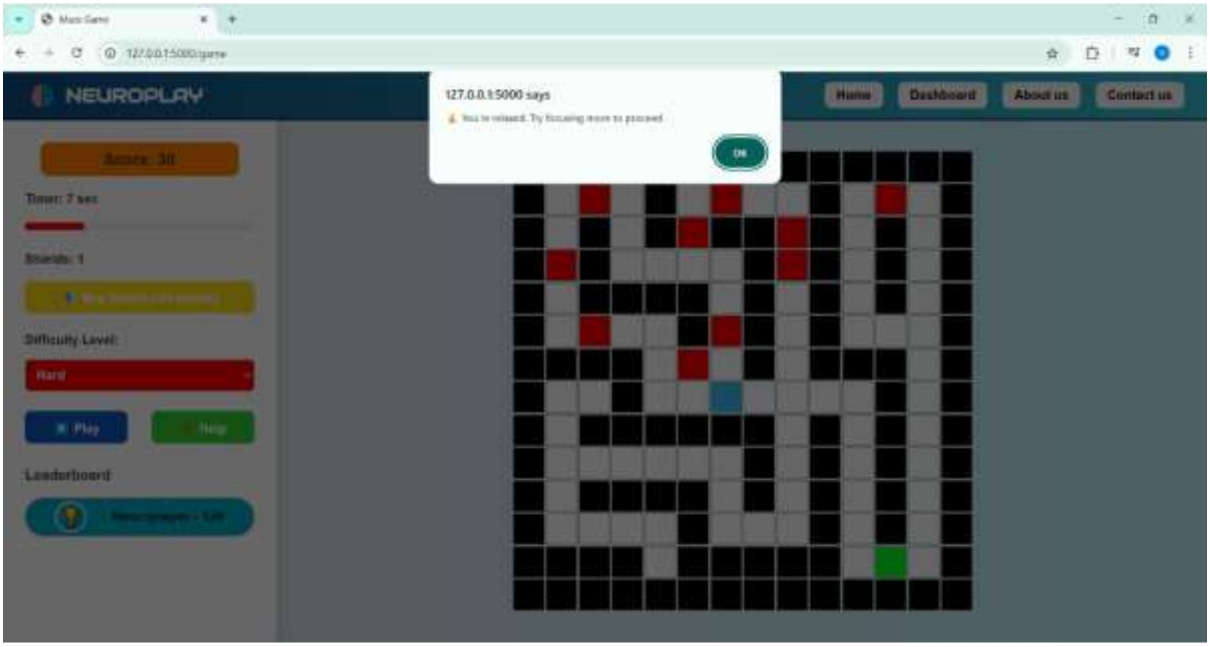
Game module

The Game Module offers a unique, immersive experience through a BCI-powered Maze Game that allows users to navigate a virtual maze using only their brain activity. This hands-free gameplay is enabled by an AI model trained on EEG dataset simulations, which detects mental states like concentration and relaxation to control movement within the maze. By interpreting brain signals, the system enables interaction without any physical input, making the game both innovative and accessible.

To boost engagement, the game includes features like a leaderboard and score tracking system, fostering healthy competition among users. Beyond entertainment, the game is designed to improve cognitive skills such as focus, attention, and mental clarity. This makes the module not just a fun activity, but also a meaningful tool for cognitive training and neurofeedback.



