Project Report On

BlinkEye: Assistive tool for NMD Patients

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology

in

Computer Science and Engineering

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April 2025

CERTIFICATE

This is to certify that the project report/seminar report entitled ***"BlinkEye: Assistive Tool for NMD Patients"*** *is a bonafide record of the work done by* ***Ebin Jose (U2103081), Denik Denny (U2103075), Jovin Jacob Jestin (U2103117), Melvin Jiju (U2103137)****, submitted to the Rajagiri School of Engineering & Technology (RSET) (Autonomous) in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology (B. Tech.) in "Computer Science and Engineering" during the academic year 2021-2025.*

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ACKNOWLEDGMENT

We wish to express our sincere gratitude towards **Rev. Dr. Jaison Paul Mulerikkal CMI**, Principal of RSET, and **Dr. Preetha K G**, Head of the Department of Computer Science and Engineering for providing us with the opportunity to undertake our project, ”BlinkEye: Assistive Tool for NMD Patients”.

We are highly indebted to our project coordinators, **Ms. Anu Maria Joykutty**, Assistant Professor, Department of Computer Science and Engineering, **Dr. Jisha G.**,Associate Professor, Department of Computer Science and Engineering, for their valuable support.

It is indeed our pleasure and a moment of satisfaction for us to express our sincere gratitude to our project guide **Ms. Reshma M R** for her patience and all the priceless advice and wisdom she has shared with us.

Last but not the least, we would like to express our sincere gratitude towards all other teachers and friends for their continuous support and constructive ideas.

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Abstract

This project, BlinkEye, is focused on developing an assistive care technology that utilizes gaze monitoring and voice control gestures to cater to the needs of Neuromuscular Disorder patients. Since these patients can only interact using their eyes and limited muscle control, BlinkEye provides an intuitive and accessible solution. Key features include a Notification Alert system for communication and IFTTT-based Home Automation for controlling smart devices.

The Notification Alert module ensures that caregivers are promptly alerted in emergencies, enabling quick assistance. Meanwhile, IFTTT integration allows patients to control smart home devices using gaze-based interactions and voice commands, improving accessibility and independence. By leveraging gaze tracking, speech recognition, and interface fixation, BlinkEye eliminates the need for conventional input devices, making it a more accessible and engaging system for individuals. The system enhances users' quality of life by promoting independence and ensuring interaction with electronic environments.

Contents

List of Abbreviations

- **AI** - Artificial Intelligence
- **CNN** - Convolutional Neural Network
- **EAR** - Eye Aspect Ratio
- **IFTTT** - If This Then That
- **IoT** - Internet of Things
- **ROI** - Region of Interest
- **WER** - Word Error Rate
- **API** - Application Programming Interface
- **ASR** - Automatic Speech Recognition
- **NMD** - Neuromuscular Disorder

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Chapter 1

Introduction

In recent years, the demand for the assistive has perhaps been felt nowhere else as it is being felt today where individuals with severely restricted mobility find it extremely difficult to use interfaces. Speaking, grasping, or even gesturing at a screen, a smartphone or tablet is a daunting challenge for paralyzed patients and those with serious motor disabilities. Since majority of the digital interfaces work with physical links such as touchscreens, keyboards or a mouse these people are socially confined and often frustrated because they cannot use gadgets that are considered fundamental in this world.

Fortunately, the development of Artificial Intelligence Computer vision is now available for implementing some of these approaches. Applications of gaze tracking, speech recognition, and adaptive user interfaces suggest that it is now feasible to create an integrated system of communication that provides tailored environments for individuals with these conditions. With such technologies, patients have full capabilities of correspondence with the environment and other digital platforms thus registering something like a proper independence thus enhanced quality of life.

BlinkEye is our answer to this growing problem. Leveraging on assistive care, this technology system will depend on gaze tracker accompanied by speech to text and an easy to use virtual keyboard to help the paralysed. Through the use of eye tracking and the voice command, users of BlinkEye can effectively interact with applications, make use of voice to type and enable caregivers to notice when they are in use. During an emergency, the system allows for immediate notification, meaning any patient can easily get in touch with his or her caretaker or family member.

Applying machine learning algorithm, computer vision, and smart interface design, BlinkEye stands not only for a tool, but for a help when the person most needs it. It is our desire to come up with an integrated and easily attainable solution that will not only fill the abovementioned gap in assistive technology but also give 'dignity' back to human beings who are diagnosed with severe physical disability.

1.1 Background

Paralysis and other forms of severe motor impairment limit a person's ability to perform everyday tasks independently. According to recent studies, a significant proportion of patients with such conditions experience psychological distress due to isolation and lack of engagement in communication and interaction. Conventional interfaces, such as smartphones and computers, rely on hand-based input, rendering them inaccessible to this population. This gap in accessibility affects patients' autonomy, often leading to frustration and a decreased quality of life.

Although voice-activated technologies have made strides in accessibility, they do not fully address the needs of users who may also face speech challenges. Recent developments in gaze tracking and eye-tracking technology offer a unique alternative, allowing users to control devices and navigate applications with eye movements alone. By integrating gaze tracking, voice recognition, and customizable interfaces, BlinkEye addresses both the technological and emotional needs of paralyzed patients, empowering them to communicate and interact more independently. This project seeks to provide a novel and accessible solution that enhances patients' quality of life and independence.

1.2 Problem Definition

The purpose of this project is to come up with an assistive technology which helps a paralyzed individ patients to effectively share and use their eye movements for communication and interfacing with computers and/or the Internet. Previuos interfaces are limited to the physical input, eliminating any sense entries to them.People with major mobility disability, leading to social exclusion and less better quality of life.

1.3 Scope and Motivation

The technical focus of the BlinkEye project includes creating an efficient and affordable assistive technology environment that allows paralyzed patients to control their devices through eye control and voice command input. This project also opens the possibilities for real time gaze tracking, a customizable virtual keyboard and emergency alert options, giving a wrap solution to non physical input. About UI and input, BlinkEye will be flexible depending on the particular need of the patients when it is used. For accurate speech input and gaze tracking, the project employs sophisticated machine learning approaches such as: wav2vec for the voice recognition, and MediaPipe for gaze tracking, that would yield highly responsive and rather efficient interface for human-computer and human-robot interaction, and control. The scope also carried out testing of the usability and efficacy of the proposed system in other types of lighting and environment to check on its efficiency in real conditions.

The purpose of developing BlinkEye comes from the experiences of people with severe mobility impairments as they barely can communicate with friends or families because they cannot control the devices. Many conventional technologies fail in access and the proposed interface calls for voice inputs and ease of use, tailoring patient's use and control. The development of AI and especially computer vision currently offers a chance to build a tool that would help patients to control devices and speak with their eyes and voice only. The aim and objective of this venture is to enhance the standard of living of these patients, afford them the appreciation of the surrounding environment and, most essentially, describe those phrases or sentiments that were hitherto virtually unthinkable to verbalize. These benefits to improve independence, morale, and emergency support offer the need for a detailed and user-oriented assistive technology to support this project.

1.4 Objectives

1. Develop a gaze tracking system using algorithms such as MediaPipe to enable precise eye movement detection and interaction with a digital interface.

2. Integrate speech-to-text functionality using Google's Speech-to-Text API to allow patients to communicate and issue commands verbally.

3. Design a customizable virtual keyboard interface that can be controlled via eye movements, facilitating easy and efficient typing for users.

4. Implement an emergency alert system that enables patients to quickly contact caregivers or emergency services when needed.

5. Ensure real-time performance and responsiveness of the system under varied environmental conditions, including lighting and user positioning.

6. Conduct usability testing to gather feedback, refine the interface, and improve the system's accessibility and ease of use for patients with severe motor impairments.

1.5 Challenges

The BlinkEye project is presented with several technical difficulties mainly in achieving high accuracy of the gaze tracking irrespective of the room's lighting conditions and positional angle of the user. Incorporation of voice recognition for patients with possible speech difficulties is also a challenge as well as striking a balance for the gaze, voice, and the user interface units. Besides, making the interface easy to use and user friendly avoiding the hard trademark of patients with physical movements disorders will be essential for the success of the project.

1.6 Assumptions

1. Patients have sufficient control over their eye movements to interact with the gaze-tracking system.

2. System needs an initial setup from caretakers/others

3. The device setup includes a stable camera with clear visibility of the user's face and eyes.

4. Adequate lighting is available to support accurate eye tracking.

5. Internet connectivity is reliable for functions that depend on cloud-based services or emergency alerts.

1.7 Societal / Industrial Relevance

The BlinkEye project has high social significance since the goal of the project is to bring improvements into the lives of many patients with severe motor disabilities who can exercise control over their environment only with the help of communicating devices.

This of course is an assistive technology that can give the patients more control of their own lives, decrease social isolation, and grant them better access to help if they ever need it.

1.8 Organization of the Report

This report will give a brief background of the BlinkEye project which is the focus of the study. In Chapter 1, the reader is briefly presented with the objectives of the project, reasons for doing the project and its relevance to the development of assistive technology for paralyzed patients. Chapter 2 further presents a background to related work in gaze tracking, speech recognition, and assistive interfaces which the BlinkEye project sought to fill. Chapter 3 outlines the proposed method, where information on how the system will track the gaze, recognise the voice, and how the user interface will work is included. Chapter four dwells on the technical administration of the project, description of system architecture and the modules involved. In Chapter 5, performance evaluation of the tools developed in the project, system accuracy and the response of preliminary users are discussed. Last, in Chapter 6, the findings and conclusion of this research project are presented with consideration of limitations and future recommendations.

Chapter 2

Literature Survey

This chapter reviews key advancements in assistive technology, smart home automation, speech recognition, and communication systems. The goal is to examine existing research and identify gaps in current methodologies, enabling a better understanding of areas where further development is needed. Each section provides insights into the strengths and limitations of state-of-the-art solutions, setting a foundation for the approaches discussed in subsequent chapters.

2.1 Eye-Gaze-Controlled Wheelchair System with Virtual Keyboard for Disabled Person Using Raspberry Pi

[1]

The paper titled *"Eye-Gaze-Controlled Wheelchair System with Virtual Keyboard for Disabled Person Using Raspberry Pi"* introduces a system to assist individuals with severe physical disabilities in operating a wheelchair and virtual keyboard solely through eye movements and blinking. Developed with a low-cost Raspberry Pi setup, the system enables users to control wheelchair navigation and type on a virtual keyboard without physical interaction. By employing real-time eye tracking and gaze direction, users can make the wheelchair move forward, left, or right, while eye blinks allow interaction with the virtual keyboard.

The system utilizes the Dlib library for precise face and eye detection, identifying 68 facial landmarks for eye movement tracking. The system's accuracy is bolstered through the application of a threshold-based algorithm for detecting blinks and gaze direction. Additionally, the wheelchair includes ultrasonic sensors to detect obstacles, stopping movement if one is too close. Experimental results demonstrate a high accuracy rate of over 97% for both wheelchair navigation and keyboard typing. Future enhancements include additional sensors for improved interaction and low-light performance. This research provides an affordable, efficient solution to enhance mobility and independence for disabled individuals.

