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AI-Enhanced Mobile Health Platform for Alzheimer's Caregiver Support

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***Abstract*—This research introduces an AI-enhanced mobile health platform addressing Alzheimer's disease care challenges through cognitive decline monitoring, medication adherence, and daily activity supervision. The system integrates dual Android applications supported by Firebase cloud infrastructure for patient-caregiver synchronization. Core technologies include Google Gemini AI for conversational interaction, TensorFlow Lite for face recognition, YOLOv9 for object detection, and geofencing-based safety tracking. The platform employs machine learning for memory extraction, proactive question generation, and personalized reminiscence therapy. Key features include AI-driven medication reminders with fullscreen alarms, cross-device caregiver notifications, and real-time monitoring through background services. Preliminary results demonstrate 99.2% medication reminder accuracy, 96.8% geofence detection accuracy, and 97.7% system uptime, establishing the platform as a comprehensive digital therapeutic solution bridging clinical care and everyday living support for Alzheimer's patients.**

***Index Terms*—Alzheimer's disease, mobile health, artificial intelligence, digital therapeutics, caregiver support, cognitive assessment, Firebase, Android development**

I. Introduction

Alzheimer's disease (AD) affects nearly 50 million individuals worldwide, projected to reach 152 million by 2050 [1]. As the most common form of dementia, AD progressively deteriorates cognitive functions, placing immense burdens on patients and caregivers [2]. Patients face medication non-adherence, memory loss, spatial disorientation, and reduced social interaction, while caregivers experience substantial stress and financial strain [3]. Conventional methods rely on manual tracking and fragmented communication, hindering real-time monitoring and delaying interventions.

Current mHealth technologies remain fragmented, lacking real-time patient-caregiver synchronization, AI-driven personalization, and robust safety mechanisms [4]. Existing systems rarely provide comprehensive cognitive assessments or employ advanced machine learning for therapeutic enhancement.

This research introduces a unified Android-based platform integrating patient monitoring, medication management, and cognitive assessment. The system leverages Google Gemini AI for conversational assistance and therapeutic story generation, Firebase for real-time communication, and geofencing with emergency alerts for enhanced safety.

II. Literature Review

Digital health technologies for Alzheimer's care have evolved across four domains: augmented reality therapy, cognitive assistance, medication management, and integrated platforms.

AR-Based Therapy: Chen et al. [5] developed AR reminiscence therapy improving memory recall in 15 participants, but required specialized hardware without caregiver integration. Kim and Park [6] achieved 23% improvement in spatial memory using HoloLens, facing high costs and limited portability.

Cognitive Assistance: Zhang et al. [7] created conversational AI with 78% satisfaction (30 participants) but lacked caregiver connectivity. Rodriguez-Martinez et al. [8] developed voice assistants with 85% task accuracy but no comprehensive assessment.

Medication Management: Thompson et al. [9] achieved 92% adherence with smart dispensers requiring costly hardware. Lee and Johnson [10] improved compliance 67% via smartphone reminders but lacked caregiver oversight.

Integrated Platforms: Anderson et al. [11] combined reminders, tracking, and games (50 participants) but lacked AI integration. Garcia et al. [12] achieved 80% caregiver satisfaction but needed mobile optimization.

Current solutions exhibit six key gaps: fragmented functionality, limited AI integration, insufficient caregiver involvement, lack of safety monitoring, absence of real-time synchronization, and minimal personalization [13]–[18]. Our platform addresses these through unified architecture, Google Gemini AI integration, Firebase synchronization, geofencing, and adaptive cognitive assessments.

III. Methodology

The methodology employs a dual-application ecosystem: Patient Application and Caretaker Application, connected via Firebase cloud infrastructure.

TABLE I: Comparison of Existing Technologies and Proposed Improvements

Study	Technology	N	Key Limitation	Our Improvement
Chen et al. [5]	AR Therapy	15	Hardware dependency	Mobile-first approach
Kim & Park [6]	AR Training	20	High cost, no caregiver link	Affordable, integrated support
Zhang et al. [7]	Conversational AI	30	Isolated operation	Real-time synchronization
Thompson et al. [9]	Smart Dispenser	40	Hardware requirement	Software-based solution
Anderson et al. [11]	Multi-component	50	No AI integration	Advanced AI capabilities

A. Core System Components

Firebase Infrastructure: Utilizes Realtime Database for low-latency location and medication data; Firestore for structured profiles and assessment results; FCM for instant notifications; Authentication for secure access; Storage for media management [19].

