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Conversational AI System for Enhancing Autonomy in Individuals with Alzheimer's Disease

Radia Belkeziz[a,b], Reda Chefira[a,b,*], Mohamed Yassine Samiri[b,c] , Said Rakrak[b]

[a]*Private University of Marrakesh, Km 13, route d'Amizmiz 42312, Morocco*
[b]*Systems and Computer Engineering Laboratory (L2IS), Cadi Ayyad University112 Bd Abdelkrim Al Khattabi, Marrakech, Morocco*
[c]*Faculty of Legal, Economis and Social Sciences Kelaa des Seraghna Cadi Ayyad University Marrakech, Morocco*

Abstract

Alzheimer's disease manifests as cognitive decline, memory loss, and impaired decision-making, hindering daily tasks and independence. Memory decline includes forgetfulness of recent events, name recall, and spatial disorientation, compounded by communication impairments and difficulty in social interaction. Routine tasks become burdensome, and compromised judgment raises safety concerns. Technology advancements, such as cognitive assistive technologies and smart home systems, aid memory, cognition, and safety. The proposed conversational AI system integrates NLP, IoT sensors, and Blockchain to provide intuitive communication, real-time monitoring, secure data management, and personalized memory-stimulating activities. This system facilitates remote patient monitoring, collaboration with caregivers, and timely interventions, promising autonomy and improved well-being for Alzheimer's patients.

Keywords: AI; Conversational AI; Alzheimer's Disease; Machine learning; NLP; Blockchain; Medication

1. Introduction

Alzheimer's disease is characterized by cognitive decline, memory loss, and impaired decision-making abilities, often leading to difficulties in performing routine tasks and maintaining independence [1]. Individuals diagnosed with Alzheimer's disease encounter a myriad of daily challenges that significantly impede their quality of life and

* Corresponding author.
E-mail address: r.chefira@upm.ac.ma

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autonomy. Foremost among these difficulties is the progressive decline in memory function, resulting in forgetfulness regarding recent events, difficulty in name and face recall, and temporal and spatial disorientation. Communication impairments further compound their struggles, leading to difficulties in verbal expression, comprehension, and social interaction [2]. Simple routine tasks, including dressing, grooming, and eating, become arduous endeavors, often overwhelming individuals with the disease. Moreover, compromised judgment and decision-making abilities heighten safety concerns, predisposing them to accidents and wandering incidents. The management of medications poses another formidable challenge, as individuals contend with memory lapses and dosing errors. Familiar environments may become disorienting landscapes, fostering anxiety and disquiet. Various technological advancements have been devised to support individuals afflicted with Alzheimer's disease, with the overarching aim of ameliorating their quality of life, ensuring their safety, and enhancing their overall well-being [3]. The proposed conversational AI system integrates NLP algorithms and IoT sensors to support individuals in their daily routines, providing intuitive communication and real-time monitoring for enhanced safety. Additionally, Blockchain ensures secure management of medical information, offering personalized memory-stimulating activities and reminders to mitigate cognitive decline. The system includes a medical portal for remote monitoring and collaboration among healthcare providers and caregivers, fostering timely interventions and continuity of care for Alzheimer's patients. Designed with a human-like interface, conversational AI systems aim to enhance engagement and overall well-being, offering a personalized and empathetic approach to addressing the challenges of the disease. The remainder of the paper is organized as follows: section II presents the related work. Section III presents the premises of the conversational AI architecture, then section IV highlights the used smart approaches and finally, section V gives the conclusion and future directions.