2.2 wav2vec 2.0: A Framework for Self-Supervised Learning of Speech Representations

[2]

The paper titled *"wav2vec 2.0: A Framework for Self-Supervised Learning of Speech Representations"* presents an innovative self-supervised framework for learning speech representations directly from raw audio data, leveraging minimal labeled data. The model utilizes a two-step approach where speech audio is initially encoded using a convolutional neural network (CNN) and subsequently masked, producing latent representations that are processed by a Transformer network to create contextualized speech representations. The training objective involves a contrastive task, where the model learns to distinguish the correct latent representations from distractors, effectively capturing meaningful speech features without labeled transcriptions.

wav2vec 2.0 demonstrates impressive results on Librispeech, achieving word error rates (WER) as low as 1.8/3.3 on the clean/other test sets using 960 hours of labeled data. Furthermore, the framework performs robustly with limited labeled data; for example, using only 10 minutes of labeled data with 53,000 hours of unlabeled pre-training, the model achieves WERs of 4.8/8.2, showcasing its applicability to low-resource languages. This approach sets new benchmarks in speech recognition by significantly reducing the dependency on labeled datasets, enabling high-quality speech recognition models to be developed for diverse linguistic applications.

2.3 Design and Implementation of Home Automation using Amazon Alexa

[3]

The paper titled *"Design and Implementation of Home Automation using Amazon Alexa"* outlines a system for controlling household devices through Alexa, aiming to enhance the user experience by enabling seamless interaction with various appliances using voice commands. The authors discuss a system that includes a cloud-based backend for data management, a smart hub for device control, and a mobile application interface. Integration with the Amazon Alexa Skills Kit allows the system to interpret and process voice commands effectively, providing users with intuitive control over devices such as lights, security systems, and temperature settings.

The methodology employed in the paper involves selecting compatible hardware components, designing the system architecture, implementing the backend infrastructure, and testing the system in a residential environment. This approach demonstrates the system's practical functionality, with results indicating high levels of user satisfaction due to hands-free control and customization options.

The paper's key contributions include the support for voice commands across multiple devices, which enhances the accessibility and user-friendliness of home automation. Experimental results show that integrating Alexa Skills Kit with IoT devices ensures smooth control, reliability, and accuracy in interpreting commands, thereby increasing the system's effectiveness.

Future directions proposed by the authors suggest that advancements in natural language processing, energy management, and security could further enhance the system's capabilities. Additionally, integrating other virtual assistants and developing AI-driven automation are identified as promising areas for future research, aiming to create a more sophisticated and personalized smart home experience.

2.4 Design and implementation of an automated security system using Twilio messaging service.

[4]

In today's fast-paced world, effective communication is essential for businesses, and Twilio provides a powerful API to facilitate this. Twilio is a cloud communication platform that enables developers to integrate messaging, voice, and video capabilities directly into their applications. This API supports a wide range of communication needs, helping businesses enhance customer engagement and improve operational efficiency. Its flexibility allows for custom solutions across industries, from e-commerce to healthcare.

Twilio's key features include programmable messaging for SMS and MMS, voice capabilities with call routing and recording, and video integration for embedded video calls.

Furthermore, Twilio supports two-factor authentication (2FA) through SMS and voice, ensuring secure user interactions. These features are designed to provide seamless and scalable communication channels, making Twilio a preferred choice for companies aiming to improve customer service and interaction.

Various companies have effectively implemented Twilio's API to streamline their operations and enhance customer satisfaction. For example, Mergein, a sales management app, connects sales associates and customers via Twilio's voice and messaging features, enabling remote call management and prompt responses. Research indicates that customers value flexible communication options across channels, and Twilio's tools help businesses meet these expectations. Overall, Twilio's robust API empowers companies to offer enhanced, flexible communication that fosters stronger customer relationships.

2.5 Summary and Gaps Identified

2.5.1 Summary

The table below provides a summary of each paper discussed in the literature review, focusing on their main contributions, advantages, and any noted limitations.

Paper Title	**Year**	**Advantages**	**Disadvantages**
Eye-Gaze-Controlled Wheelchair System with Virtual Keyboard for Disabled Person Using Raspberry Pi	2022	Enables wheelchair control and virtual keyboard input through eye movement; affordable and efficient for disabled users	Limited functionality in low-light conditions; requires further sensor integration for improved accuracy
wav2vec 2.0: A Framework for Self-Supervised Learning of Speech Representations	2020	High performance on low-resource languages; reduces reliance on labeled data	Computationally intensive; may require substantial computing resources for real-time applications
Design and Implementation of Home Automation using Amazon Alexa	2023	Intuitive voice-controlled home automation; high user satisfaction and ease of integration with Alexa Skills Kit	Challenges with privacy, security, and system scalability; requires reliable internet connectivity
Design and implementation of an automated security system using Twilio messaging service	2017	Versatile API for communication across multiple platforms; enhances customer engagement	Dependency on third-party API; potential security concerns with data privacy

Table 2.1: Summary of Literature Review on Various Systems and Frameworks

2.5.2 Gaps Identified

The following gaps were identified in the reviewed literature, indicating areas for further research and development:

1. Limited exploration of adaptive algorithms for eye-tracking in diverse lighting conditions, affecting reliability of gaze-controlled systems.
2. High computational demand in self-supervised learning frameworks like wav2vec 2.0, suggesting the need for optimized models suited for real-time applications.
3. Scalability and privacy concerns in voice-controlled home automation systems, with a need for improved security protocols.
4. Dependence on third-party APIs, such as Twilio, raises issues of data privacy and security, warranting further studies on secure communication methods.
5. Limited integration of context-aware features across communication and automation platforms, which could enhance user experience through personalization.

Chapter Conclusion In this chapter, we reviewed recent advancements in assistive technologies, home automation, speech processing, and communication APIs. The literature highlights significant contributions in enhancing accessibility, efficiency, and security across different applications. However, there are notable gaps that need to be addressed in future research to improve system robustness, user personalization, and security across these platforms. .

Chapter 3

System Design

This chapter details the methodologies used in developing the BlinkEye system, a supportive care solution aimed at assisting paralyzed individuals in interacting with digital platforms. The system comprises five key modules: Eye-Tracking using Gaze Detection, Predictive Keyboard, Home Automation Control, Speech Recognition, and Communication module.

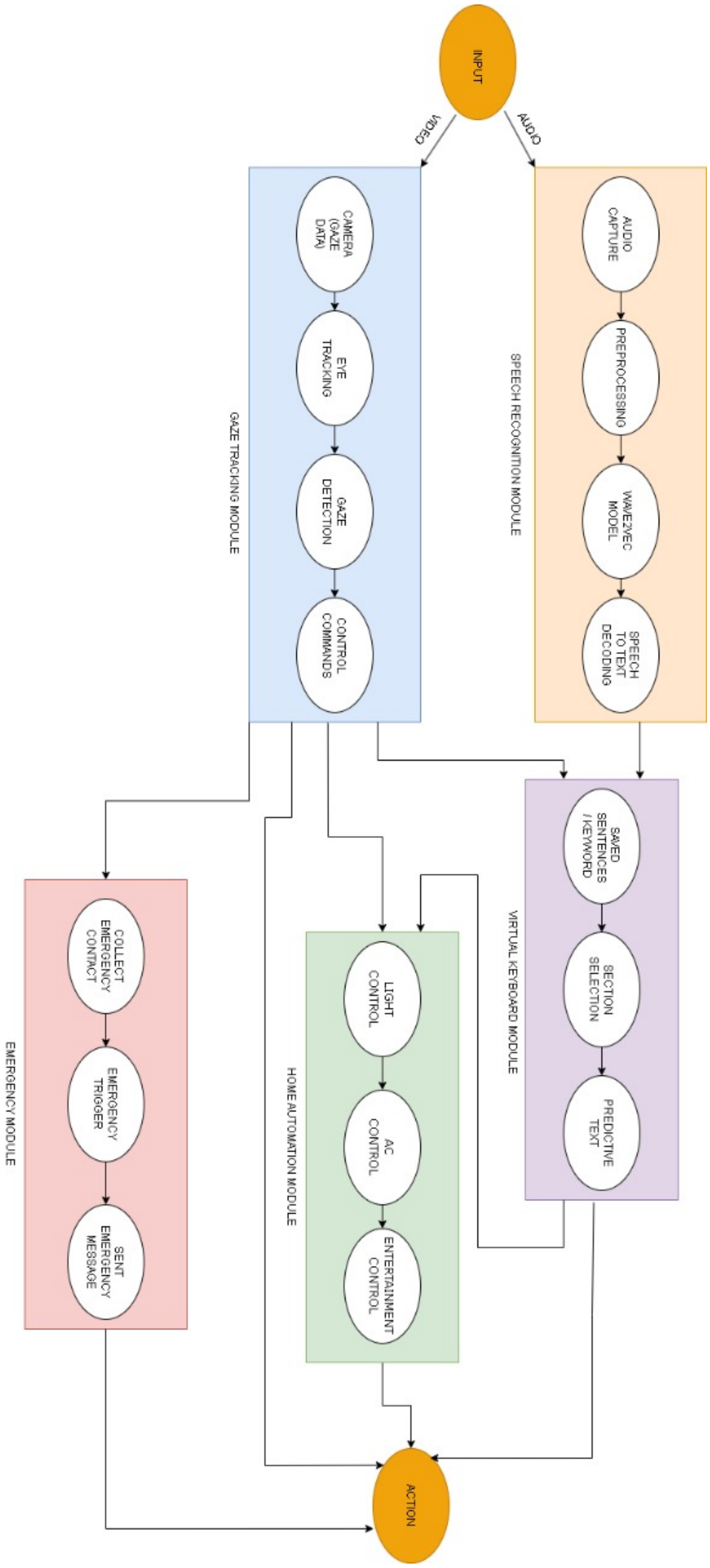

Figure 3.1: Architecture diagram

3.1 Component Design

3.1.1 Eye-Tracking and Gaze Detection

This module utilizes Mediapipe's 468-point face mesh to extract detailed facial landmarks, enabling accurate eye-tracking. A calibration step ensures precise alignment between the user's gaze and interface components, allowing for intuitive navigation. Blinks are detected through Eye Aspect Ratio (EAR) calculations and are used to perform predefined actions like selection, navigation, or system control. This module serves as the primary method for receiving user input.

3.1.2 Gaze-Controlled Keyboard

The gaze-enabled keyboard facilitates communication by allowing users to type using eye movements and blinks. It includes quick-access predefined phrases and a structured layout for detailed input, enhancing both speed and accuracy. The typing experience is further improved by predictive text and immediate visual feedback. Users have found the keyboard easy to use, which simplifies message creation while offering personalized typing support.

3.1.3 Home Automation Control

This module works with IFTTT (If This Then That) to allow control over smart home devices via gaze commands. Only devices compatible with IFTTT are supported. Users can carry out tasks such as toggling lights or executing automation routines. Communication is handled using HTTP POST requests sent through Webhooks, ensuring smooth interaction with IFTTT services. This functionality increases patient autonomy by enabling them to manage their environment independently.

3.1.4 Speech Recognition

The speech input module leverages Google's Speech-to-Text API to transform spoken words into text accurately. It performs well in various conditions, including environments with background noise. Recognized voice commands are mapped to corresponding system functions, making verbal interaction effective. This module complements the gaze-tracking feature by offering an additional means of user control.

3.1.5 Communication Module

This module enables patients to send alerts or initiate voice calls to caregivers or family members. It integrates Twilio's virtual number services to enable seamless communication. A feedback system confirms successful message delivery or call connection. Text entered through gaze input is converted into speech for calls, providing an accessible method for emergency communication.

Chapter 4

Implementation

4.1 Tools and Technologies

4.1.1 Hardware

Initially, the BlinkEye system was conceptualized as a standalone assistive device comprising an external camera, an LED screen, and an adjustable arm stand for better accessibility. However, to optimize budget constraints and improve practicality, the system has been adapted into a software-based prototype that runs on a laptop, utilizing its built-in camera and display.

