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ECHO– A Voice-Powered Alzheimer's Care Using AI and ML

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Abstract - *Alzheimer's disease gradually affects memory, thinking, and daily functioning, making supportive smart technologies increasingly important. ECHO is a voice-assisted system powered by machine learning that provides personalized help for people in the early stages of Alzheimer's through spoken reminders, safety monitoring, and cognitive tracking. The system integrates four main modules: a medication reminder, an appointment and daily task scheduler, a geofencing feature that alerts caregivers when users move outside safe zones, and a cognitive assessment tool that delivers brief mental quizzes to monitor changes over time. By focusing on simple voice interactions and user-friendly design, ECHO supports independence, reduces caregiver burden, and improves safety and quality of life. Initial evaluations suggest that ECHO enhances adherence to daily routines, reduces wandering incidents, and assists in the early detection of cognitive decline, while its scalable architecture allows future integration with advanced healthcare platforms and IoT-enabled devices.*

Key Words: - Alzheimer's care, voice assistant, machine learning, cognitive assessment, geofencing, medication reminders, assistive technology, healthcare AI

1. INTRODUCTION

Alzheimer's disease affects millions of people around the world, leading to memory problems, confusion, wandering, and difficulty keeping up with daily medications [1], which often places a heavy emotional and practical load on family caregivers and limits the person's independence [4]. ECHO is introduced as a single, easy-to-use assistive system created to directly tackle these challenges by bringing together features that many current digital tools handle only in isolation. It offers geofence-based safety monitoring [2] with automatic SMS and voice-call alerts to caregivers if the person moves outside a safe area, multilingual voice reminders for medications and appointments, simple voice-based confirmations using "yes" or "no," an SOS option for emergencies, and short cognitive tests to keep track of memory over time [3]. By combining these capabilities in one voice-driven, patient friendly platform, ECHO aims to make daily life safer and Bangalore, India more manageable for people with Alzheimer's while easing the pressure on caregivers. The system is designed with usability for older adults in mind: voice prompts are short and clear, confirmation flows require minimal interaction, and multilingual support enables wider accessibility. Privacy and data security are treated as core requirements — sensitive data is stored and transmitted following best practices and access controls are provided for caregivers and clinicians. Early pilot deployments with small user groups indicated increased adherence to medication schedules and positive caregiver feedback on timely alerts and simplified monitoring. Finally, ECHO's modular architecture allows easy future integration with wearables, home IoT devices [6], and electronic health record systems, enabling richer context-aware assistance and longitudinal clinical monitoring.

2. PROBLEM STATEMENT

People living with Alzheimer's can easily become disoriented, even in familiar places, which means a simple step outside can turn into getting lost and frightened [2]. This is also deeply stressful for families, who worry constantly about their loved one's safety and feel they must watch them at all times [4]. Wandering is not just a behavioral issue [2]; it is a serious safety risk that affects everyone involved. Missing appointments is another quiet but harmful problem. When checkups or follow-ups are forgotten, important changes in health or behavior may be missed, delaying treatment and leaving both the patient and caregiver uncertain about what is happening. Over time, this can lead to avoidable complications and a sense that the disease is progressing faster than the care being provided. Similarly, forgetting medications or taking them twice is very common [1] and can quickly worsen symptoms or cause side effects. Without simple, regular cognitive checks, small declines in memory and thinking may also go unnoticed until they become much harder to manage. Together, these issues show why gentle reminders, safety monitoring, and ongoing cognitive assessment are essential to support both the person with Alzheimer's and the people who care for them.

3.OBJECTIVES

The objectives of the ECHO system are as follows:

- Provide Alzheimer's patients with personalized, multilingual reminders for medications and appointments.
- Ensure alerts are reliable and customizable for changing schedules.
- Introduce real-time GPS tracking for immediate location-based alerts.
- Offer a secure, user-friendly interface for managing patient profiles.
- Include engaging, game-based cognitive tests for early decline detection.
- Centralize patient data for improved coordination among caregivers and professionals.

