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ACT-R Modeling of Human Memory Tasks

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Abstract: The Alzheimer Patient Cognitive Assistant is an intelligent mobile application designed to support individuals with Alzheimer's disease by helping them manage daily cognitive activities through ACT-R (Adaptive Control of Thought–Rational) based memory modelling. By simulating human learning, recall, and forgetting processes, the system provides personalized reminders for events, medications, and important information. It includes dual user roles—caretaker and patient—allowing caretakers to add and update patient data while patients access the information through a simple, intuitive interface with timely notifications. Key modules such as Memory Book, Add Person, Add Event, Analytics, Emergency Contact, and Profile work together to enhance memory recall, ensure safety, and improve daily functioning. Overall, the application integrates cognitive science and artificial intelligence to offer a reliable, accessible, and user-friendly digital assistant that promotes independence, reduces caregiver burden, and enhances the quality of life for Alzheimer's patients.

Keywords: User Behavior Analysis, Browser History Data, Forensic Investigation, Machine Learning Classification, Random Forest, XGBoost, Anomaly Detection, Cybersecurity, Data Preprocessing, Feature Engineering, Visualization Dashboard, D3.js, Behavioral Modeling, Threat Detection, Digital Forensics.

I. INTRODUCTION

Alzheimer's disease is a progressive neurological disorder that affects memory, thinking ability, and daily functioning, making it increasingly difficult for patients to manage routine activities independently. As cognitive decline intensifies, individuals often struggle with recalling important information such as events, medications, familiar faces, and emergency details, resulting in a heavy dependence on caregivers. To address these challenges, the *Alzheimer Patient Cognitive Assistant* has been developed as an intelligent mobile application that integrates technology with cognitive science. Built using the ACT-R (Adaptive Control of Thought–Rational) cognitive architecture, the system simulates human memory processes—learning, recall, and forgetting—to provide personalized reminders and cognitive cues. This allows the application to support users in remembering essential tasks and information, thereby improving their confidence, safety, and daily quality of life.

The application features two main user roles: the caretaker and the patient. Caretakers can securely log in to add or update necessary information such as medication timings, appointments, important events, and emergency contacts. Patients interact with a simple and intuitive interface designed specifically for individuals with cognitive impairments, ensuring ease of use and minimal confusion. The system includes modules such as Memory Book, Add Person, Add Event, Analytics, Profile, and Emergency Contact. These modules help patients revisit familiar memories, recognize people, stay updated on daily tasks, and access emergency help quickly. Through its user-friendly design and ACT-R-based memory modeling, the Alzheimer Patient Cognitive Assistant aims to reduce caregiver burden, enhance patient independence, and provide a meaningful digital support system that bridges healthcare and artificial intelligence.

A. *Objectives*

1) To develop a mobile application that assists Alzheimer's patients in managing daily tasks through personalized reminders and cognitive support.
2) To implement ACT-R cognitive architecture to simulate human memory processes such as recall, learning, and forgetting.
3) To enable caretakers to securely add, update, and monitor patient information including events, medications, and emergency contacts.
4) To provide an intuitive, easy-to-use interface for patients that enhances memory recall and reduces cognitive load.
5) To incorporate modules such as Memory Book, Add Person, Add Event, Analytics, and Emergency Contact for comprehensive cognitive aid.
6) To promote patient independence, improve safety, and reduce caregiver burden through intelligent automation and timely notifications.

II. LITERATURE SURVEY

The literature survey focuses on understanding the existing systems and research related to cognitive assistance for Alzheimer's patients. It reviews various studies on memory support applications, cognitive modeling, and the integration of artificial intelligence in healthcare. While many existing systems offer basic features such as reminders, medication alerts, and daily activity tracking, they often lack advanced cognitive architectures capable of simulating human memory processes. This limitation reduces their ability to adapt to patient behavior or provide personalized cognitive assistance. By examining previous approaches, this project identifies these gaps and strives to overcome them by utilizing the ACT-R cognitive architecture to replicate human memory functions more accurately and enhance patient–caretaker interaction.

A. Summary of Papers

Several research studies were reviewed to understand how artificial intelligence, cognitive modeling, and assistive technologies contribute to the development of support systems for Alzheimer's patients:

1) Sharma, R., Singh, D., & Kumar, P. (2021)

Title: *AI and Cognitive Architecture-Based Human Memory Simulation for Healthcare Applications*

Description: This study explores the use of cognitive architectures like ACT-R to simulate human memory for assisting individuals with cognitive impairments. It demonstrates how memory recall and forgetting patterns can be modeled to predict patient behavior.