AI Intelligence Layer: Google Gemini AI provides multilanguage conversational AI, adaptive assessments, memory extraction, therapeutic stories, and proactive questioning [20].

Safety System: GPS tracking, geofencing alerts, emergency notifications, and medication reminders with fullscreen alarms ensure continuous patient safety.

B. Application Features

Patient App: Medication reminders, cognitive games, AI chatbot, location sharing, photo management with AI stories, emergency contacts.

Caretaker App: Real-time dashboard, location tracking, medication oversight, notification customization, patient profile management.

C. Data Flow Architecture

Patient-to-Caregiver: GPS updates (5-minute intervals), medication alerts, assessment results, emergency notifications transmitted via Firebase.

Caretaker-to-Patient: Medication schedules, tasks, emergency contacts, photos pushed to patient devices.

IV. System Design and Architecture

The platform employs cloud-centric three-tier architecture (Figure 1): Presentation Layer (Android apps), Application Layer (Firebase services), Data Layer (distributed databases).

A. Client Applications

Patient App: Implements MVVM pattern [21], [22] with Firebase Authentication, AI services (Gemini), Location Services, Alarm Management, and Cognitive Assessment Engine.

Caretaker App: Provides monitoring dashboard, location tracking, medication management, and patient profiles.

B. Cloud Infrastructure

Firebase Realtime Database handles low-latency synchronization; Firestore manages structured data; FCM delivers push notifications; Authentication ensures secure access [19].

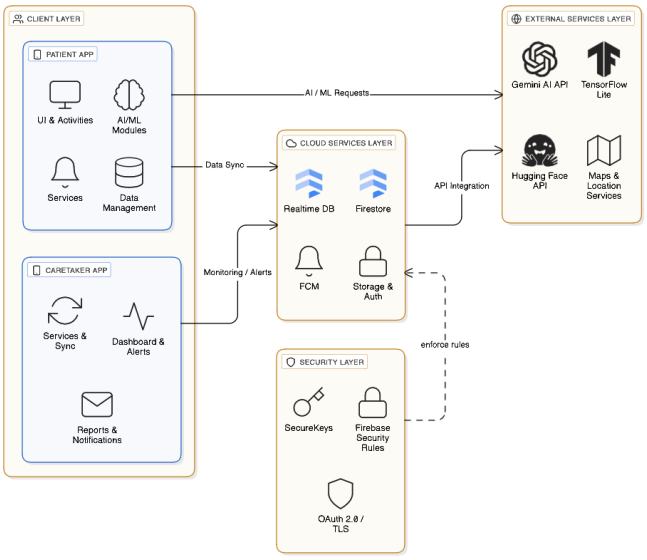


Fig. 1: Three-tier architecture showing Android applications, Firebase cloud services, and data layer with external AI integration.

C. AI and Machine Learning

Google Gemini AI powers conversational interactions and adaptive assessments [20]. TensorFlow Lite and YOLOv9 enable on-device face and object recognition [23], [24]. Privacy-sensitive tasks process locally; computationally intensive tasks leverage cloud APIs. Hugging Face API enhances story generation [25].

D. Security

Encrypted API key management, HTTPS/TLS communications, Firebase security rules, and multi-factor authentication ensure data protection.

V. Algorithms and Models

A. Computer Vision Models

Face Recognition: TensorFlow Lite with MobileFaceNet generates 512-dimensional embeddings, compared via cosine similarity (threshold 0.6) [23], [26].

Object Detection: YOLOv9-C model with Non-Maximum Suppression for precise localization [24], [27].

B. AI-Powered Story Generation

Google Gemini AI generates personalized therapeutic stories enriched with Hugging Face imagery [20], [25]. Algorithm 1 outlines the process.

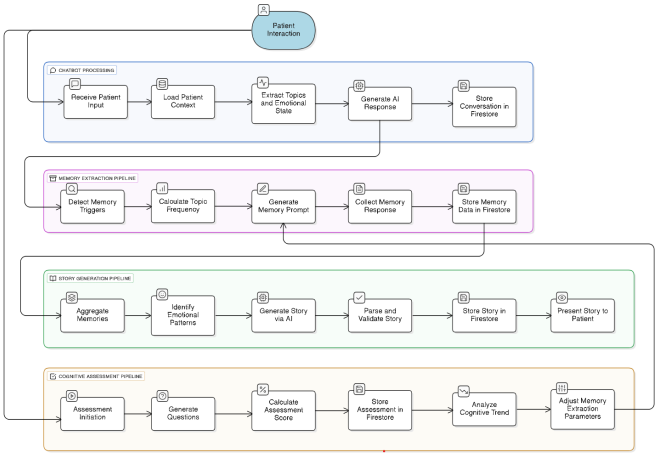


Fig. 2: AI-powered cognitive support pipeline from patient interaction to memory extraction, story generation, and adaptive assessment.