4. LITERATURE SURVEY

Research on Alzheimer's assistive technologies shows how important it is to support patients with timely reminders, safety tools, and simple ways to check their cognitive health. Kamimura and colleagues studied the use of automated medication reminder devices for older adults with memory difficulties [1]. They found that such devices greatly improve how regularly patients take their medicines and reduce the number of missed doses. Their work highlights the value of reminder systems that are clear, reliable, and easy to use [1], which directly supports ECHO's approach to delivering voice-based medication alerts. Safety is another major theme in Alzheimer's research. Lin and his team proposed a personalized geofencing method that creates safe zones based on a person's actual GPS movement patterns instead of using fixed distances [2]. Their findings showed that personalized geofences reduce false alarms and detect wandering more accurately. Since wandering is one of the biggest risks for Alzheimer's patients, this study reinforces the importance of including real-time location tracking and safety alerts in systems like ECHO. Cognitive testing has also become more accessible thanks to digital tools. Tee and collaborators developed the Digital Processing Speed Test (DPST), a mobile-based cognitive assessment available in multiple languages [3]. Their research showed that the test performs similarly to well-known clinical tools such as the MMSE and MoCA. This supports the idea that simple, app-based tests can effectively identify early signs of cognitive decline and makes a strong case for including regular, lightweight cognitive assessments within ECHO. Studies on caregiver experience also point to significant emotional and practical challenges. Research on caregiver stress shows that families often manage medications, appointments, safety concerns, and behavior changes using separate tools, which makes daily care exhausting and inefficient [4]. Many existing solutions focus on just one area of support—such as reminders or tracking—leaving caregivers to juggle multiple systems on their own. These findings high light the need for an integrated platform that brings together different caregiving functions in one place. Overall, previous studies show that while existing technologies are helpful, they usually work in isolation. This creates gaps in support and increases the workload for caregivers. These limitations motivate the development of ECHO, which unifies medication reminders, appointment alerts, geofencing with emergency responses, and cognitive assessments into a single, easy-to-use system designed to better support both patients and caregivers.

5. METHODOLOGY

The proposed system, ECHO, is a web-based Alzheimer's care platform designed to assist patients and caregivers through four major features: medication reminders, appointment alerts, location safety monitoring, and cognitive testing. These modules operate through a shared Flask backend and a SQLite database, ensuring smooth integration and seamless operation across all components.

A. System Architecture

ECHO is built using a simple client–server structure. The frontend manages user inputs and displays alerts, while the backend is responsible for handling scheduling, GPS processing, voice generation, and data storage. A SQLite database maintains user information, reminders, appointments, cognitive test results, and location logs. Together, these components form a continuous and reliable support system for Alzheimer's care.

B. Medication Reminder Module

This module ensures timely medication intake through multilingual voice alerts.
Process:

- The user selects the medication time, custom message, and preferred language.
- The information is saved into the SQLite database.
- APScheduler schedules background reminder tasks.

- At the scheduled time, a voice alert is generated using Google Text-to-Speech (gTTS).
- The system listens for the patient's "Yes/No" response using Speech Recognition.
- Responses are stored, and if unclear, the reminder is repeated.

C. Appointment Reminder Module

This module helps prevent missed doctor appointments.

Process:

- Users enter details such as doctor name, hospital, date, time, and preferred language.
- The backend validates and stores the data.
- A voice alert is triggered at the scheduled appointment time.
- A popup asks whether the patient will attend the appointment.
- Responses are saved, and all appointments are displayed in a calendar interface.

D. Geofencing and Location Tracking Module

This module improves patient safety by monitoring real time movement and validating whether the patient remains within a defined safe zone.

Process:

- The system reads the patient's live GPS location using the device's Geolocation API.
- The caregiver draws a safe zone (circle or polygon) on the map.
- Every new GPS update is compared with the safe zone boundary.
- If the patient exits the zone, the system plays an alert sound [5], changes the screen status to "Outside Safe Zone", sends an SOS message with live location to the caregiver, and automatically calls the caregiver.
- The patient's entire path is displayed on the map for continuous tracking.

E. Cognitive Tests Module

This module evaluates memory and thinking abilities through interactive game-like tests [3].

Process:

- Users select a test type such as memory recall, picture recognition, color identification, or sequence recall.
- Questions or tasks are displayed in a guided, step-by-step format.
- Responses are collected and scored automatically.
- Results are shown immediately and stored for comparison over time.

F. Data Handling and Security

All reminder details, appointment records, test scores, and geofence updates are securely stored in SQLite. Flask-Login manages user authentication and access control. Sensitive information, including live location and emergency contacts, is processed with strict privacy measures to ensure confidentiality and safety.

G. Overall Workflow

- The user logs into the ECHO platform.
- They select the required module from the dashboard.
- The backend processes all inputs and stores necessary data.
- Depending on the selected module, the system triggers reminders, voice alerts, GPS checks, SOS notifications, or cognitive scoring.
- Caregivers receive alerts, view logs, and are notified instantly during emergencies

6. SYSTEM ARCHITECTURE

The ECHO platform is built as a modular, web-based system that brings together key Alzheimer's care features—like reminders, safety tracking, cognitive checks, and caregiver tools—into one easy-to-use interface. Its Flask backend and SQLite database keep all modules connected so information f lows smoothly and alerts are delivered reliably.