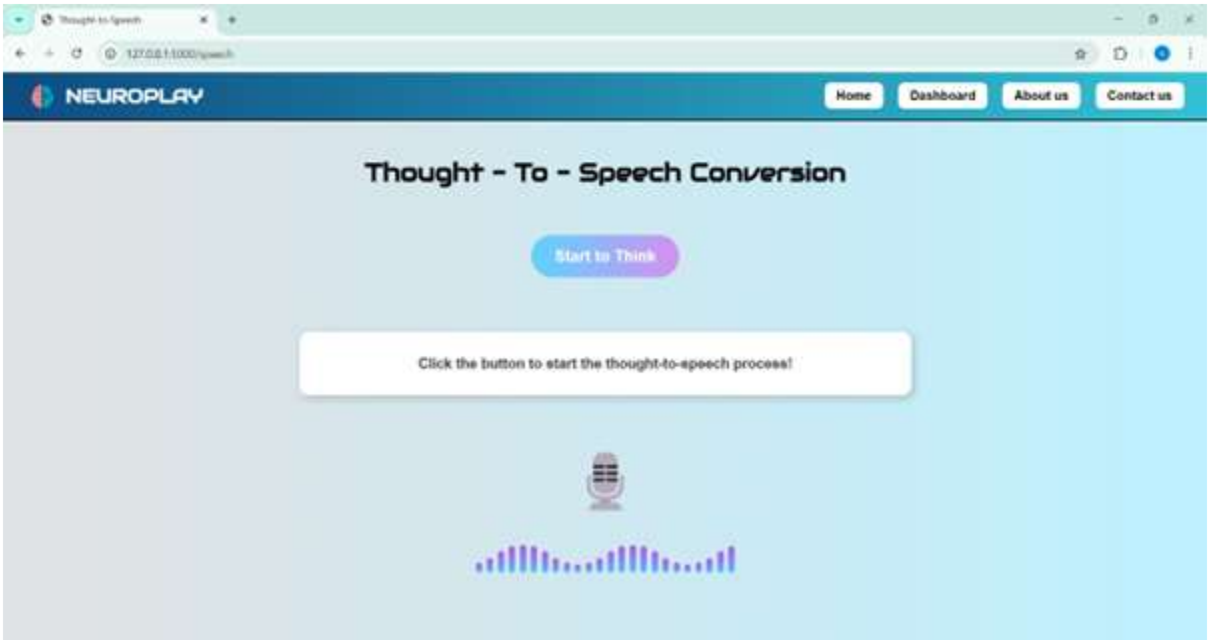


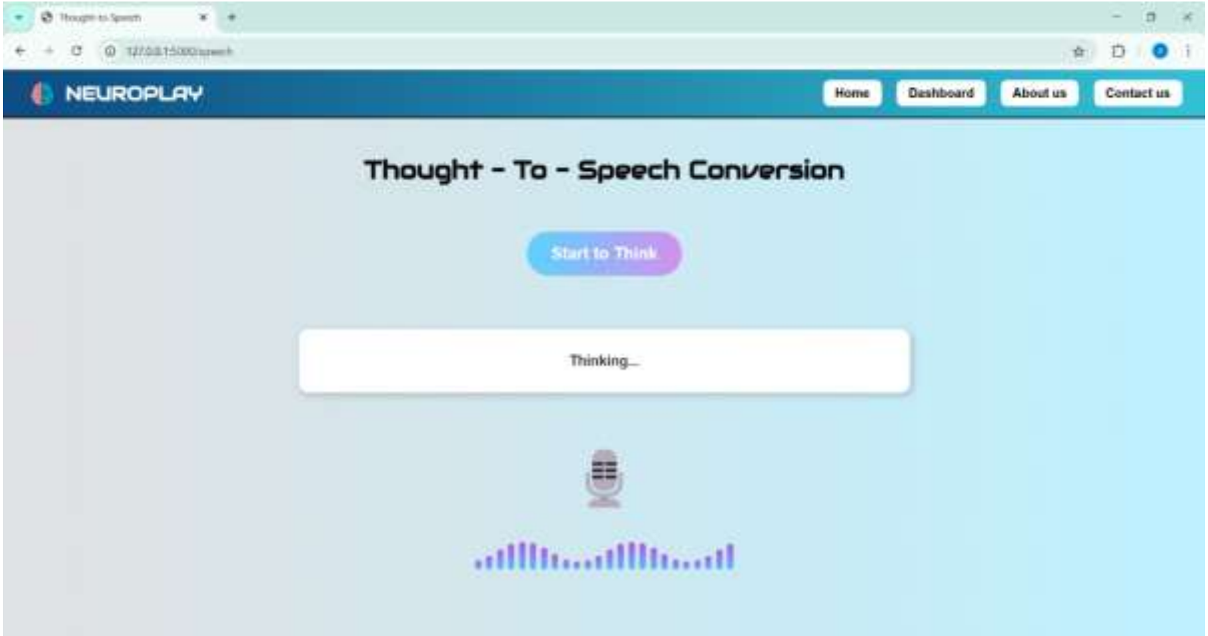


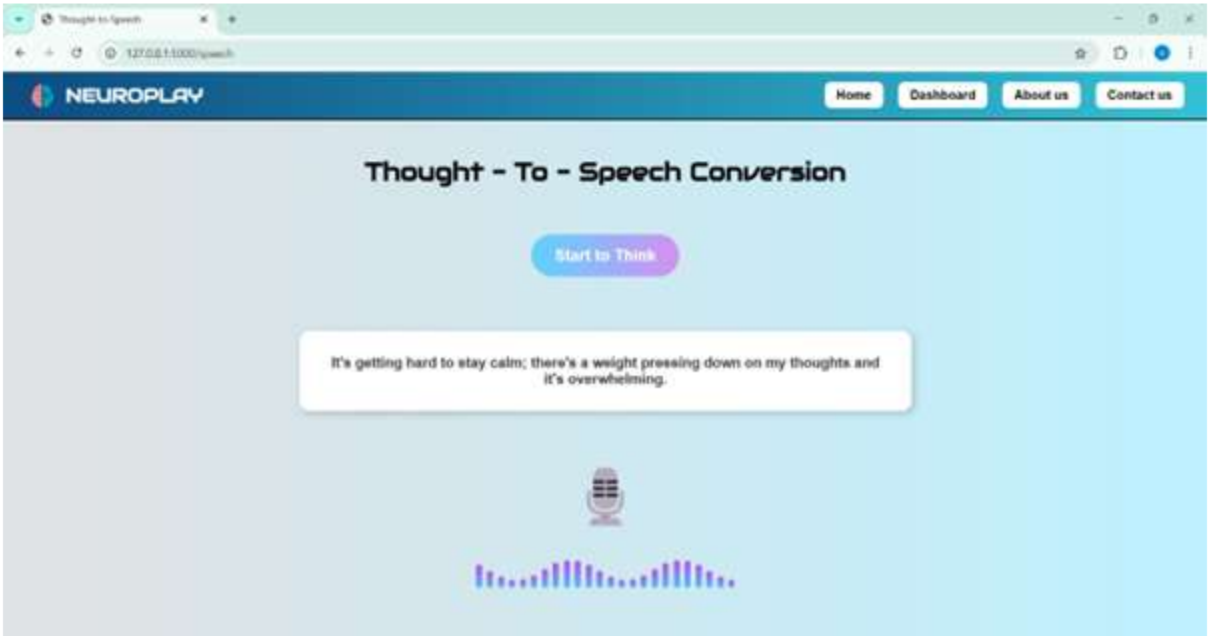
Thought-to-Speech module

The Thought-to-Speech Conversion module is an advanced assistive tool designed to help individuals with speech impairments communicate more effectively. By leveraging AI-driven text-to-speech (TTS) technology and EEG-based brain signal simulations, the system interprets users' mental activity into textual commands. These commands are then converted into natural-sounding speech through advanced synthesis.

This hands-free communication method is especially beneficial for individuals with motor or speech disabilities, providing an intuitive and