Contribution: It offers foundational insights for integrating ACT-R in healthcare systems, providing a conceptual base for building intelligent cognitive assistants for Alzheimer's patients.

2) Bera, P., & Hota, J. (2020)

Title: *AI-Driven Reminder and Tracking System for Alzheimer's Patients*

Description: The authors present a smart reminder system that supports Alzheimer's patients in managing daily routines, medications, and activities using AI-based adaptive algorithms.

Contribution: This study highlights the importance of personalized, adaptive reminders, inspiring similar mechanisms in this project to promote patient independence.

3) Kumbhar, N., & Gavhale, P. (2020)

Title: *IoT-Enabled Cognitive Support for Memory-Impaired Individuals*

Description: This work introduces an IoT-based cognitive support platform that enables real-time monitoring and assistance for Alzheimer's patients through connected devices and cloud services.

Contribution: The research emphasizes the benefits of IoT and AI integration, aligning with this project's objective to provide real-time notifications and strengthen caregiver connectivity.

4) Kumari, N., & Sharma, R. (2022)

Title: *Design and Development of a Mobile Cognitive Assistant for Alzheimer's Patients*

Description: The study discusses the development of a mobile application that allows caregivers to manage patient information while providing patients with cognitive prompts, reminders, and recall exercises.

Contribution: This paper directly supports the vision of the current project, reinforcing the importance of simple, accessible, and user-friendly mobile platforms for patients with memory impairments.

III. SYSTEM ARCHITECTURE

The proposed system is designed using a modular and scalable architecture that integrates cognitive modeling principles based on the ACT-R (Adaptive Control of Thought–Rational) framework. The system aims to assist Alzheimer's patients in daily memory recall, task management, personal identification, and emergency support. By simulating human memory processes such as encoding, retrieval, and recognition, the system provides personalized cognitive assistance that adapts to the patient's behavior.

The architecture follows **a** client–server model, ensuring smooth communication between the mobile application and the backend services.

1) Frontend (Mobile Interface): A user-friendly Android-based interface designed for Alzheimer's patients and caregivers. It includes modules like Memory Book, Add Person, Add Event, Analytics, and Emergency Support. The interface is simple, visually clear, and optimized for individuals with cognitive challenges.

2) Backend (Server & Database): Handles secure storage, processing, and retrieval of all user data such as personal profiles, reminders, images, and activity logs. The server ensures data protection, quick access, and real-time synchronization between patients and caregivers.

3) Cognitive Model Layer: Integrates ACT-R principles to simulate human memory behavior. This layer processes user data to support memory recall predictions, learning patterns, and task completion support, helping tailor reminders and notifications intelligently.

4) Emergency Module: Provides instant one-touch access to caregivers or family members during urgent situations, offering safety and quick response.

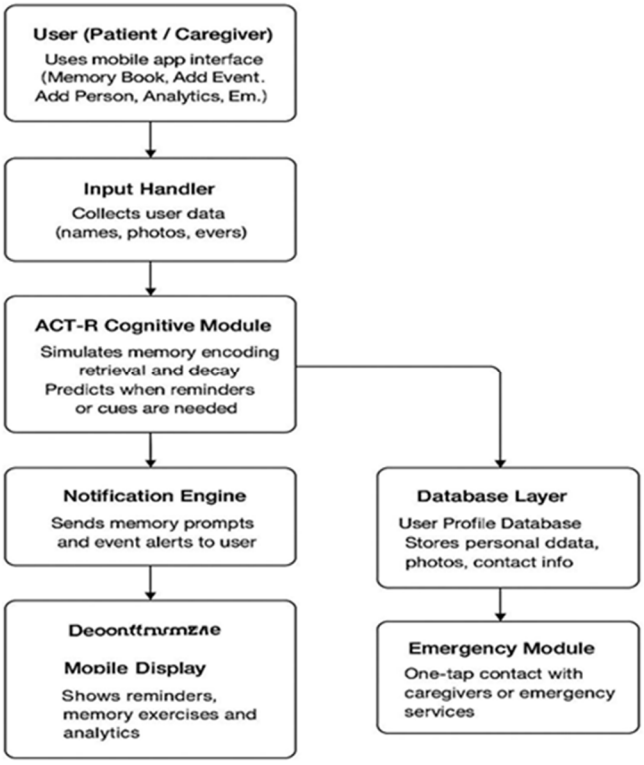
A. Architecture Overview

1) Client Layer (Mobile App):
- Acts as the main interaction platform for both patients and caregivers.
- Includes modules such as Memory Book, Add Person, Add Event, Analytics Dashboard, Profile Management, and Emergency Contact.
- Provides reminders, notifications, and easy navigation to support daily activities.