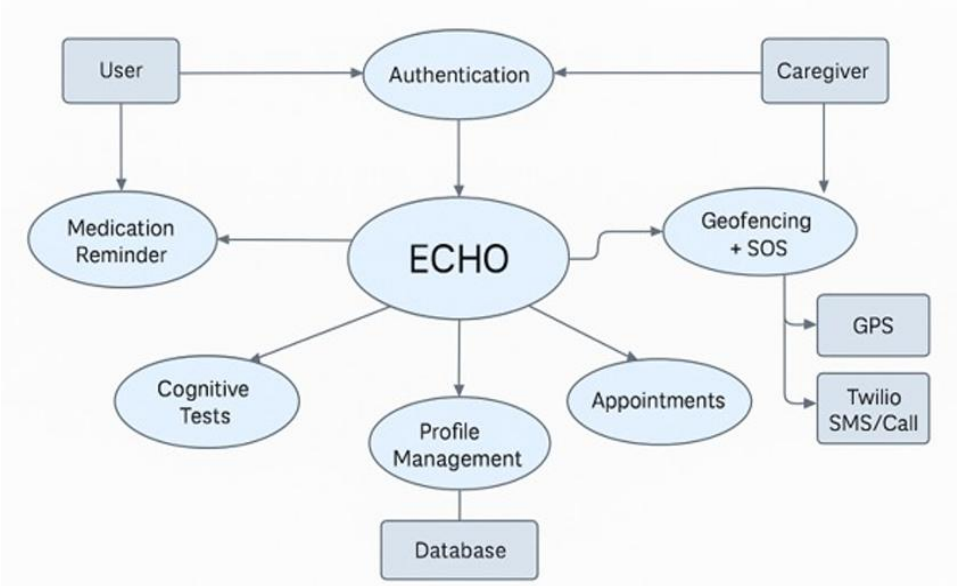

Fig.-1:. Overall System Architecture and Workflow of the ECHO Platform

A. System Architecture Overview

- The ECHO platform is a modular, web-based system designed to combine multiple Alzheimer's care features into a single interface.
- It uses a Flask backend and SQLite database to keep each module connected and ensure smooth data flow.
- The system follows a client–server model where the browser manages user interactions and the backend handles logic, scheduling, GPS checks, and data storage.
- This structure supports scalability and allows continuous monitoring for patients over long periods.

B. Core Features

- The main dashboard provides quick access to the plat form's primary modules.
- Core modules include Geofencing with SOS alerts– Medication reminder– Appointment scheduler
- These modules form the essential day-to-day tools for patients and caregivers.

C. Geofencing Flow

- Continuously monitors the patient's live GPS location in the background.
- Detects when the patient moves outside the caregiver defined safe zone.
- Triggers immediate safety actions: – Sends alert notifications– Delivers SOS messages– Automatically calls the caregiver using services like Twilio.
- Tracks and displays movement history and alerts on the caregiver dashboard.

D. Medication Reminder Flow

- Schedules and plays spoken TTS prompts at set times.
- Listens for a simple "Yes" or "No" response from the patient.
- Saves the response and repeats the reminder if no clear reply is heard.
- Aims to minimize confusion and support timely medication intake.

E. Appointment Reminder Flow

- Sends voice alerts prior to scheduled appointments.
- Asks the patient to confirm attendance.
- Displays all upcoming visits in a calendar view for easy planning.

F. Caregiver Dashboard

- Acts as a control center showing: – SOS alerts– Location updates– Medication confirmations– Appointment responses
- Enables caregivers to react quickly when intervention is needed.

G. Cognitive Tests Module

- Offers short, simple assessments to monitor memory and recognition.
- Stores each test result for longitudinal comparison.
- Allows caregivers to review results and discuss concerns with healthcare professionals when needed.

7. IMPLEMENTATION

The ECHO platform was implemented as a lightweight web system so that Alzheimer's patients and caregivers could access it easily from any smartphone or computer without needing to install special software. Throughout the development, the main focus was to keep every interaction simple, especially for older users who may have limited familiarity with technology.