- **Laptop Camera:** The system leverages the built-in laptop camera, which typically provides HD resolution (720p or higher). This ensures accurate tracking of eye movements and blinks using the MediaPipe framework, which is optimized to function effectively with standard laptop cameras.
- **Laptop Screen:** Instead of an external LED screen, the prototype runs on a laptop display of at least 15 inches. The user interface is designed with large, high-contrast buttons to facilitate easy navigation through gaze-based selection.
- **Processor:** Given the computational requirements for real-time video processing, gaze tracking, and system responses, the prototype is best suited for devices with a quad-core processor or higher to ensure smooth performance.
- **RAM:** The system requires at least 8GB of RAM, though 16GB is recommended for optimal multitasking, especially when running real-time gaze tracking, speech processing, and text-to-speech conversion simultaneously.

4.1.2 Software

- Operating System (Windows): Windows stands for the primary software environment on which the BlinkEye application is to be launched and for which the necessary software components are implemented.

- OpenCV: OpenCV is used for frame processing captured from the webcam. This is a crucial function that you get with an image and video processing layer, which in turn is a critical aspect for evaluation of gaze and blink.

- MediaPipe: MediaPipe is a machine learning framework for eye tracking and for detecting facial landmarks. Concretely, it tracks the gaze directions and can detect blinks with high accuracy using real-time video feeds.

- Twilio: Twilio allows developers to add voice, video, and messaging functionality to applications through its APIs. It offers programmable SMS, voice calls, and real-time engagement features for businesses. The platform offers scalable communication solutions across sectors such as tech, healthcare, and e-commerce. Its solutions are applied for customer interaction, notifications, and authentication services

- Google Speech-to-Text: This speech recognition framework converts audio input into text with high accuracy. It efficiently processes spoken commands, even in varied environmental conditions, enabling effective communication and control for patients.

- IFTTT Integration: The system leverages IFTTT (If This Then That) for home automation, allowing patients to control smart devices using gaze and voice commands. Through Webhooks, it facilitates seamless interaction with compatible smart home accessories, such as lights, fans, and televisions, enhancing user independence.

4.2 Module Divisions and Work Breakdown

4.2.1 Module Division

- **Gaze Tracking and Control:** Implements advanced gaze tracking algorithms to detect and interpret eye movements for system navigation and control.

- **Speech Recognition:** Converts spoken commands into text using speech-to-text technology, allowing users to interact with the system through voice input.
- **Virtual Keyboard:** Provides an on-screen keyboard controlled through gaze tracking, enabling text input without the need for physical interaction.
- **Home Automation Control:** Integrates with smart home devices using IFTTT to enable patients to control their environment through gaze and voice commands.
- **Communication and Emergency System:** Sends emergency notifications and calls via Twilio, ensuring that caregivers are alerted promptly in case of urgent situations.
- **User Interface Development:** Designs and implements an intuitive and user-friendly graphical interface for seamless patient interaction.

4.2.2 Work Breakdown

1. **Graphical User Interface (Denik Denny, Jovin Jacob Jestin)**
    - GUI Development: Designed and implemented an accessible and intuitive user interface for BlinkEye.
    - User Interaction Flow: Optimized layout and workflow to ensure seamless interaction using gaze tracking and speech control.
2. **Gaze Control System (Ebin Jose, Melvin Jiju Mathew)**
    - Gaze Tracking: Developed gaze tracking functionality to enable accurate detection of eye movements.
    - System Integration: Integrated gaze-based control with other modules for smooth interaction.
3. **Speech Control System (Denik Denny)**
    - Speech Recognition: Implemented a speech-to-text system for voice-based interaction.

- Command Processing: Mapped recognized speech inputs to corresponding system actions.

4. **Virtual Keyboard (Jovin Jacob Jestin)**
   - Keyboard Implementation: Developed an on-screen virtual keyboard operated via gaze tracking.
   - Optimization: Enhanced keyboard usability for efficient text input.

5. **System Integration and Communication (Ebin Jose)**
   - Backend Integration: Ensured seamless communication between modules.
   - Data Flow Management: Handled processing and storage of system interactions.

6. **Home Automation(Melvin Jiju Mathew)**
   - IFTTT Integration: Implemented IFTTT for controlling smart home devices using gaze or voice commands.
   - Twilio Alerts: Developed an emergency notification system using Twilio for immediate caregiver alerts.

4.3 Key Deliverables

The BlinkEye system starts by initializing the camera and software for gaze tracking. The system then continuously tracks the user's gaze data, mapping these inputs to specific actions like selecting options, navigating menus, or triggering emergency alerts. Commands are executed based on predefined patterns, such as focusing on a button and selection using dwell time. Additional features include a virtual keyboard for typing, text-to-speech for communication, and integration with IFTTT for smart home control. The system runs in real-time, adapting to user preferences and ensuring a seamless, intuitive experience.

4.4 Project Timeline

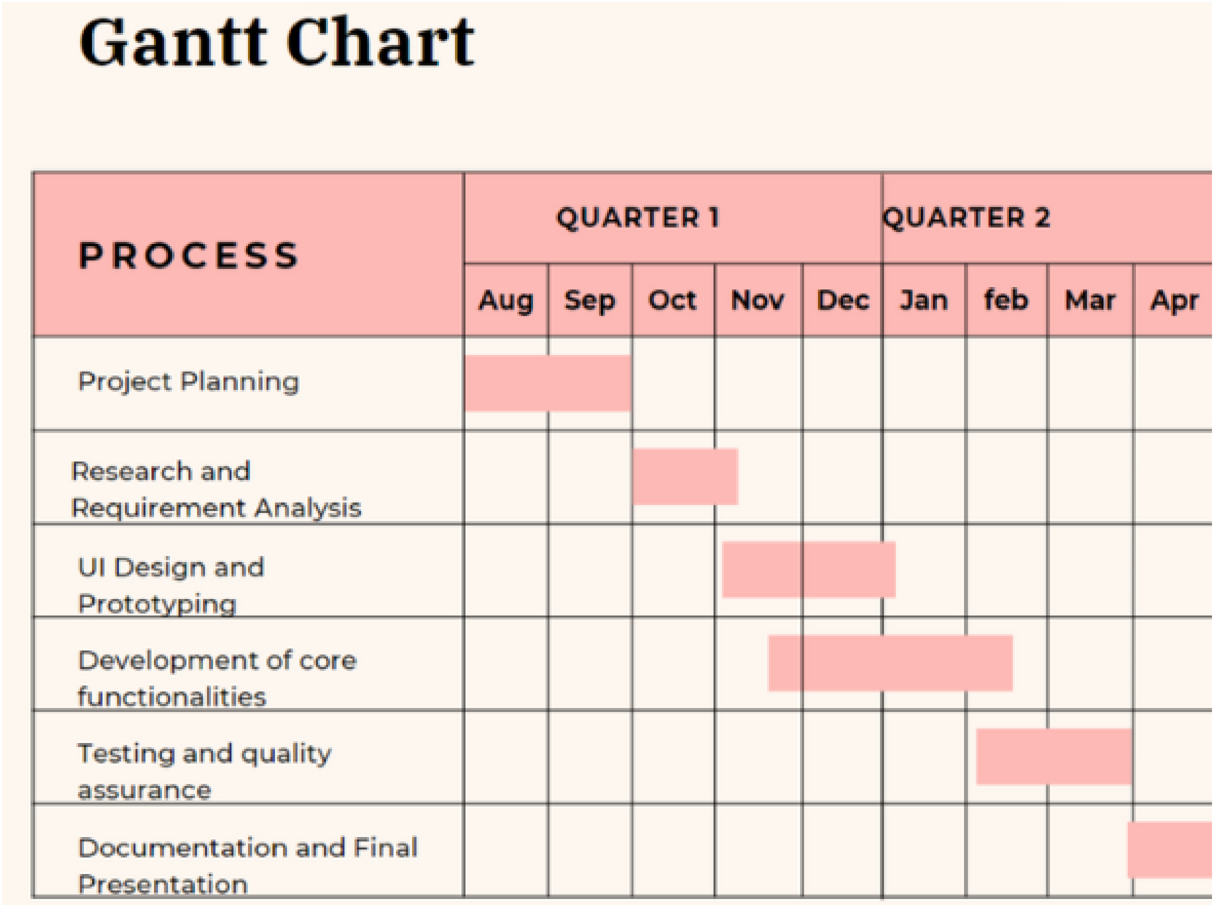

Figure 4.1: Gantt Chart

4.5 Conclusion

Throughout the development of this project, various speech-to-text solutions were assessed to identify the most appropriate one for our needs. Initially, Facebook's Wav2Vec model was chosen due to its strong performance in voice-to-text conversion. To improve the accuracy of the transcribed text, the LanguageTool API was also incorporated for real-time grammar correction. However, after further evaluation, the Wav2Vec model was replaced by Google's Speech Recognition API, which offered more efficient integration and reliable results within our system framework.

For gaze tracking, the system employs MediaPipe's FaceMesh, which provides 468 facial landmarks for precise pupil detection and monitoring. This enabled accurate mapping of eye movements relative to the screen dimensions, ensuring smooth and intuitive gesture control. Currently, efforts are focused on calibration to refine the accuracy of gaze detection, with the aim of achieving dependable and responsive tracking.

Emergency communication was also a major focus in our system. To address this, a notification feature was implemented using Twilio, which allows users to send immediate alerts to caregivers. This ensures timely assistance in case of emergencies. Additionally, a minimalistic virtual keyboard was designed with user comfort in mind. Its simple, accessible layout supports ease of use for individuals with limited mobility, contributing to the overall user-friendly experience of the system.

Chapter 5

Results and Discussions

This chapter presents the results obtained from the implementation of the BlinkEye system. The outputs from various modules, including eye tracking, home automation, emergency alerts, and communication, are analyzed and discussed. The system's efficiency, usability, and performance in real-time conditions are evaluated.

5.1 Main GUI Overview

The main graphical user interface (GUI) serves as the central hub for user interaction. As shown in **Figure 5.1**, the interface is designed with accessibility in mind, featuring large, clearly labeled buttons for easy navigation. The top-left section displays the current date and time, ensuring users stay aware of the present moment. The top-right corner features toggle options for switching between **Voice Mode** and **Eye Mode**, allowing users to control the system using either speech commands or gaze-based input.

One of the primary features of the interface is the **Emergency Alert** system, which is highlighted in the GUI. In case of an emergency, a user can trigger an alert, which then sends a notification to pre-configured contacts or caregivers.