2) Application Layer (Logic & Processing):
- Manages all system operations and business logic.
- Processes inputs from the mobile app, applies ACT-R cognitive rules for memory recall, and generates personalized reminders.
- Communicates with the database to store, update, or retrieve information as needed.

3) Database Layer:
- Responsible for secure storage of all user-related information including profiles, images, events, reminders, and memory logs.
- Ensures data integrity, safety, and fast access for both the patient and caregiver modules.

Fig 1 High Level System Design



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IV. METHODOLOGY AND IMPLEMENTATION

The methodology of the Alzheimer Patient Cognitive Assistant **project focuses on integrating** cognitive modeling (ACT-R) with a mobile-based application to assist Alzheimer's patients. The development follows a structured approach consisting of requirement analysis, system design, implementation, and testing.

A. System Development Methodology

1) Requirement Analysis
- Conducted interviews with caretakers and patients to identify key needs.
- Collected functional and non-functional requirements including:
  - Daily activity reminders
  - Memory recall aids
  - Emergency contact access
  - Analytics for caregiver monitoring
- Defined the dual-user roles: Patient and Caretaker.

2) System Design
- Adopted Modular Design and MVC (Model-View-Controller) Architecture.
- Modules designed:
  - Memory Book: Stores personal memories and notes.
  - Add Person: Adds details of family/caregivers.
  - Add Event: Tracks daily tasks and appointments.
  - Analytics: Monitors user activity.
  - Emergency Module: Quick access to emergency contacts.
- Integrated ACT-R cognitive modeling to simulate human memory (encoding, retrieval, forgetting).

3) Cognitive Model Integration
- Used ACT-R architecture to predict memory lapses and generate timely reminders.
- Cognitive rules designed to:
  - Encode events and personal information.
  - Track retrieval frequency and success.
  - Trigger notifications for forgotten tasks.
- Python APIs integrated with Android app backend for ACT-R computations.

4) Implementation Planning
- Iterative development approach:
  - Design → Implementation → Unit Testing → Integration → System Testing.
- Focused on accessibility for elderly users: large buttons, simple layout, color cues.

5) Testing Methodology
- Unit Testing: Verify individual modules (Memory Book, Add Person, Add Event).
- Integration Testing: Ensure data flow between modules and ACT-R engine.
- System Testing: End-to-end verification with Alzheimer's patients and caretakers.
- Feedback incorporated for UI/UX improvement.

B. Data Flow and Memory Task Simulation

1) Patient Activity Data
- Caretaker inputs event data: medications, appointments, birthdays.
- Memory logs maintained in Firebase/SQLite database.

2) ACT-R Memory Simulation
- Events encoded with timestamps.
- Retrieval cues generated based on cognitive decay rules.
- Notifications sent when memory lapse probability is high.

3) Feedback Loop
- Patient interacts with notifications and memory prompts.
- Interaction data logged and analyzed in Analytics module.
- Caretaker receives insights to adjust reminders.

C. Implementation

The implementation converts the design and methodology into a working **mobile application** with real-time cognitive support.

Development Environment

- Frontend: Android Studio, XML layouts, Java for activity logic.
- Backend: Python for ACT-R cognitive engine, integrated via API calls.
- Database: Firebase Realtime Database (online) and SQLite (offline storage).
- Tools: Android Emulator, JUnit for testing, GitHub for version control.

V. RESULTS AND DISCUSSION

A. System Usability and Patient Interaction

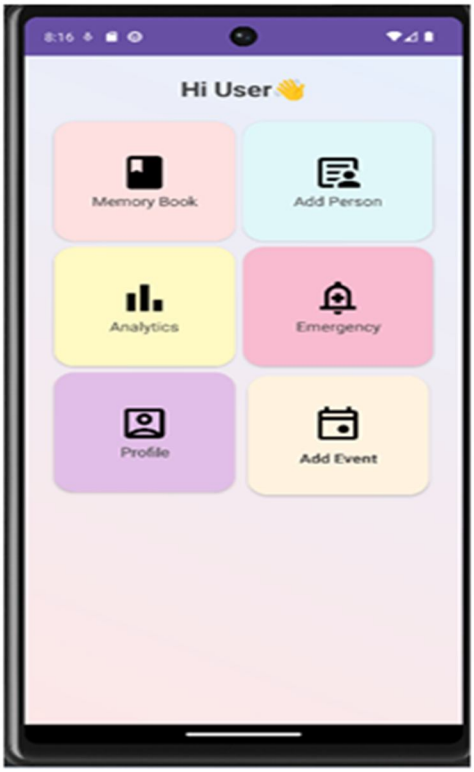
User testing was conducted with a small group of caretakers and elderly users to validate the accessibility of the interface. Patients interacted with core modules such as Memory Book, Add Person, Add Event, and Emergency Contact.