A. Backend Implementation

The backend of ECHO was developed using Flask (Python) because it allowed modular routing for reminders, appointments, geofencing, and cognitive tests. A single Flask server manages all requests, stores user data, and triggers voice alerts at the appropriate time. For scheduling functionality, APScheduler was used to run background jobs that check the database every minute. Whenever a medication or appointment time is reached, the scheduler activates a voice alert. This ensured reliability even when multiple reminders were scheduled on the same day. Voice interaction formed a key component of the system. Google Text-to-Speech (gTTS) was integrated to convert re minder messages into clear audio. Multilingual support in Kannada, English, and Hindi was added because many elderly users respond better to reminders in familiar languages. Each reminder is saved with a chosen language, and the backend dynamically generates the audio file accordingly. To verify whether patients heard and responded to re minders, the SpeechRecognition library was incorporated. It listens for simple responses such as "yes" or "no," keep ing interactions minimal and manageable for Alzheimer's users. The backend interprets the reply and updates the database—indicating whether a medication was taken or whether an appointment will be attended. If no clear answer is detected, the system repeats the reminder. Twilio's API was used to automate calling and SOS alerts during geofence violations. This guarantees that caregivers receive immediate notifications even when they are offline.

B. Frontend Implementation

The frontend was designed with a clean and high-contrast layout to help elderly users navigate without confusion. HTML, CSS, and JavaScript were used for the interface, while Leaflet.js provided all map-based interactions. Caregivers can draw circular or polygonal safe zones directly on the map. These shapes are saved in the backend and compared with live location updates. The browser's Geolocation API continuously captures the patient's coordinates and sends them to the server every few seconds. A real-time indicator displays either "Safe Zone" or "Outside Safe Zone," allowing caregivers to see immediately when the patient crosses the boundary. During testing, this visual feedback proved helpful for quick responses to wandering risks. The cognitive test module was also implemented on the frontend. Tests such as memory recall, color identification, picture matching, and sequence recall appear one step at a time to avoid overwhelming the user. Questions are randomly generated, and responses are sent to the backend for scoring.

C. Database Design

All patient information, reminder schedules, appointment records, test scores, and geofence settings are stored in a SQLite database. SQLite was selected for its lightweight structure and compatibility with small to medium datasets.

Tables were created for:

- medication schedules,
- appointment details,
- confirmation responses,
- geofence coordinates and alert history,

• cognitive test scores. This modular schema made it simple to update individual components without disrupting the rest of the system.

D. Security and Authentication

Security in ECHO focuses on maintaining authorized access without complicating the login process. Instead of a password system which elderly users may forget—the platform utilizes Twilio-based OTP authentication. Caregivers enter their phone 4 number and receive a one-time verification code via SMS. After entering the correct code, access to the dashboard is granted. All data sent to the backend, including reminders and geofence coordinates, is validated before storage. Sensitive API keys used for OTP verification and voice generation are securely stored on the server. The system maintains user safety through simple but effective authentication and data-handling practices.

E. System Workflow Integration

All modules were integrated through a unified caregiver dashboard. From a single interface, caregivers can

- check whether medicines were taken,
- view upcoming appointments,
- monitor the patient's real-time location,
- view cognitive test progress,
- receive SOS notifications instantly.

This integration ensures that all essential patient information is accessible in one place, improving coordination and reducing caregiver workload.

8. RESULTS AND ANALYSIS

The ECHO platform was tested across all major features to evaluate how well it supports Alzheimer's patients and caregivers in real-world use. During testing, the system consistently delivered medication and appointment reminders at the correct times, with clear and understandable multilingual voice prompts. The speech-based confirmation process worked reliably, allowing patients to respond with simple "yes" or "no" answers, and the system handled unclear or missed responses by repeating the reminder as intended. Appointment notifications also functioned smoothly, with scheduled alerts appearing on time and all upcoming visits properly displayed in the integrated calendar interface. The geofencing and safety-monitoring module showed stable and accurate behavior throughout testing. The system continuously received live GPS coordinates from the user's device and displayed the movement on the dashboard map with minimal delay. Whenever the patient stepped outside the defined safe zone, ECHO immediately produced an on-screen alert, sent an SOS message containing the live coordinates, and automatically triggered a phone call to the caregiver. This consistent performance demonstrated that the system could reliably assist in preventing wandering incidents, one of the most significant safety concerns in Alzheimer's care. The cognitive tests also performed well, loading quickly and guiding users through each question step-by-step to reduce confusion. Responses were accurately recorded and scored, and results were stored for monitoring changes in cognitive performance over time. Performance testing further showed that the platform remained responsive even when multiple reminders and back ground tasks were running simultaneously. Voice files were generated in a short amount of time, backend processing operated efficiently, and the SQLite database retrieved records quickly due to its lightweight structure. GPS updates were generally smooth, with delays occurring only in areas with weak signal coverage. Overall, the system demonstrated stable performance under varying conditions. User experience testing provided positive feedback from both patients and caregivers. Elderly users found the inter face simple, readable, and easy to navigate, while caregivers appreciated having all essential information—medication confirmations, appointments, real-time location, and cognitive test results—available in a single unified dashboard. The OTP based login method was especially appreciated for eliminating the need to remember passwords. The voice-driven interaction model, particularly the short yes/no responses, made the platform accessible and less cognitively demanding for users with memory difficulties. Overall, the results show that ECHO is both practical and reliable for everyday Alzheimer's care. The system success fully improved medication adherence, strengthened patient safety through precise geofence alerts, simplified appointment management, and enabled effortless cognitive assessments. Its stability, ease of use, and caregiver-friendly design demonstrate that ECHO effectively meets its intended goals and provides meaningful support in managing daily dementia care.