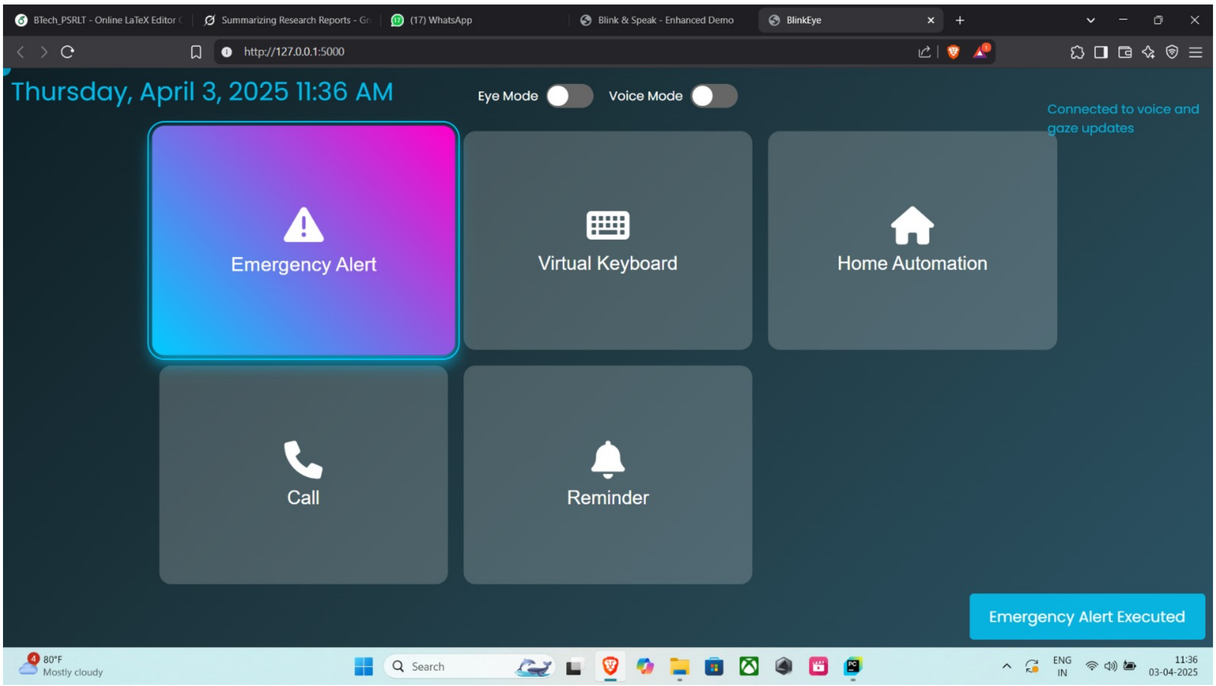

Figure 5.1: Main GUI of the BlinkEye System

5.2 Home Automation Output

The BlinkEye system is equipped with a **Home Automation** feature that allows users to control various smart devices. As shown in **Figure 5.2**, the system successfully interacts with connected devices, demonstrating its ability to **turn on and off lights** and control other smart appliances.

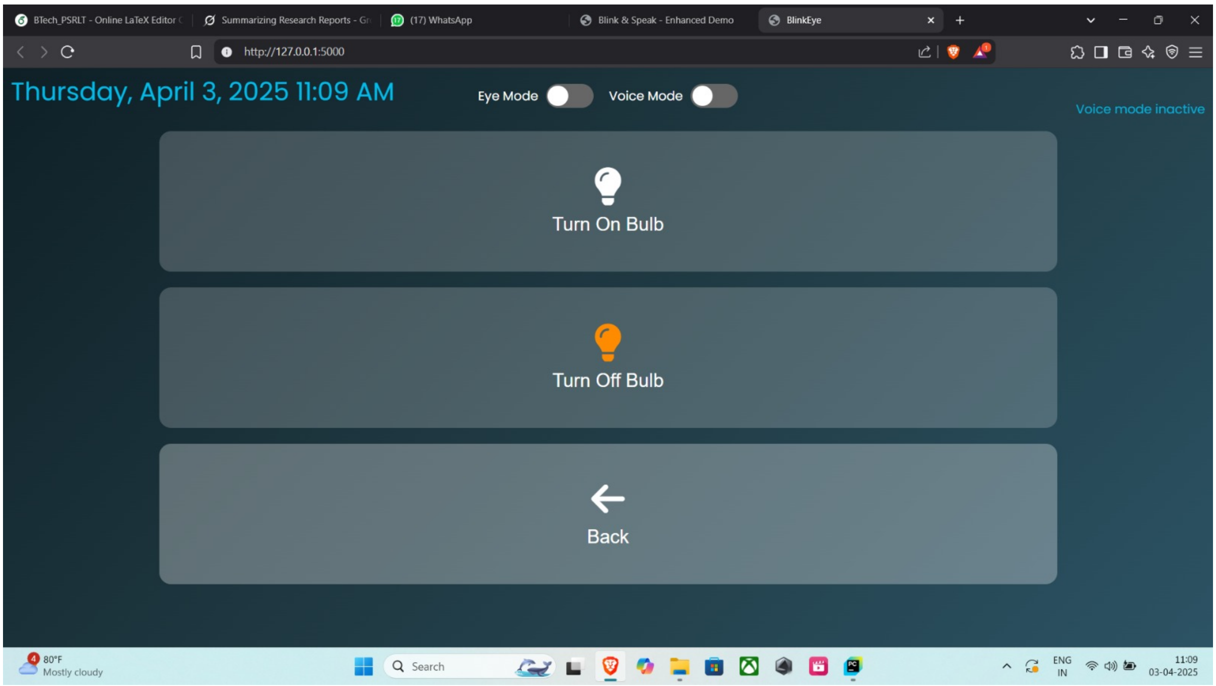

Figure 5.2: Home Automation Feature Output

5.3 Eye Tracking and Gaze-Based Interaction

A core component of the BlinkEye system is its **eye-tracking module**, which enables users to interact with the interface through gaze-based selections. As depicted in **Figure 5.3**, the system accurately detects and tracks the user's eye movements in real time.

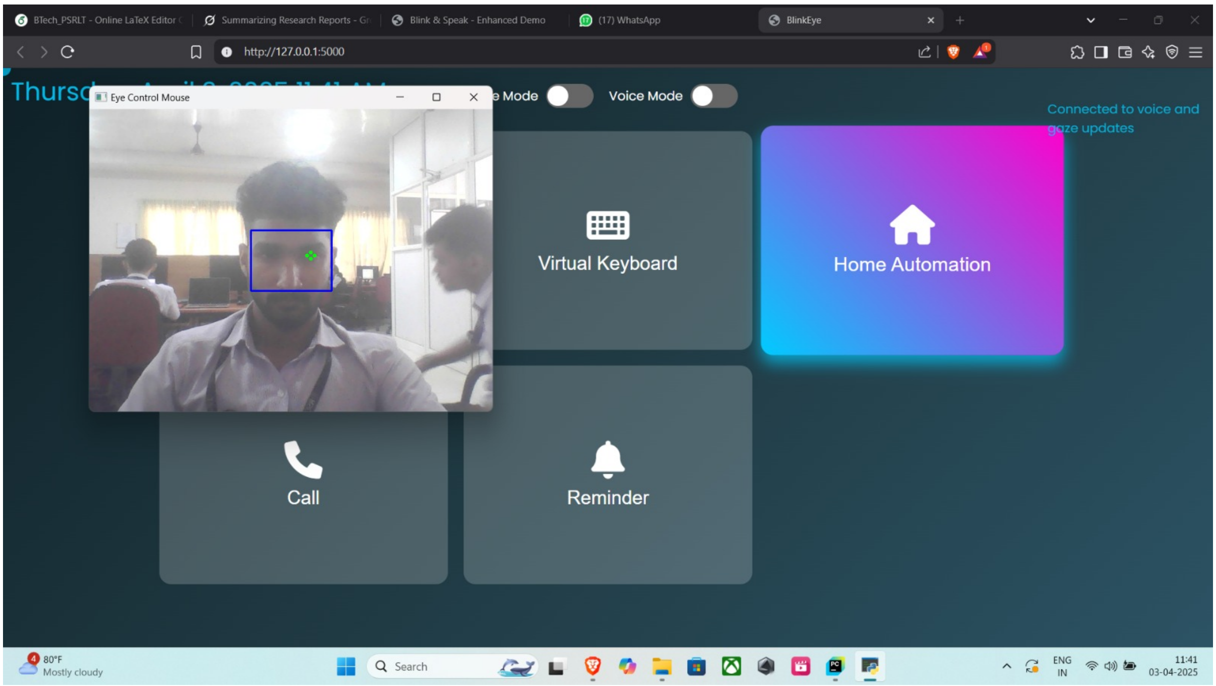

Figure 5.3: Eye Tracking Output

5.4 Requesting a Service: Calling a Caretaker

Another essential feature of the system is the ability to **request assistance**. As shown in **Figure 5.4**, users can request a caretaker's help by triggering a **Call** function within the interface.

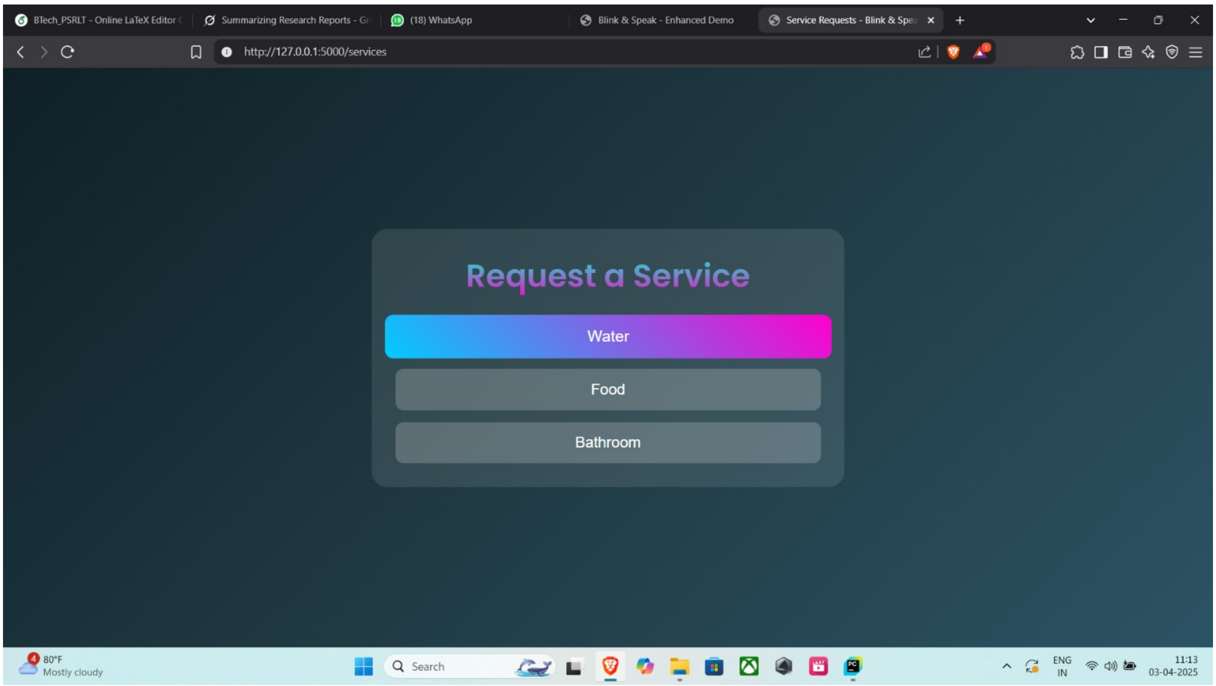

Figure 5.4: Requesting a Service: Calling a Caretaker

5.5 Reminder Functionality for Scheduled Tasks

To assist patients in managing their daily activities, the BlinkEye system includes a **Reminder module**, as demonstrated in **Figure 5.5**. This feature allows caregivers to **schedule reminders** for medications, appointments, or other essential tasks.