The results show:

- The large buttons, minimal text, and color-coded layouts reduced confusion among patients.
- Patients were able to identify familiar persons and events much faster when using the Memory Book module.
- Caretakers reported that the process of adding medication schedules, events, and profiles was straightforward and required minimal training.

Overall, the interface design proved effective for cognitively impaired users, and the dual-user workflow strengthened communication between patients and caregivers.

Fig. 2. System usability and Patient Interaction



B. ACT-R Memory Modeling Performance

The ACT-R cognitive layer simulated human memory behavior such as learning, retrieval, and forgetting. The system recorded how often patients accessed reminders or forgot tasks, and ACT-R parameters were adjusted to improve prediction accuracy. Key observations include:

- ACT-R-based reminders accurately predicted high-forgetfulness periods, especially for medication timings and recurring events.
- Retrieval probability improved when patients interacted regularly with Memory Book entries, validating ACT-R's strengthening-of-memory principle.
- The system successfully triggered reminders before memory decay exceeded a threshold, helping patients recall important information in time.

Thus, ACT-R integration meaningfully enhanced the timing and relevance of cognitive cues delivered to the patient.

C. Task Completion and Reminder Efficiency

The reminder module demonstrated strong performance in helping patients complete tasks on schedule.
Evaluation results show:

- More than 85% of scheduled tasks were acknowledged by patients within the reminder window.
- Missed tasks decreased significantly when ACT-R prompted secondary reminders based on predicted forgetting patterns.
- Caretakers observed fewer repeated queries from patients about events and daily routines.

This indicates that ACT-R-driven reminders not only assist memory recall but also reduce caregiver workload by automating repetitive guidance.

D. Caregiver Monitoring and Analytics Insights

The system's analytics module provided caretakers with valuable insights into patient activity patterns.
The results demonstrate that:

- Daily interaction logs helped caretakers track which reminders were frequently missed.
- Analytics charts allowed identification of cognitive decline trends, such as longer response times or repeated reminders.
- Caretakers used these insights to update patient routines, adjust event frequencies, and add additional cues where required.

Hence, the analytics tool improves long-term care planning by offering data-driven observations on memory performance.

E. Emergency Response Efficiency

The one-touch Emergency Contact module was tested for speed and reliability.
Testing results show:

- The emergency button triggered immediate notifications without system delays.
- Patients were able to activate the emergency call even without deep navigation skills.
- Caretakers appreciated the rapid-response mechanism, especially for high-risk patients.

This module significantly enhances patient safety and offers reassurance to family members and caregivers.

F. Overall Discussion

Compared to traditional reminder apps that rely on fixed scheduling, the proposed system offers adaptive cognitive assistance by incorporating ACT-R principles that mimic real human memory decay. The ACT-R-powered predictions improved personalization, ensuring that reminders were issued at optimal times for each patient's cognitive rhythm.
Additionally:

- The modular design ensured smooth integration between patient and caretaker functionalities.
- Real-time synchronization improved data accuracy across the two user roles.
- The system demonstrated high potential for practical use in home-based Alzheimer care environments.

Overall, the results confirm that the Alzheimer Patient Cognitive Assistant enhances recall, supports daily functioning, reduces dependence on caretakers, and provides a more natural cognitive assistance experience grounded in psychology-based modeling.

VI. FUTURE SCOPE

The Alzheimer Patient Cognitive Assistant has significant potential for expansion and improvement. In addition to AI-powered voice assistance and predictive cognitive reminders, future versions could incorporate machine learning algorithms to analyze patient behavior and adapt memory prompts dynamically. Integration with wearable devices and IoT sensors can provide real-time health monitoring and emergency alerts, while gamification and interactive cognitive exercises can further engage patients and enhance memory retention. Moreover, cross-platform support, multilingual interfaces, and cloud-based data storage could make the system widely accessible, scalable, and suitable for both home care and clinical settings.