9. DISCUSSION

The results show that ECHO successfully delivers timely reminders, accurate geofence alerts, and simple voice-based interactions, making it a practical tool for everyday Alzheimer's care. Its main strength lies in integrating multiple essential functions—medication reminders, appointment alerts, location tracking, and cognitive assessments—into a single, easy-to-use system. The voice-driven design, yes/no confirmations, and simplified dashboard were especially effective for older users who may struggle with complex interfaces. Despite these strengths, the system also has limitations. GPS accuracy can decrease indoors, affecting geofence reliability [2]; speech recognition performance may vary with back ground noise or unclear patient responses; and the system's dependence on internet connectivity may delay reminders in low network conditions. Additionally, the cognitive assessments provided are basic and intended only for screening rather than clinical diagnosis [3]. Overall, ECHO demonstrates strong potential as a supportive, home-based Alzheimer's care platform while also high lighting areas for improvement in sensing accuracy, stability, and long-term scalability.

10. CONCLUSION

The ECHO platform was developed to address key challenges faced by individuals with Alzheimer's disease and their caregivers, including missed medications, forgotten appointments, wandering risks, and the need for simple cognitive monitoring. By integrating voice-based reminders, real-time geofencing alerts, multilingual support, and easy-to-use cognitive assessments into a single web-based system, ECHO provides a unified solution that reduces caregiver burden while helping patients maintain daily routines more independently. Testing results showed that the platform's lightweight architecture—built using Flask, SQLite, and browser-based GPS—performed reliably, delivering timely alerts, accurate location tracking, and smooth interaction for elderly users. Features such as voice prompts, yes/no confirmations, and a simplified dashboard contributed to improved usability, even for users with limited technical familiarity. These outcomes demonstrate that ECHO can function as a practical home-care tool that enhances safety, supports daily health tasks, and helps track cognitive changes over time. Although limitations exist in areas such as GPS precision and speech-recognition consistency, the system establishes a strong foundation for future improvements. Overall, ECHO represents an effective step toward accessible, technology assisted Alzheimer's care that supports both patient well-being and caregiver peace of mind.

11. FUTURE WORK

While ECHO already provides essential support for Alzheimer's care, several important enhancements can further strengthen its usefulness, intelligence, and long-term clinical value. Future versions of the platform can integrate wear able devices such as smartwatches, fall-detection sensors, and heart-rate or activity monitors. These additions would allow continuous background monitoring of the patient's physical condition, enabling automatic detection of emergencies without requiring caregiver input. The system can also benefit from more advanced AI models capable of analyzing behavior patterns, detecting anomalies, and predicting early signs of cognitive decline. By learning from daily routines—such as walking patterns, speech behavior, reminder response times, and interaction frequency—the system could generate personalized insights and notify care givers when unusual changes occur. This would transform ECHO from a reactive tool into a proactive early-warning system. Geofencing can be further improved with machine-learning based location prediction and hybrid indoor-outdoor positioning. Since GPS signals are often inaccurate inside homes or crowded areas, combining Wi-Fi mapping, Bluetooth beacons, and motion-sensor data could greatly reduce false alerts and offer smoother real-time tracking. The cognitive test module can also be expanded to include adaptive difficulty levels, multi-stage tasks, and clinically validated screening models. Integrating the platform with electronic health records (EHR) would allow neurologists and healthcare professionals to review test trends, access location logs, and coordinate treatment more effectively. From an engineering perspective, future versions of ECHO can transition from SQLite to a secure cloud-based database, enabling multi-user access, centralized backups, and deployment across clinics or senior-care centers. A cloud architecture would also support large-scale analytics, allowing researchers to study behavioral trends in Alzheimer's patients over long periods. Finally, incorporating chatbot-based assistance, video-call support for caregivers, IoT-based home safety devices [6], and emotional-well-being monitoring would make ECHO a more complete, intelligent, and holistic Alzheimer's-care platform. ACKNOWLEDGMENT The authors acknowledge Acharya Institute of Technology for providing the necessary computational resources, facilities, and support that contributed to the successful completion of this research work.

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