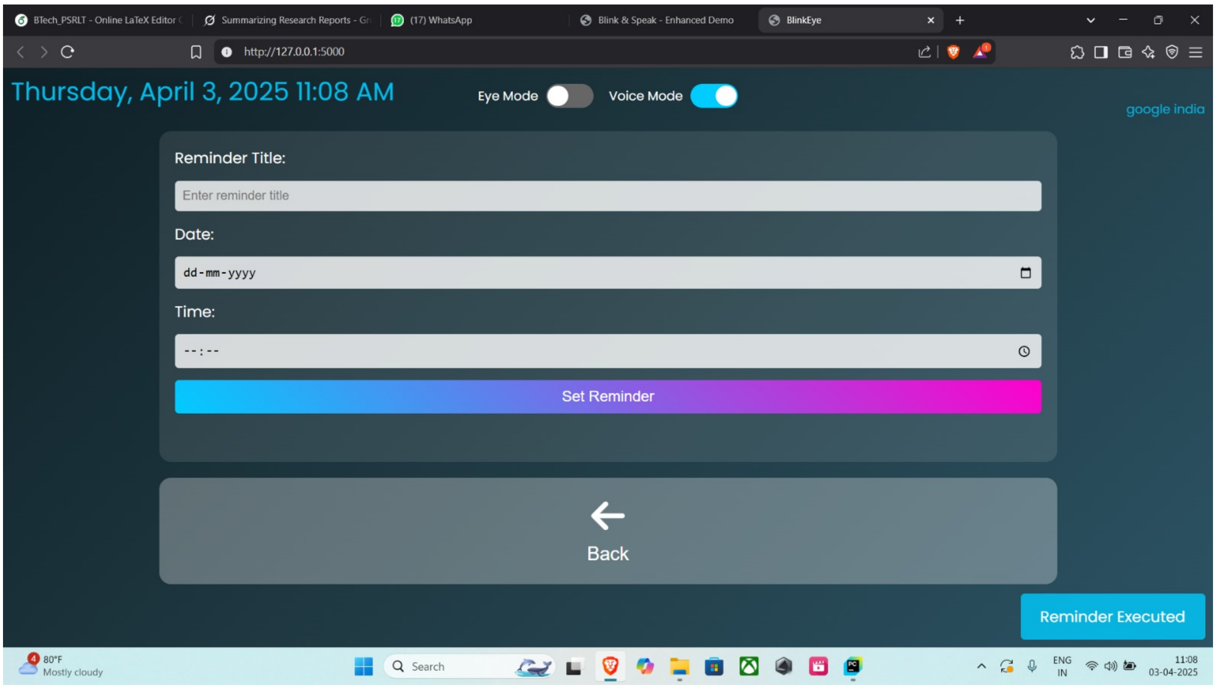

Figure 5.5: Reminder Module for Scheduling Tasks

5.6 Discussion and Future Scope

The results demonstrate that the BlinkEye system successfully integrates multiple assistive features, including **eye tracking, voice control, home automation, emergency alerts, and scheduled reminders**. The system's real-time performance is optimized by **processing gaze and blink inputs locally**, reducing dependency on external servers.

Initially, our approach focused on a fully hardware-based system, including an external **LED display, separate high-resolution camera, and an adjustable arm stand**. However, to reduce costs and improve accessibility, we developed a software-based prototype, utilizing a **laptop's built-in camera and screen** while ensuring smooth interaction via gaze tracking and voice commands.

5.6.1 Future Scope

The BlinkEye system has the potential for significant enhancements in both **software and hardware**:

- **Hardware Optimization**: Implementing a **dedicated external camera** and a **custom-designed display mount** to improve the user experience.

- **Improved AI Models**: Enhancing **eye-tracking accuracy** using deep-learning-based gaze estimation models.
- **Expanded Home Automation**: Supporting additional **IoT-based appliances** to provide greater flexibility for users.
- **Voice Assistant Integration**: Adding **Alexa or Google Assistant support** to expand accessibility options.
- **Battery Backup**: Implementing an uninterrupted power supply (UPS) to ensure continued operation during power failures.

5.6.2 Proposed Hardware Requirements for a Fully Developed System

For the fully developed version of BlinkEye, the following hardware components will be necessary:

- **Camera**: A minimum 720p (HD) camera is recommended since the MediaPipe framework is optimized for this resolution. Higher resolution cameras may improve gaze tracking accuracy.
- **Display Screen**: A 15-inch or larger screen will ensure proper visibility of the UI, with large buttons for easier navigation via gaze.
- **Adjustable Arm**: A flexible mounting arm to position the camera and screen according to the user's line of sight.
- **Processor**: A quad-core or higher processor is essential to handle real-time video processing, gaze detection, and system responses.
- **RAM**: A minimum of 16GB RAM is advised to avoid lag while running multiple processes, such as real-time eye tracking and text-to-speech conversion.

These enhancements aim to provide an improved user experience, offering both portability and ease of use for neuromuscular patients requiring an assistive communication system.

5.7 Conclusion

The development of the BlinkEye system marks a significant step toward providing an accessible and cost-effective assistive solution for individuals with neuromuscular disabilities. Initially conceptualized as a hardware-integrated system with a dedicated camera, LED screen, and adjustable stand, the project was restructured into a software-based prototype to optimize budget and feasibility. By leveraging a laptop's built-in camera and display, the system successfully delivers essential functionalities such as **eye-tracking, voice control, home automation, emergency alerts, and scheduled reminders**, making it a viable alternative to costly assistive devices.

The discussion highlights the effectiveness of BlinkEye in enhancing user independence through its real-time processing capabilities and intuitive interface. The system's performance demonstrates the potential of AI-powered gaze tracking and voice recognition in assistive communication. However, to further refine its usability and accuracy, future developments should focus on integrating **dedicated external cameras, custom display mounts, and AI-driven gaze estimation models**. Additionally, expanding its home automation capabilities and integrating voice assistants like Alexa or Google Assistant could significantly enhance its versatility.

In the long term, BlinkEye has the potential to evolve into a fully developed assistive device by incorporating purpose-built hardware components. A more advanced implementation could include compact and lightweight hardware tailored for prolonged use by individuals with severe mobility restrictions. By continuously improving both software and hardware aspects, the system can be adapted for broader applications in healthcare, rehabilitation, and independent living solutions.

Overall, the BlinkEye system represents a promising step toward accessible and intelligent assistive technology. With ongoing enhancements and integration of advanced AI models, the system has the potential to become a robust and scalable solution, empowering individuals with disabilities to communicate and interact with their surroundings more efficiently.

Chapter 6

Conclusion

The BlinkEye project represents a significant advancement in assistive technology, offering paralyzed individuals greater autonomy through gaze tracking and speech-based interaction. By integrating features like emergency alerts, smart home automation via IFTTT, and a Gaze Keyboard, BlinkEye provides a comprehensive solution that enhances accessibility and independence.

A review of existing literature highlights that while assistive technologies have improved in recent years, many systems still face limitations. Eye-gaze tracking solutions, though beneficial, often struggle with accuracy in low-light conditions. Speech recognition models such as Google's speech-to-text, while effective, tend to be resource-intensive, making them less suitable for real-time use. Smart home automation via voice control enhances convenience but also raises concerns related to privacy and internet dependency. Similarly, emergency communication services like Twilio are efficient but rely on third-party services, introducing potential data privacy risks. The findings of this study underscore the need for a more customizable, stable, and interconnected solution—precisely what BlinkEye aims to deliver.

By replacing traditional input methods like keyboards and mice with gaze and voice-based controls, BlinkEye not only empowers users to interact with technology independently but also redefines the future of assistive tools. This project serves as a reminder that technology should be designed with inclusivity in mind, ensuring both safety and practicality for those who rely on it the most.

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Appendix A: Presentation

BlinkEye: Assistive tool for NMD Patients

Project Guide:
Ms. Reshma M R
Associate Professor
Dept. of CSE, RSET

By
Denik Denny
Ebin Jose
Jovin Jacob Jestin
Melvin Jiju Mathew

Table Of Content

Problem Defintion

- Neuromuscular patients face challenges in communication and interaction.
- Traditional interfaces relying on physical input are inaccessible.
- Lack of effective assistive technology leads to isolation and frustration.
- Need for solutions enabling seamless interaction with digital interfaces.

Purpose & Need

- Enhance quality of life for paralyzed patients through communication and control.
- Need for intuitive assistive technologies to empower self-expression.
- Bridge the gap in existing solutions with personalized and accessible approaches.

Project Objective

- Develop software allowing interaction via gaze and voice commands.
- Implement a robust gaze tracking system for accurate input.
- A setup which can be easily handled by caretakers
- Create an intuitive user interface for easy navigation.
- Include emergency communication features for safety and caregiver connectivity.

Proposed Method

01. Gaze Tracking

Use algorithms (e.g., MediaPipe) to detect eye movements, mapping gaze to interface elements.

02. Voice Recognition

Implement a voice command interface for system control and communication.

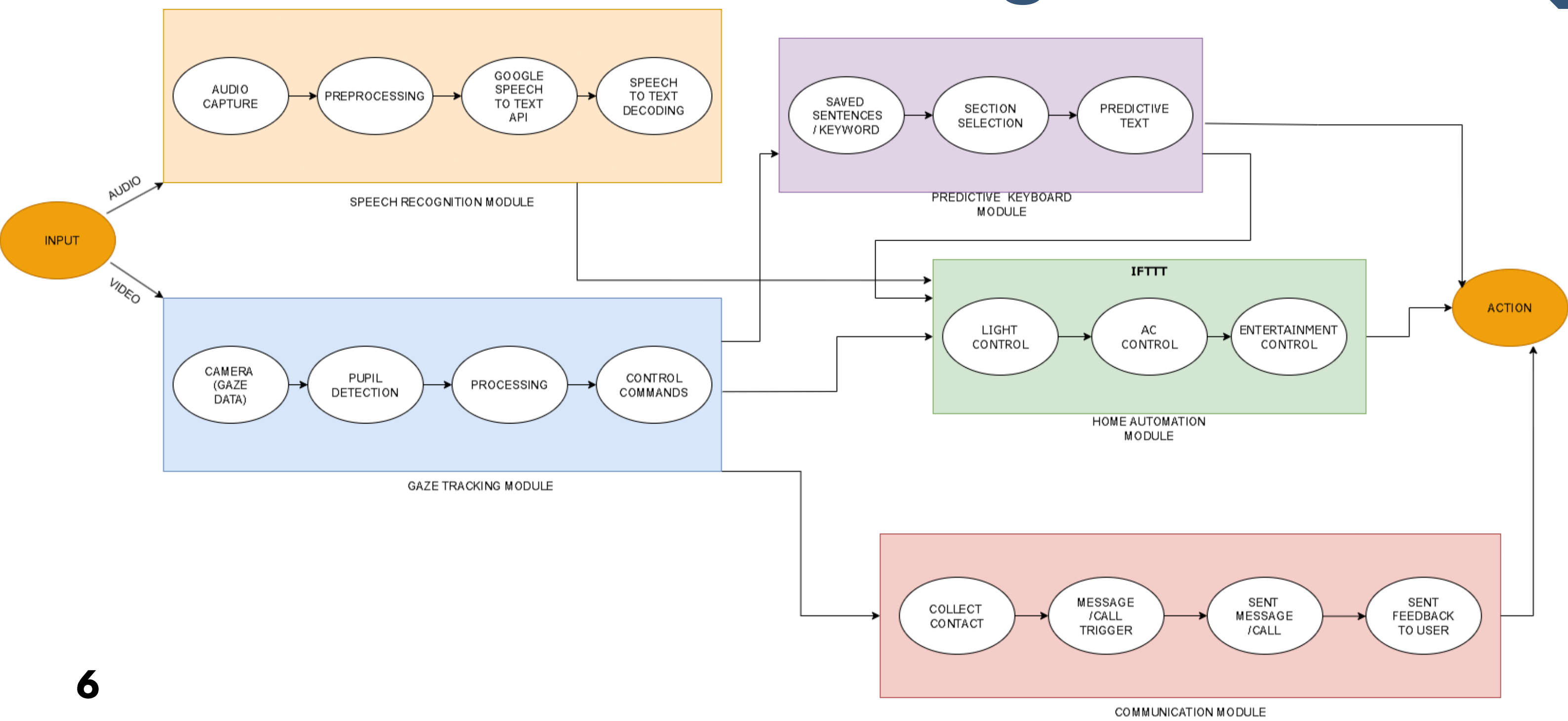
03. User InterfaceDesign

Develop a user-friendly UI with large buttons and simple navigation, incorporating emergency alerts and speech recognition for command execution

04. Integration and Testing

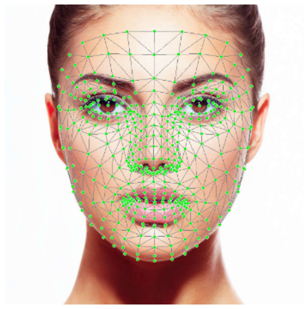
Conduct user testing to gather feedback and refine the system for effectiveness

Architecture Diagram



Module-wise Diagrams

Gaze Module



- **Detecting the user's eye position** using a webcam and the MediaPipe Face Mesh library.
- **Mapping the detected eye position** to screen coordinates to control a cursor.
- **Tracking gaze dwell time** to trigger actions (e.g., clicks) when the user fixates on a specific area.
- **Sending gaze data** to the frontend via WebSocket for real-time interaction with the GUI.