2. Related work

Emerging insights into AI and cognitive assistance technologies have led to significant progress in the development of intelligent systems to assist drug management for people with Alzheimer's disease. This paper [4] introduces an intelligent system created to oversee the healthcare of Alzheimer's patients in geriatric facilities in real-time. Named AGALZ, this system is a self-governing planner that dynamically organizes nurses' schedules, maintains comprehensive activity reports, and ensures patients receive appropriate care. Operating wirelessly, AGALZ is part of a larger system called ALZ-MAS, collaborating with other agents to interact with the environment. This study [5] introduces a novel approach to supporting caregivers in monitoring individuals with Alzheimer’s disease (AD) through an Internet of Things (IoT) based monitoring system. The proposed computational model, built on an ontology framework, leverages physiological data from external IoT devices to detect potentially hazardous behaviors in AD patients. A significant contribution of this research is the development of a specialized model tailored for AD, employing context history analysis and prediction—an innovative method not found in existing literature. Additionally, a simulation tool is proposed to generate realistic daily activities of AD patients, facilitating the creation of standardized datasets for evaluating the model's effectiveness. In [6], an AI system prototype rooted in DL algorithms to aid Alzheimer’s patients in restoring a sense of normalcy and independence is introduced. The system employs AI to discern human activities from video footage, enabling the identification of instances when the individual requires nourishment or hydration. Through auditory prompts, it reminds the individual to eat or drink when necessary and alerts them if they have consumed excessively. The aim of [7] is to create a prototype that offers psychological support services and ensures the secure transmission of information, which can be reviewed by a family member to safeguard individuals with Alzheimer's disease. The designed wearable prototype can categorize detected images into two groups: family and non-family members, employing a CNN. Additionally, the prototype can track the location of the person with AD. Furthermore, it employs IoT technology to safeguard images captured by the webcam using steganography, enabling the recipient to decode the original image with a key. Another feature of the prototype facilitates communication through voice messages between the person with AD and their family member. Moreover, it integrates Google Assistant to support individuals with AD by answering their queries, reducing social isolation, and predicting their psychological state. This research [8] aims to develop and implement a specialized medical system to improve the lives of those with Alzheimer’s disease and ease the burden on their caregivers. It tracks their location, provides medication reminders, and includes an emergency call button for unexpected situations. The following technologies that are relevant to our system:

Personalized Memory Aids: People experiencing mild memory impairments frequently depend on external memory aids to offset cognitive limitations and facilitate the accomplishment of everyday tasks autonomously [9]. The gradual onset of cognitive, emotional, and behavioral challenges results in a loss of independence and reliance on others, marking the onset of the dementia phase. Language difficulties often emerge as one of the initial clinical cognitive

symptoms of the condition [10].

Enhanced Communication Tools: Improved communication tools for individuals with Alzheimer's disease can enhance their quality of life. Facial emotion recognition and identifying gaze direction are fundamental aspects of social cognition that could be compromised in numerous psychiatric or neurological disorders [11].

Safety and Monitoring Applications: Intelligent sensing systems possess the ability to offer adaptive feedback tailored to the context. Such systems aid individuals with Alzheimer's disease through continuous monitoring, functional assistance, crucial and timely therapeutic interventions [12].

Therapeutic and Educational Tools: Patient education for therapy involves healthcare providers conveying knowledge to empower patients in self-managing their chronic illnesses. It constitutes a crucial aspect of long-term disease and condition management [13]. Therapeutic and educational tools such as digital memory aids, virtual reality or robot-assisted therapy encompass a range of interventions and resources designed to address various aspects of the disease, including cognitive decline, memory loss, and emotional well-being.

Blockchain for Medical Data Management: EHR are shared among various healthcare entities, making them vulnerable to issues like data breaches, privacy concerns, lack of security measures and audit trails. Blockchain has the capacity to address these challenges by introducing a decentralized and secure framework, thereby enhancing privacy, security, and reliability in data exchange [14]. Blockchain can manage medical data usage, ensuring that patients and their families have control over who can access their medical information with the use of smart contracts.

3. System’s architecture

The conversational AI system’s architecture is explained in the following.

- **Conversational AI interface**

The Conversational AI interface serves as the primary interaction point for the Alzheimer's patient, allowing them to communicate their needs, preferences, and emotions using natural language. This interface integrates NLP capabilities to understand and interpret the patient's spoken or typed commands, questions, and statements.

Emotion Recognition Integration: Emotion recognition technology is integrated into the Conversational AI system to detect the patient's emotional state based on their voice tone, facial expressions, and other cues, to adapt the system's responses and provide empathetic communication and support tailored to the patient's emotional needs.

NLG for Responses: NLG capabilities are employed to generate personalized are personalized responses to the patient's queries, navigation requests, or emotional expressions.

- **Guidance System**

Input: The patient issues a statement such as "Where is the kitchen."

NLP Processing: In one hand, the NLP component parses the command and determines the intended destination. In another hand, a range of pre-defined responses or scripts can be developed to address different levels of distress. These responses should be empathetic, supportive, and tailored to the specific context of the patient's distress.

Sensor Data Collection: The system gathers data from sensors throughout the environment, such as detecting obstacles, monitoring the patient's location, and assessing the current environmental conditions. The system integrates physiological sensors to monitor the patient's emotional states, such as heart rate variability, skin conductance, or body temperature as changes in these physiological parameters indicate heightened emotions like stress.

Decision Making: The RL agent analyzes the input from the NLP component and sensor data to determine the best course of action to navigate the patient to their desired destination. This decision-making process considers factors such as the patient's current location, obstacles in the environment, and any safety considerations.