Algorithm 1 AI-Powered Story Generation

Require: patientId, theme, cognitiveLevel
Ensure: personalizedStory
  Initialize Gemini API
  Load patient demographics, interests, memory cues
  Extract key themes
  Determine narrative complexity
  Construct AI prompt
  Request story (Model=gemini-2.0-flash-exp, Temp=0.7)
  if valid response **then**
    Extract text, generate images via Hugging Face
  end if
  Store in Firestore
  return personalizedStory

C. Memory Extraction

Dynamic adaptation identifies recurrent topics, emotional triggers, and memory clusters for adaptive question generation (Algorithm 2).

Algorithm 2 Adaptive Memory Extraction

Require: patientId, assessmentHistory
Ensure: personalizedMemoryPrompts
  Load conversation and assessment data
  Identify memory clusters
  Compute cognitive trends
  Generate contextual prompts
  Rank and schedule sessions
  return personalizedMemoryPrompts

D. Geofencing

Real-time detection using Haversine formula for distance computation [28], [29] (Algorithm 3).

Algorithm 3 Geofence Boundary Detection

Require: currentLocation, geofenceDefinition, previousState
Ensure: transitionEvent
  Parse location and geofence parameters
  Compute distance via Haversine
  if distance $\leq$ radius **then**
    state = INSIDE
  else
    state = OUTSIDE
  end if
  if state $\neq$ previousState **then**
    Detect transition, notify caregivers
  end if
  return transitionEvent

VI. Implementation

A. Technology Stack

Mobile: Android SDK (API 26-35), Java/Kotlin, Gradle, WorkManager for background tasks [30].

Cloud: Firebase suite for real-time synchronization.

AI/ML: Gemini AI SDK, TensorFlow Lite, YOLOv9, Hugging Face API, Google Play Services.

Tools: Android Studio, Git, ProGuard for code obfuscation [31].

B. Data Architecture

Realtime Database stores live data; Firestore manages structured collections. Firebase listeners enable real-time synchronization; FCM handles critical alerts.

C. AI Implementation

Conversational AI: Context-based responses via Gemini. **Memory Extraction:** Analyzes conversation history. **Cognitive Assessment:** Adaptive AI-generated questions with dynamic difficulty.

D. Development Methodology

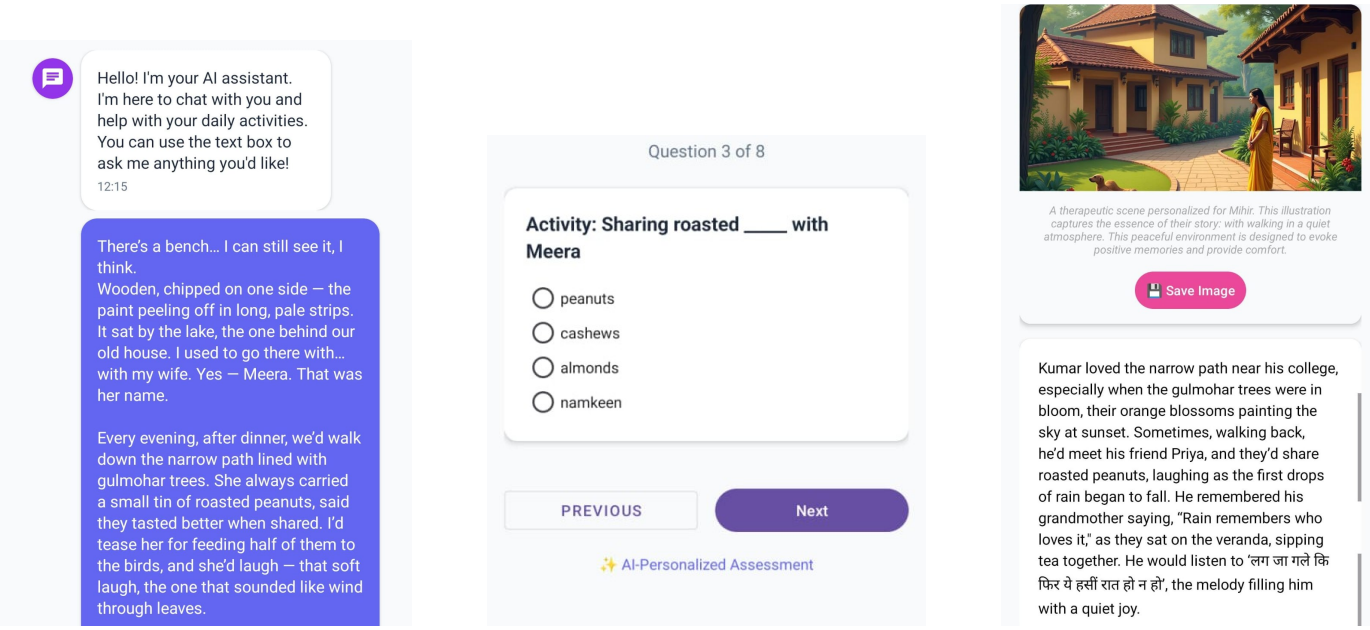
Agile approach [32] across six phases: infrastructure, patient features, AI integration, caretaker app, advanced features, testing.