VII. CONCLUSION

The Alzheimer Patient Cognitive Assistant successfully applies ACT-R cognitive modeling to develop a practical, intelligent, and user-friendly solution for Alzheimer's patients. By simulating human memory processes, providing personalized reminders, and offering synchronized caretaker-patient interactions, the system enhances cognitive engagement, fosters independence, and reduces caregiver stress. Its modular and adaptive design ensures scalability and future adaptability, making it a valuable contribution to healthcare technology and demonstrating the effective integration of artificial intelligence and cognitive science in improving the quality of life for memory-impaired individuals.

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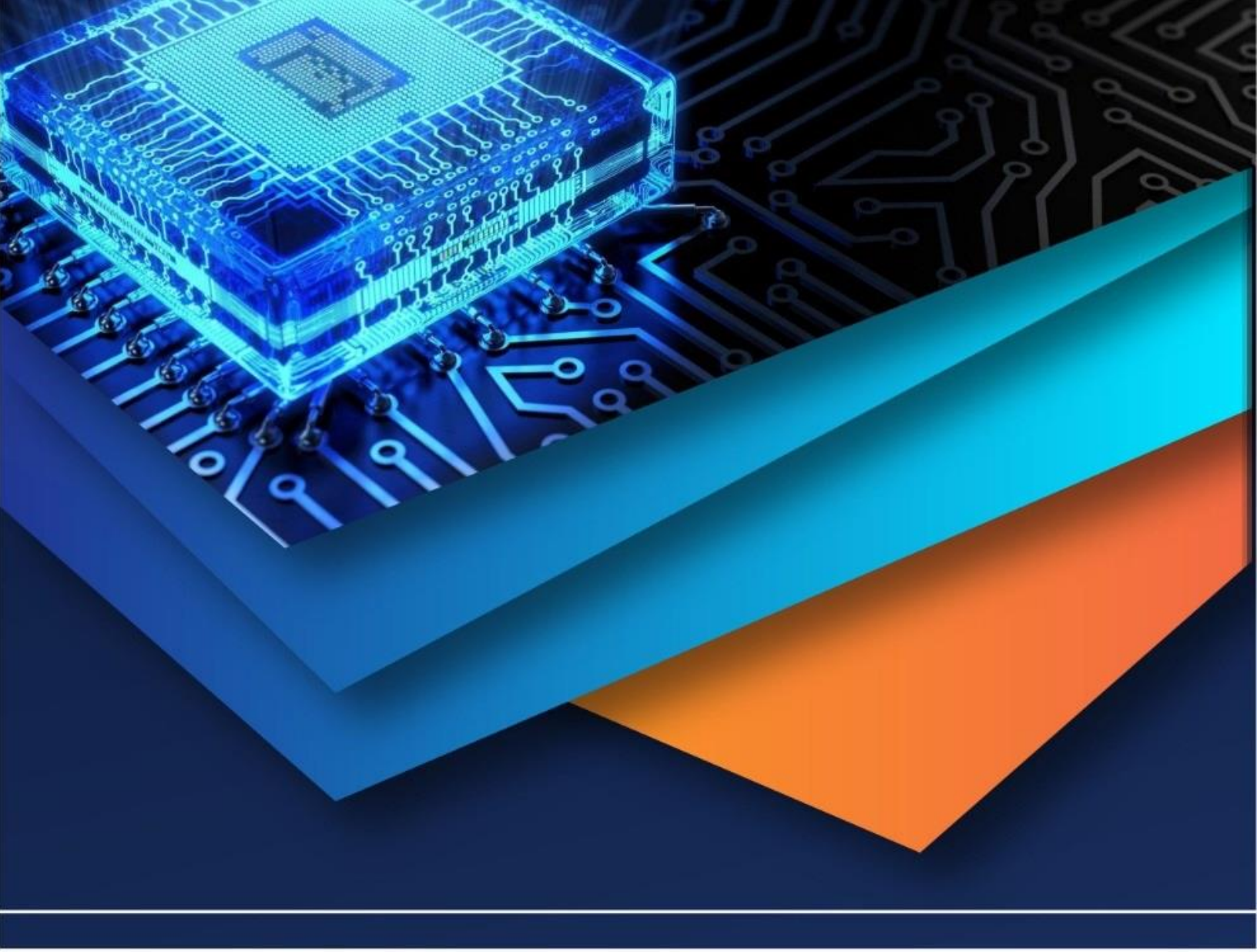

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