Action Execution: Based on the RL agent's decision, the system executes the necessary actions to guide the patient to the desired destination. This might involve providing verbal instructions to the patient, adjusting the patient's path to avoid obstacles, or making other real-time adjustments as needed.

- **Belongings Tracking**

BLE and RFID Tagging of Belongings: The patient's belongings are equipped with RFID tags for identification and BLE beacons for localization which are integrated into the existing sensor network of the guidance system. This allows the system to detect the patient's location and the presence of tagged belongings throughout the environment.

Localization and Tracking: The system utilizes data from the BLE beacons and RFID readers to localize the patient and track the locations of their belongings in real-time.

NLP Interface: The system retains its NLP interface, allowing the patient to verbally communicate with the system

to request assistance or locate their belongings. For example, the patient can say, "Where are my glasses?"
Emotion Recognition: The system incorporates emotion recognition capabilities to detect signs of distress or frustration in the patient's voice or behavior. The system can adapt to responses and provide additional support.

- **Behavior monitoring**

Sensor Networks: sensor networks throughout the patient's environment capture data on movement, activity levels, and environmental conditions.
Emotion Recognition: emotion recognition technology analyzes the patient's facial expressions, voice tone, and other physiological cues to detect changes in mood or emotional states.
Data Fusion and Analysis: data from sensor networks, emotion recognition, and NLP are fused for analysis to create a comprehensive picture of the patient's behavior and emotional state.

- **Blockchain-based record-keeping**

Integrating a blockchain-based record-keeping system into the overall solution can add an extra layer of security, transparency, and integrity to the data collected and managed by the system.
Patient Profile and History: Each Alzheimer's patient has a unique blockchain-based digital identity or profile. This profile contains relevant information about the patient, such as medical history, preferences, and caregiver contacts.
Emotional State Monitoring: Data related to the patient's emotional state, such as distress signals or feedback on system interactions, could be recorded on the blockchain. This information could help caregivers and healthcare professionals better understand the patient's emotional well-being over time.
Smart Contracts for Care Plans: Smart contracts could be utilized to automate and enforce care plans for Alzheimer's patients. These contracts could specify conditions under which certain actions or interventions should be triggered based on the patient's behavior or health status.
Integration with Healthcare Providers: The blockchain-based record-keeping system could be integrated with healthcare providers' systems to facilitate secure data sharing and collaboration. Authorized parties, such as caregivers or medical professionals, could access relevant patient information stored on the blockchain as needed.

4. System's implementation for drug intake management

4.1. System modeling

In this section, the focus will shift to a specific use case related to the drug intake management, from the scheduling of the reminder message between the system and the Alzheimer's patient, right through to the recording of the various activities in the Blockchain system. First, the reminder is scheduled and controlled according to the patient's medical instructions for drug dosage (morning, frequency, etc.). As soon as the reminder is launched, a voice message is spoken by the system, drawing the patient's attention to the need to get on with the medication. The system observes the patient's real-time behavior and oral feedback, to provide the appropriate instructions at the right time. In addition, it assesses whether the patient has taken their medication correctly, or whether it needs to loop back to a prior process to guide them again. Four actors are collaborating in the system:
Patient: the target of this assistance, whose medical data (age, state of health, level of mobility, etc.) are predefined.
AI system: which is central to the different processes, with multiple tasks including behavioral analysis, interaction with the patient, decision-making and continuous learning of the model.
Blockchain system: which registers drug intake, drug stock replenishment and any patient-related medical action.
Drug Supply Managers receive replenishment alerts and checking stock continuity and expiry dates.

4.2. System's processes

Each process is developed below, highlighting the role of NLP, AI and Blockchain in the assistance system:
Patient behavior analysis: AI is used to process the patient's behavioral data. NLP plays a crucial role by analyzing the patient's vocal and textual interactions, revealing sudden changes in their cognitive state or mood. AI subsequently processes this information to create a proactive behavioral profile, essential for personalized care.
Drug-taking process: AI uses behavioral and contextual data to determine the optimal medication time. NLP generates personalized reminders, tailored to the patient's level of understanding.