Gaze Module

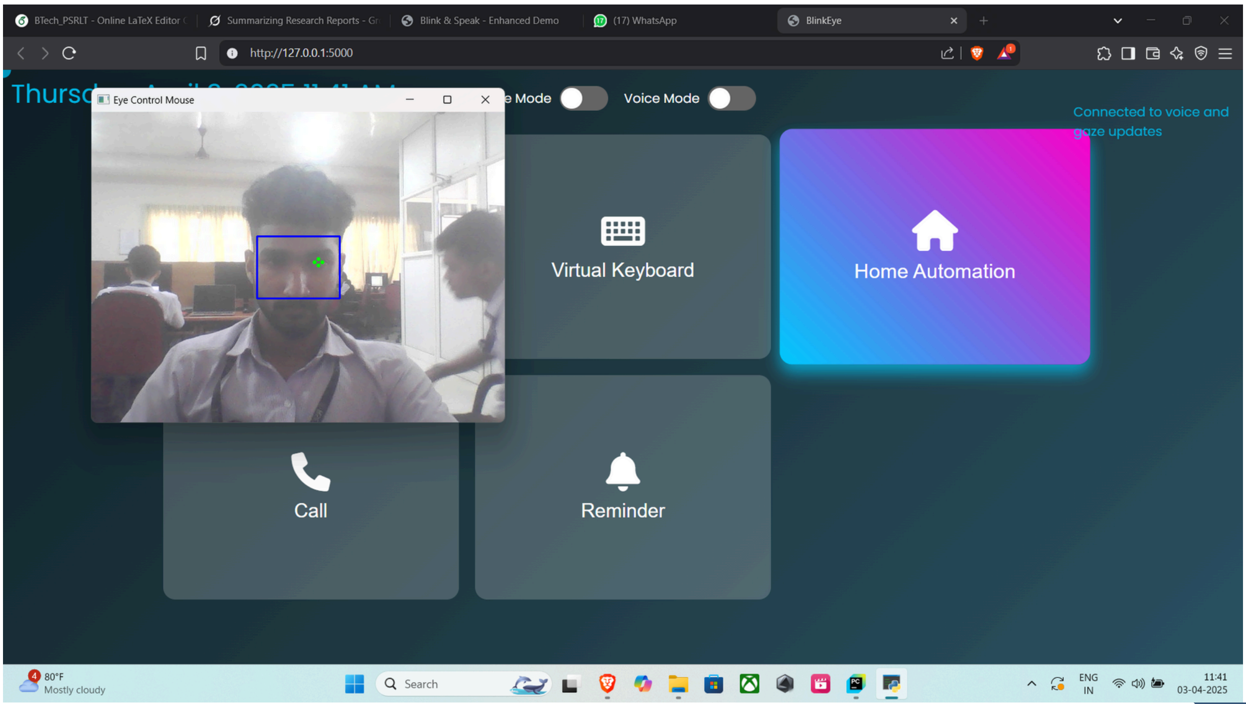
- **Normalization and Interpolation**: The normalized eye coordinates (landmarks[475].x and landmarks[475].y) are mapped to screen coordinates using np.interp. The range [0.4, 0.6] is used as a calibration window to focus on the central area of the frame, avoiding extreme edges.

$$y = y_0 + (x - x_0) \cdot \frac{y_1 - y_0}{x_1 - x_0}$$

Where:

- x: The input value (e.g., the normalized eye coordinate from MediaPipe).
- x_0, x_1: The input range (e.g., the normalized range `[0.4, 0.6]`).
- y_0, y_1: The output range (e.g., the screen coordinates `[0, screen_w]` or `[0, screen_h]`).
- y: The interpolated output value (e.g., the cursor position on the screen).

Output



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Predictive Keyboard Module

- **Hierarchical Keyboard Structure -** The keyboard begins with four groups (A-I, J-R, S-Z, 0-9), each opening into a sub-keyboard with specific characters. Sub-keyboards include Space, Caps, and Backspace, streamlining the typing process. This tiered layout reduces complexity and enhances navigation ease.

- **Dual Message Sending Options** - Typed messages can be sent as SMS or voice calls via Twilio, with buttons aligned side by side. The Flask /api/send-message route processes both, delivering to a predefined phone number. Notifications confirm success or errors, keeping users informed.

- **Predictive Text Assistance** : Four word suggestions display based on the last typed word, using a predefined phrase list. These options, clickable for selection, speed up message creation for common needs. Random words appear if no matches are found, ensuring continuous support.

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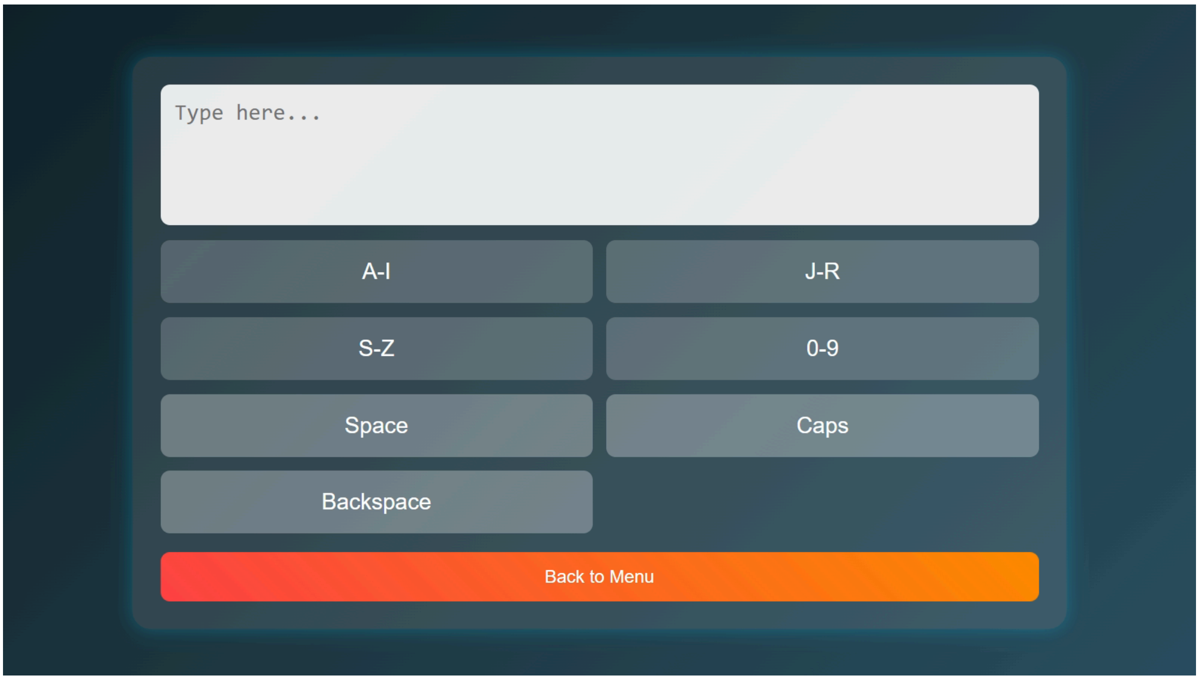
Predictive Keyboard Module

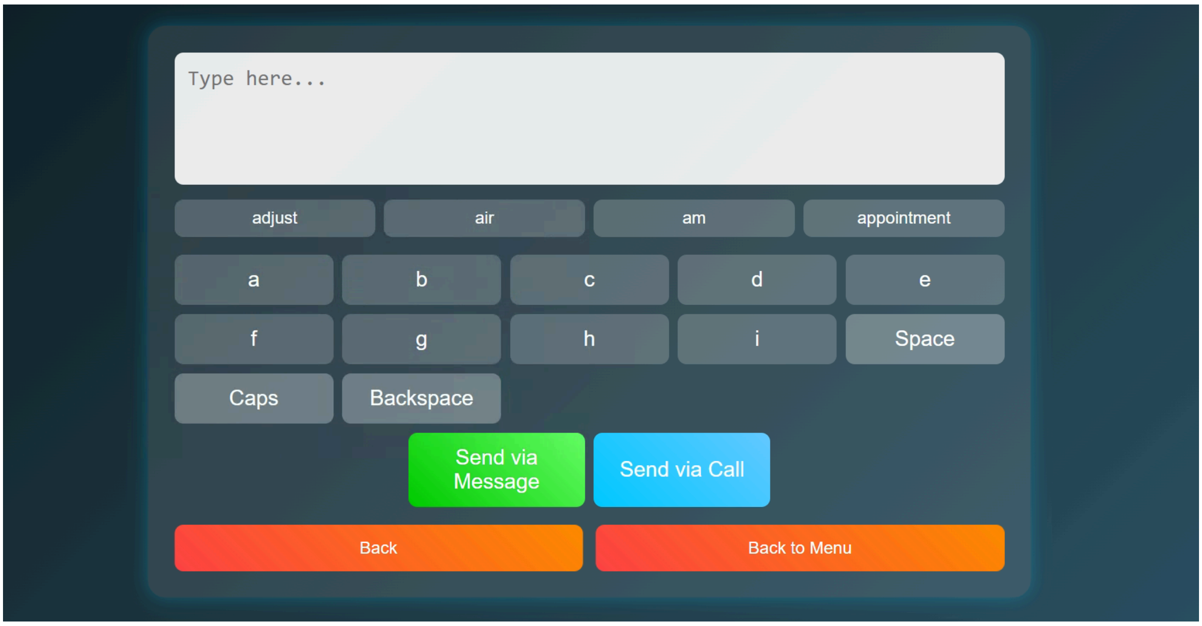
- **Caps Lock and Editing Tools -** Caps Lock toggles case across all keyboard levels, maintaining consistent text input. Backspace deletes characters and updates predictive text, aiding error correction. These features, always accessible, provide essential editing capabilities.

- **Responsive and User-Friendly Design** - Large, high-contrast buttons in a grid layout optimize visibility and interaction simplicity. The design adjusts to a 3-column layout on smaller screens for broad usability. "Back" and "Back to Menu" buttons offer clear, styled navigation options.

OUTPUT 1



OUTPUT 2



Home Automation Control Module

Step 1: Sign Up for IFTTT

- Sign up for an IFTTT account to enable triggering smart home actions.