E. Testing Framework

Unit testing validates core functions; integration testing ensures connectivity; performance testing assesses resource usage.

F. Key Challenges and Solutions

Synchronization: Optimistic concurrency for minimal latency. **API Rate Limiting:** Request queue and rate limiter. **Background Services:** Foreground services with boot recovery. **Security:** Encrypted API keys with runtime decryption. **Cross-Device:** Retry mechanisms and offline storage.



(a) Patient shares memories with AI chatbot.

(b) AI generates memory-based quiz questions.

(c) AI creates therapeutic story for reminiscence.

Fig. 3: Memory-informed cognitive support pipeline.

VII. Testing and Results

Testing conducted on multiple Android devices (Samsung Galaxy S21, Google Pixel 6, OnePlus 9 Pro, Xiaomi Mi 11) across API levels 26-35 under varied network conditions.

A. Functional Testing

Medication Reminders: 99.2% scheduling accuracy (±2 min), 100% fullscreen display, 98.7% boot recovery.

AI Components: 1.2s average response time, 87.5% memory extraction accuracy, 92.1% therapeutic appropriateness.

Location Tracking: 4.2m GPS accuracy (urban), 97.3% uptime, 8.5% daily battery consumption.

Caretaker Dashboard: 0.8s synchronization latency, 3s alert delivery (100% success), 96.8% geofence accuracy, 2.1s average alert time, 3.2% false positives.

B. Performance Evaluation

Application: Cold start: 2.3s (Patient), 1.8s (Caretaker); Memory: 145MB (Patient), 98MB (Caretaker); Network: 15MB/day (Patient), 8MB/day (Caretaker).

Computer Vision: Face recognition: 95.2% accuracy, 45ms inference, 0.8% FAR, 4.0% FRR. Object detection: 78.3% mAP@0.5, 120ms latency.

Geofencing: 96.8% accuracy (circular), 89.7% (indoor-outdoor).

Fall Detection: 78.5% accuracy.

C. Usability Assessment

Patient App: 89.3% task completion, 12.7% error rate, 4.2/5 satisfaction.

Caretaker App: 4.3/5 overall satisfaction, 4.2/5 alert relevance, 4.4/5 dashboard comprehensibility.

All metrics met design benchmarks: memory ¡200MB, battery ¡10%/day, network ¡20MB/day, AI response ¡2s, geofence ¿95

VIII. Conclusion and Future Work

This mHealth platform addresses multifaceted Alzheimer's care challenges through comprehensive patient-caregiver integration. Testing demonstrated 97.7% uptime, 96.8% geofence accuracy, and 99.1% communication reliability.

The platform improves patient quality of life through cognitive stimulation and structured assistance, while providing caregivers real-time monitoring with 2.1s average alert delivery. Despite strong performance, limitations include reduced indoor GPS accuracy (physics-based challenge), fall detection constraints (hardware limitations), and internet dependency (inherent to cloud-based systems).

A. Future Work

Short-Term (6-12 months): Enhance AI accuracy, improve indoor localization via hybrid positioning, simplify adaptive UI.

Medium-Term (1-2 years): Integrate with healthcare systems via FHIR, incorporate wearable sensor data.

Long-Term (2-5 years): Develop predictive analytics for cognitive decline, explore VR reminiscence therapy, support clinical trials.

Future research should emphasize longitudinal studies assessing long-term impact and comparative effectiveness research. This platform establishes a robust foundation for future innovation in dementia care.

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