accessible way to express their thoughts. By translating brain signals into spoken words, the module bridges critical communication gaps and fosters greater inclusivity and independence in everyday interactions.

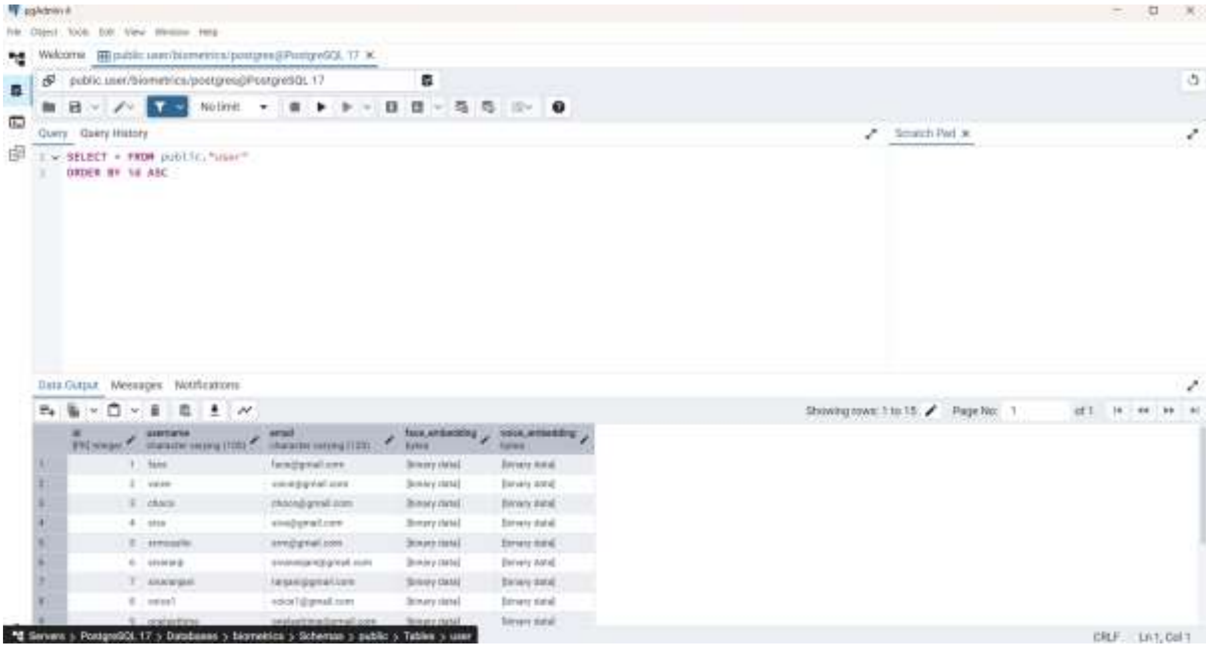






Database

A PostgreSQL user table in pgAdmin 4, used for biometric authentication. It stores user details like id, username, and email, along with face_embedding and voice_embedding as binary data. These embeddings are generated from AI models for facial and voice recognition. The SQL query retrieves all user records ordered by ID, supporting a secure and accessible login system.



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