Step 2: Create IFTTT Applets

- Create two applets in IFTTT: one for turning the bulb on (turn_on) and one for turning it off (turn_off).

Step 3: Set Up the Trigger (Webhooks)

- Use IFTTT's Webhooks service to set triggers for HTTP requests. Name the events turn_on and turn_off. Obtain the Webhooks key for use in the Flask app.

Home Automation Control Module

Step 4: Set Up the Action (Tapo)

- In the “Then That” section, select the Tapo service. Set the action to turn on the Tapo L530B bulb for the turn_on applet and turn off for the turn_off applet.

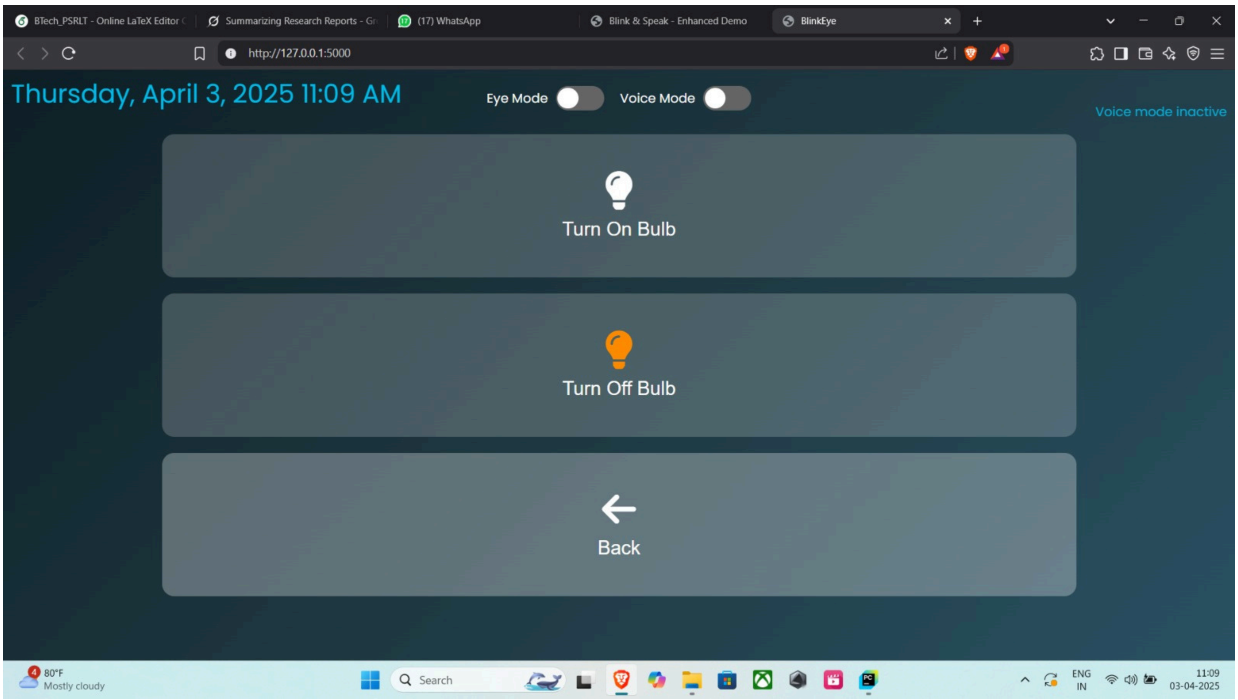
Step 5: Send the HTTP Request from Your Web Application

- Use the IFTTT Webhook URLs in your Flask app to send HTTP POST requests when the user interacts via Eye Mode (gaze) or Voice Mode (commands), triggering the applets.

Step 6: Tapo Executes the Action

- IFTTT receives the HTTP request, triggers the applet, and sends the command to Tapo, which turns the Tapo L530B bulb on or off.

Output



Speech Recognition Module

Initial Approach – Facebook Wav2Vec 2.0:

- Learns speech features directly from raw audio without the need for labeled data.
- Uses a Transformer-based architecture to capture long-range dependencies.
- Performs well even in low-resource and noisy environments.

Output

```
Press '1' to start recording, '0' to stop recording, and 'q' to quit.
Enter command: 1
Recording. Press '0' to stop.
Enter '0' to stop recording: 0
Recording stopped.
Transcription: HALLO HOW CAN I HELP YOU
Corrected Transcription: HALLO HOW CAN I HELP YOU
Enter command: q
Exiting program.
PS C:\PROJECT 30%>
```

Speech Recognition Module

Final Implementation – Google Speech Recognition API

- Cloud-based system that converts spoken language to text with high accuracy.
- Performs feature extraction to identify key characteristics like phonemes and pitch.
- Maps extracted features to words using pre-trained language models.
- Supports real-time audio processing for instant transcription.

Speech Recognition Module

1.Audio Capture

- The system captures audio through a microphone.
- Ambient noise is filtered to minimize interference and enhance recognition accuracy.

2.Speech Recognition

- The captured audio is analyzed and processed to detect speech.
- The audio data is converted into text by sending it to a cloud-based speech recognition service.

Speech Recognition Module

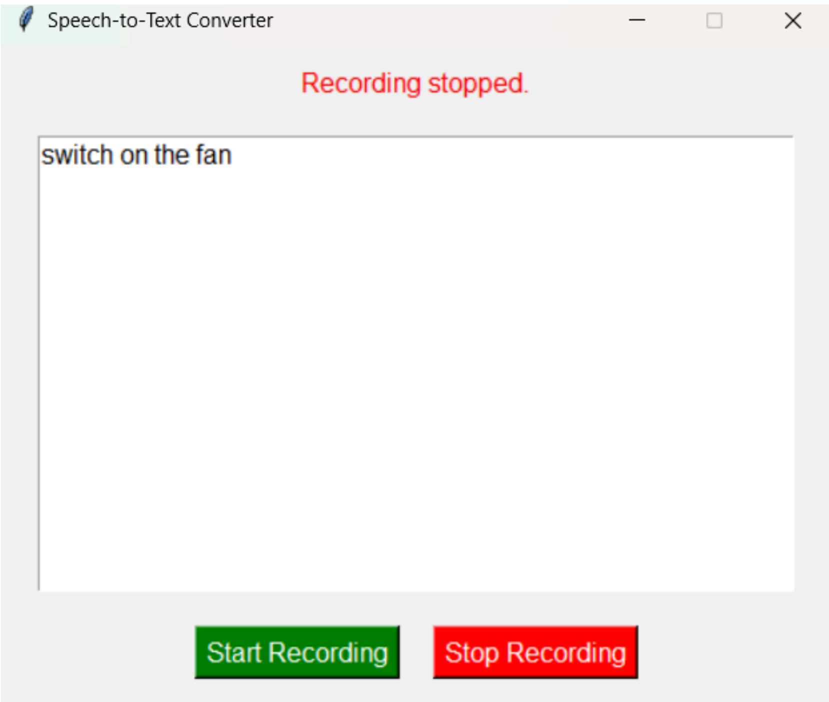
3.Cloud-Based Speech Recognition

- The audio is processed on remote servers, where:
  - Feature Extraction: Key characteristics of the audio, such as phonemes, pitch, and intonation, are identified.
  - Model Matching: These features are compared with a pre-trained language model to interpret spoken words.
  - Text Output: The recognized speech is returned as text

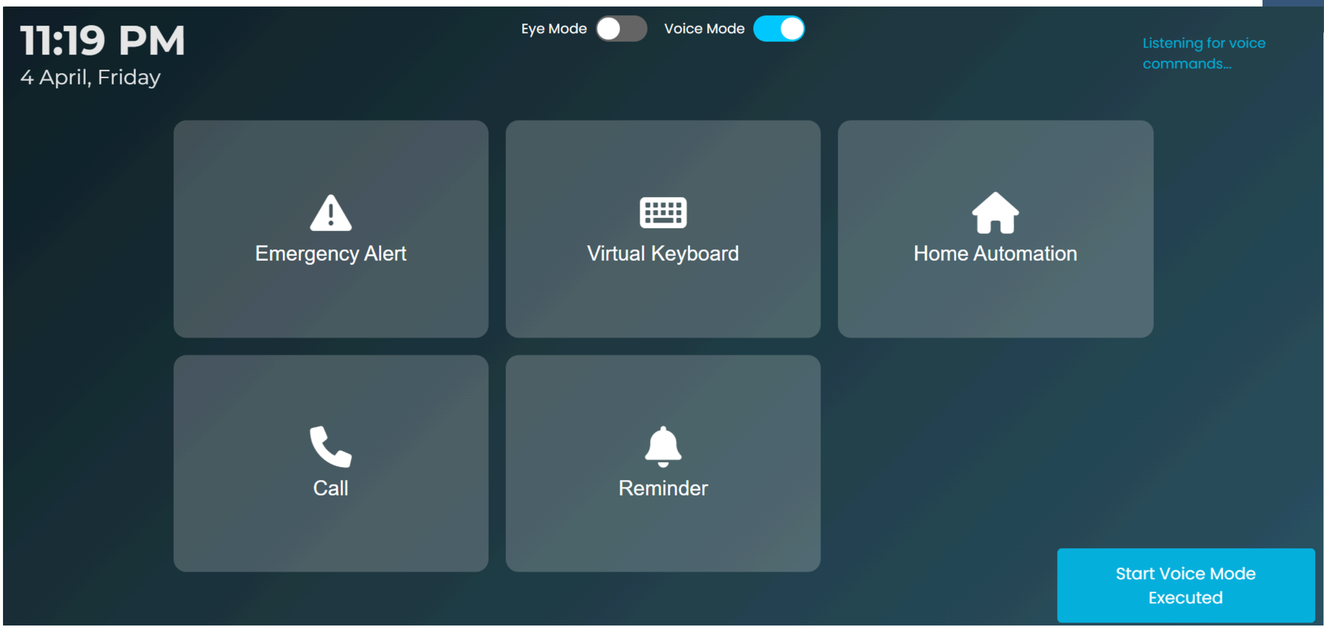
4.Real-Time Updates

- The system displays the converted text in real time, allowing users to view their speech as it is transcribed

Output



Output



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Communication Module

Twilio platform is used as communication platform

1. Collect Emergency Contacts.
2. Add Triggers for respective buttons in UI:

- Reminder : Sents reminder on scheduled date and time
- Call : Patient can select option regarding bathroom, food, water
- Emergency : Sends help message to immediate contacts