Assisting in medication administration: An NLP-based virtual assistant guides the patient through the entire process. The AI updates instructions in real-time to match the patient's reactions, providing empathetic, patient support. NLP enables a natural and reassuring level of interaction, particularly important for Alzheimer's patients.
Recording medications in the blockchain: Each drug intake is immutably registered in the blockchain. AI ensures data consistency before recording to guarantee accurate monitoring of treatment, vital for caregivers.
Ensure continuous drug availability: AI analyzes consumption data and predicts future drug requirements. NLP interprets medical prescriptions to transform them into precise stock requests.
Request drug supply manager to restock: AI triggers replenishment requests based on forecasts. Aided by Blockchain, NLP facilitates communication between the system and the stock manager.
Record actions in the blockchain: Every drug intake and replenishment action are recorded in the blockchain, providing an unalterable history. The AI checks the integrity of the data before recording. This step guarantees complete traceability of the supply chain, crucial for safety and dosage compliance.

4.3. Case scenario

Here's a scenario: “John Doe, an Alzheimer's patient, needs to take his medication”.

i. The system analyzes John Doe’s behavior and determines that it's time to take his morning medication.
ii. The VA, using NLP, triggers a voice reminder: “Hello John, it's time to take your morning medication.”
iii. John Doe replies, “Okay, but I can't remember which ones to take.”
iv. The assistant guides John Doe: “Check the drawer in your bedside table for a blue box. Do you see it?”
v. John doe confirms: “Yes, I see it.”
vi. The assistant continues: “Perfect. Open it and take the round white tablet and the oval red pill.”
vii. Once John Doe has taken his medicine, the system records the action in the blockchain.
viii. The AI analyzes the remaining stock and determines that replenishment is necessary.
ix. The system therefore sends an automatic request to the stock manager.
x. The replenishment request is also recorded in the blockchain.

Altogether, this scenario outlines the integrated processes forming a system where NLP aids natural interactions and contextual understanding, AI optimizes decision-making and personalization, and blockchain ensures the security and traceability of all actions. This technological synergy offers a comprehensive solution to improve medication management for Alzheimer's patients, increasing their autonomy while ensuring rigorous and secure monitoring.

Table 1. Main approaches to the drug assistance system highlighting the processes they cover in our scenario and their advantages

Approach	¨Process covered	Advantages
BERT Transformer (NLP)	- Analyze patient behavior -Trigger medication intake - Assist the patient	- Better contextual understanding - Linguistic adaptability - Real-time rapid processing
LSTM (behavioral analysis)	- Analyze patient behavior - Manage medication availability	- Continuous behavior analysis - Adaptation to temporal variations
CNN (visual recognition)	- Assist with medication intake	- Rapid medication identification - Visual verification of intake
Q-learning (medication management)	- Trigger medication intake - Manage medication availability	- Continuous optimization of reminders - Adaptation to patient preferences - Improved adherence
Expert system (medical rules)	- Assist with medication intake - Manage medication availability	- Management of drug interactions - Application of medical protocols - Increased patient safety
Hyperledger Fabric (blockchain)	- Record medication intakes - Record restocking actions	- Data security and traceability - High real-time performance
Multi-task attention model	- Coordination of all processes	- Seamless module integration - Coherent and contextual responses - Resource optimization

Table 1 outlines the main elements of the system for Alzheimer's patients, with a focus on drug intake monitoring. Advanced AI techniques are used to cover all aspects of the processes involved. NLP using Transformer models provides contextual understanding and interaction with the patient. Behavioral analysis is performed by LSTM, while CNN handle visual recognition tasks. RL, in particular Q-learning, optimizes drug programming and recall. An expert system ensures compliance with medical protocols, while blockchain technology, Hyperledger Fabric, secures data transactions. The entire system is coordinated by a multi-tasking attention model, enabling seamless integration of workflow approaches. This solution aims to provide real-time adaptive assistance to patients, improving medication adherence and overall quality of care. Implementation involves developing each component separately, then integrating them via the multi-tasking attention model, to ensure coordinated responses across all processes.

5. Conclusion

The conversational AI system presents a promising solution for supporting individuals living with Alzheimer's disease. By leveraging capabilities such as NLP, Emotion Recognition, NLG and sensors, we have developed a comprehensive assistive system that provides personalized assistance, navigation support, belongings tracking, and emotional support tailored to the unique needs of each patient. Through the integration of NLP, emotion recognition, and sensor networks, our system can understand and respond to the patient's verbal commands, detect changes in their emotional state, monitor their behavior, and provide timely assistance. The integration of blockchain ensures the security, transparency, and integrity of patient data, while ML algorithms enable adaptive responses and continuous improvement over time. Looking ahead, we envision further expansions of the conversational AI system to serve as an everyday assistant that can accompany Alzheimer's patients outdoors and aid throughout their journeys.

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