3. Feedback to user:
    - Displays, a “sent successfully message” when sent without any exception

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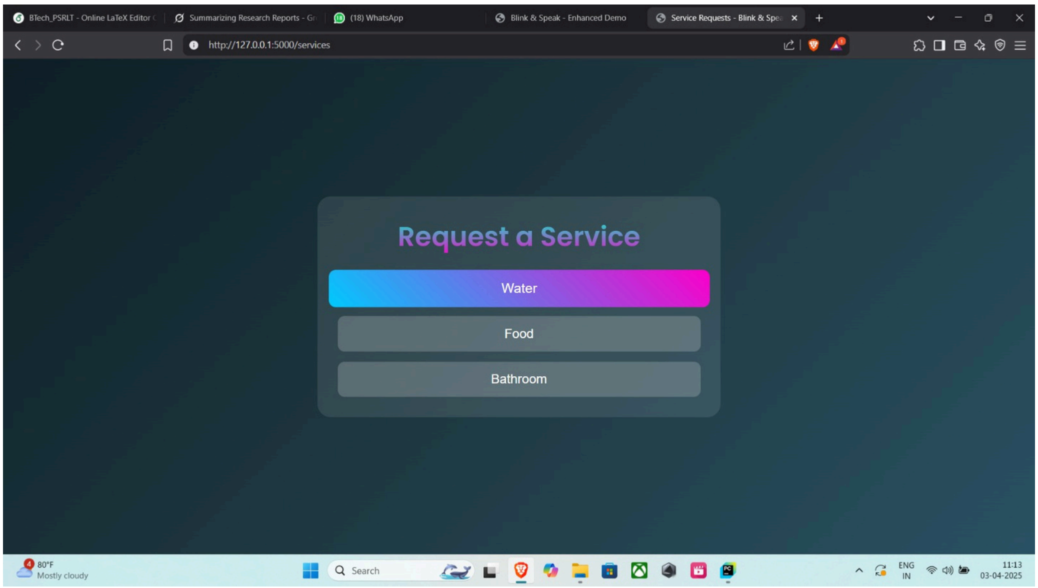
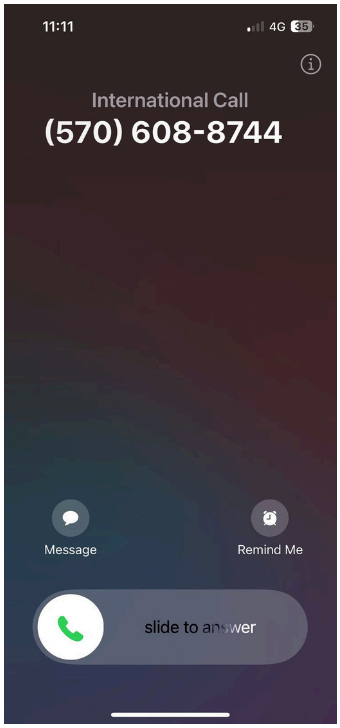
Output 1





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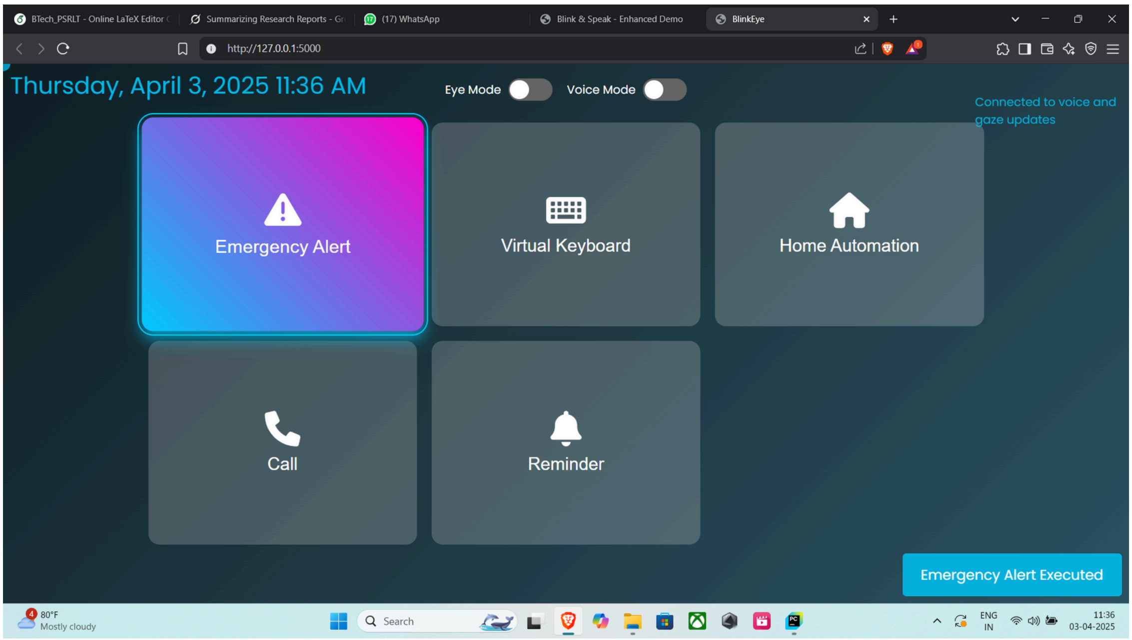
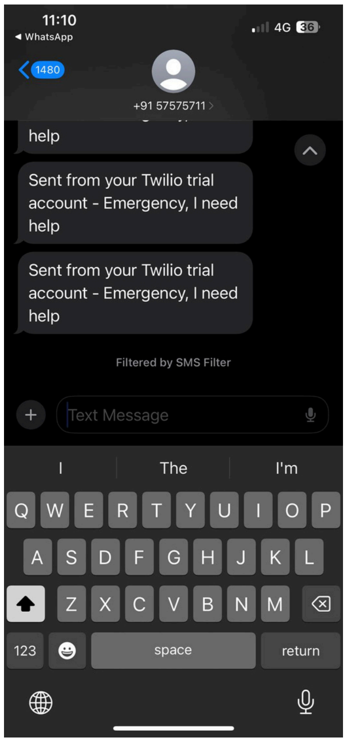
Output 2





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Assumptions

1. **Patient Capability:**
   - Patients have some degree of control over their eye movements.
   - Patients can vocalize basic sounds or words for voice recognition, even if they have speech impairments.

2.Environment Setup:

- A stable camera can be mounted in front of or above the patient, providing a clear view of their eyes.
- The lighting in the patient's environment is sufficient for accurate eye tracking (adequate for the camera to capture eye movements clearly).

3.User Interface:

- Patients will be able to navigate the interface intuitively after minimal training.

Assumptions

4.Hardware Requirements:

- The device (tablet or computer) will have sufficient processing power to handle real-time gaze tracking and voice recognition simultaneously.

5.Network and Connectivity:

- For features like emergency alerts,calls, reliable internet connectivity will be available.

Work Breakdown

1. **Graphical User Interface (Denik Denny, Jovin Jacob Jestin)**
   - GUI Development
   - User Interaction flow
2. **Gaze Control System (Ebin Jose, Melvin Jiju Mathew)**
   - Develop gaze tracking using MediaPipe.
   - System integration of gaze tracking.
3. **Voice Recognition (Denik)**
   - Implement voice recognition for commands.
   - Integrate voice commands with system functions.
4. **Virtual Keyboard (Jovin)**
   - Develop the on-screen virtual keyboard and user feedback features.
   - Optimize the keyboard using frequently used words
5. **System Integration and Communication (Ebin Jose)**
   - Ensure Seamless communication between modules
6. **Home Automation(Melvin Jiju Mathew)**
   - IFTTT and Twilio integration into system

Hardware And Software Requirements

Hardware (Prototype & Future Implementation)

Prototype Implementation (Current System)

- The project is currently a software prototype, demonstrated using a laptop's built-in camera and screen.
- All necessary features, including gaze tracking, voice commands, and automation, are tested using a laptop setup to reduce hardware costs.

Hardware And Software Requirements

Hardware (Prototype & Future Implementation)

Future Full System Implementation

- High-Resolution Camera: 1920 x 1080, minimum 30fps for precise eye tracking
- Display Screen: Minimum 15-inch touchscreen for a dedicated assistive interface
- Processor: Quad-core or higher for efficient real-time processing
- RAM: Minimum 16 GB to support smooth gaze tracking and automation
- Adjustable Arm: A flexible stand to position the camera and screen at an optimal angle

Hardware And Software Requirements

Software Used (Prototype Version)

- OS: Windows
- OpenCV: Captures and processes webcam frames for gaze tracking
- MediaPipe: Detects eye gaze and facial landmarks in real time
- Google Speech Recognition API: Processes spoken commands for system control
- IFTTT: Enables automation of smart home devices for improved accessibility

Budget

Budget – Software Prototype

Current Setup:

- Implemented as a software prototype on a laptop
- Uses laptop camera for eye tracking instead of an external camera
- Smart home automation tested with basic smart bulb

Budget

Future System Components

Component	Estimated Cost (₹)
High-Resolution Camera (Eye Tracking)	2,000 - 6,000
Adjustable Mount	1,200
Tablet (Processing Unit)	10,000 - 24,000
Smart Home Integration (IFTTT, Twilio API)	1,000 - 2,500 per year

Risk and Challenges

1. **Technical Challenges:**
    - Accuracy of gaze tracking under varying conditions.
    - Limitations in voice recognition for patients with speech impairments.

2.Hardware Dependence:
- Quality of hardware affecting tracking accuracy.
- Logistical challenges in camera and tablet mounting.

Risk and Challenges

3.Integration Issues:
- Challenges in combining gaze tracking, voice recognition, and UI.
- Risk of software bugs disrupting functionality.

4.User Adoption:
- Potential learning curve for patients.
- Designing an intuitive user interface that meets patient needs.

Expected Outcomes

1. **Enhanced Interaction**: Enable effective interaction for paralyzed patients through gaze tracking and voice recognition.
2. **Improved Quality of Life**: Increase patient independence and control over their environment.
3. **User-Friendly Interface**: Develop an intuitive interface tailored to patient needs.
4. **Real-Time Interaction**: Allow quick navigation and command execution with minimal delay.
5. **Emergency Communication**: Implement features for patients to easily alert caregivers or contacts.

Conclusion

- Accessible Control: BlinkEye enables paralyzed patients to interact with digital interfaces using eye movements and blinks, providing an intuitive and accessible control system.
- Accurate Tracking: Leveraging MediaPipe's real-time eye-tracking with a calibration process ensures precise mapping of gaze and blinks for accurate input.
- Comprehensive Assistance: With features like emergency alerts, smart keyboard, and home automation, BlinkEye offers a complete, customizable solution for daily assistance and communication.

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Appendix B: Vision, Mission, Programme Outcomes and Course Outcomes

Appendix B

Vision: To become a Centre of Excellence in Computer Science & Engineering, moulding professionals catering to the research and professional needs of national and international organizations.

Mission: To inspire and nurture students, with up-to-date knowledge in Computer Science & Engineering, Ethics, Team Spirit, Leadership Abilities, Innovation and Creativity to come out with solutions meeting the societal needs.

Program Outcomes:

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes:

PSO1: Computer Science Specific Skills: The ability to identify, analyze and design solutions for complex engineering problems in multidisciplinary areas by understanding the core principles and concepts of computer science and thereby engage in national grand challenges.

PSO2: Programming and Software Development Skills: The ability to acquire programming efficiency by designing algorithms and applying standard practices in software project development to deliver quality software products meeting the demands of the industry.

PSO3: Professional Skills: The ability to apply the fundamentals of computer science in competitive research and to develop innovative products to meet the societal needs thereby evolving as an eminent researcher and entrepreneur.

Course Outcomes

CO1: Model and solve real world problems by applying knowledge across domains.

CO2: Develop products, processes, or technologies for sustainable and socially relevant applications.

CO3: Function effectively as an individual and as a leader in diverse teams and to comprehend and execute designated tasks.

CO4: Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms.

CO5: Identify technology/research gaps and propose innovative/creative solutions.

CO6: Organize and communicate technical and scientific findings effectively in written and oral forms.

Appendix C: CO-PO-PSO Mapping

Appendix C

CO-PO AND CO-PSO MAPPING

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO 1	2	2	2	1	2	2	2	1	1	1	1	2	3		
CO 2	2	2	2		1	3	3	1	1		1	1		2	
CO 3									3	2	2	1			3
CO 4					2			3	2	2	3	2			3
CO 5	2	3	3	1	2							1	3		
CO 6					2			2	2	3	1	1			3

3/2/1: high/medium/low