

CogniAid: A Comprehensive System to Manage Alzheimer's Patients

Suma M R¹, Namita Pavan², Prajwal Hegde³, Kamineni Sohan⁴ and Prasanna Holla⁵

¹⁻⁵Department of ECE, DSCE, Karnataka, India

Email: sumamr-ec@dayanandasagar.edu, namitapvn@gmail.com, prajwalgh4747@gmail.com, sohankamineni@gmail.com, prasannaholla@gmail.com

Abstract—IoT has revolutionized modern health care with promising technological, economic, and social prospects. CogniAid is an IoT-based support system developed to enhance the safety and quality of life for Alzheimer's patients while reducing the burden of caregivers. The system provides real-time health and location tracking, alerting caregivers if the patient exits the designated safe zones through the user application created. Health monitoring features track vital signs, with data stored in a cloud platform for easy real-time access. Additionally, CogniAid uses facial recognition to help patients identify close relatives, with a voice assistant that provides medication reminders and announces relatives' names upon recognition. This adaptable solution supports Alzheimer's care across various platforms promoting patient independence and safety.

Index Terms— Alerting system, Alzheimer's care, Facial recognition, Geofencing, Health monitoring, IoT, User application.

I. INTRODUCTION

Alzheimer's disease presents memory loss, disorientation, and behavior changes, leading to significant caregiving needs. CogniAid offers an IoT-based system for real-time health and location tracking, supporting patient safety and easing caregiver responsibilities. Built on a Raspberry Pi platform, it uses GPS tracking for defined safe zones and alerts caregivers via a mobile application if the patient leaves the safe zone. For offline communication, a GSM module sends alerts to ensure continuous monitoring.

The system also includes a health monitoring module using sensors like MAX30100 to track vital signs, with data stored in a real-time database of Firebase. This enables caregivers to monitor health trends and be alerted in case of abnormalities. Facial recognition helps patients recognize family members, while a voice assistant provides periodic reminders for medication promoting routine adherence. The voice assistant also gives alerts to the patient and calls out the names of the relatives after detection.

CogniAid is designed for flexible use in home and clinical settings. Its remote monitoring, alerts, and support tools enhance patient safety and support caregiver decision-making. Combining features like geofencing, health monitoring, face recognition, and routine reminders within a single platform, CogniAid provides comprehensive and accessible solutions while ensuring more security and well-being of the patient.

II. PROBLEM STATEMENT

Alzheimer's disease profoundly impacts memory, cognition, and behavior, causing challenges such as

disorientation, confusion, and wandering. Patients often forget familiar faces and places, leading to risky situations if unsupervised. Caregivers face significant stress in providing constant vigilance, as traditional approaches rely on manual supervision, which is often insufficient for ensuring patient safety.

CogniAid addresses these challenges by integrating IoT-based features like GPS tracking, health monitoring, face recognition, and GSM alerts for offline communication. It enables caregivers to receive real-time updates on patient location and health, reducing the need for physical supervision while enhancing patient safety. CogniAid bridges the gaps in traditional Alzheimer's care by ensuring continuous, automated monitoring and personalized alerts, even in the absence of Wi-Fi, offering a comprehensive solution to support patients and caregivers alike.

III. MATERIALS AND EXPERIMENT PROCEDURE

A. Hardware

The Raspberry Pi 4B serves as the main Processor Hub for all modules. The main advantage of this Single-Board Computer is, it is robust, cheap and offers great reliability and connectivity. Its Processor is powered by a 1.5GHz ARM Cortex-A72 quad-core CPU which will handle the most computationally intensive tasks to be carried out in order to perform facial recognition, health monitoring, and data transmission. It also comes with 4GB RAM memory with an SD card slot which is flashed with the Raspbian OS which is a Debian based Operating System. The most recent OS is the Bookworm OS which offers a much more optimized performance. The Raspberry Pi also comes with a 40-pin GPIO header where each GPIO offers various functions like I2C, SPI, UART and various Alternative Functions. It also consists of a 15 Pin Camera Serial Interface as Raspberry Pi is used in multiple Computer Vision and Machine Learning applications. It also has Integrated 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless (Wi-Fi) and Bluetooth 5.0 for optimal connectivity.

Sensors & Modules used are

MAX30100 Pulse Oximeter sensor module is a modern, integrated pulse oximeter and heart rate sensor IC, from Analog Devices. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry (SpO2) and heart rate (HR) signals. The idea is that you shine a single LED at a time, detecting the amount of light shining back at the detector, and, based on the signature, you can measure blood oxygen level and heart rate.

Ublox NEO6M is a GPS module which consists a Ublox 6M chip as its core which can track up to 22 satellites over 50 channels. Unlike other GPS modules, it can perform 5 location updates in a second with 2.5m horizontal position accuracy. The U-blox 6 positioning engine also has a Time-To-First-Fix (TTFF) of less than 1 second. One of the best features offered by the chip is Power Save Mode (PSM). This allows a reduction in system power consumption by selectively switching certain parts of the receiver on and off. There is an LED on the NEO-6M GPS module that indicates the status of the 'Position Fix'. The module is equipped with HK24C32 Two Wire Serial EEPROM. It is 4KB in size and is connected via I2C to the NEO-6M chip. Combined with a rechargeable button battery Battery Backed RAM is formed which contains clock data, latest position data (GNSS orbit data) and module configuration.

SIM808 is a high-performance GSM/GPRS module which also consists of a GPS engine and a BT engine and GSM/GPRS engine which quad-band module. The GPS solution offers best-in-class acquisition and tracing sensitivity, Time-To-First-Fix (TTFF) and accuracy. SIM808 is designed with power saving technique so that the current consumption is as low 1mA in sleep mode (GPS engine is powered down). It is a compact design, integrating GPRS and GPS in a Surface Mount Technology (SMT) package, making it suitable for developing GPS-enabled applications. In short field deployments either in areas with no stable Wi-Fi connection or in places with a rather unstable Wi-Fi connection, it effectively avails itself as a means of transfer or alert relay over cellular networks

The Speaker system utilizes 2030 Cavity Speakers with a PAM8403 Stereo Audio Amplifier which gives 6W power output. It also comes with a Bluetooth module for wireless connectivity.

B. Software

Raspbian Bookworm is the latest Debian-based operating system optimized for Raspberry Pi devices, officially launched by the Raspberry Pi Foundation as an upgrade from the previous Bullseye version. It is built to be lightweight and highly compatible with the Raspberry Pi's ARM architecture, delivering optimized performance and resource efficiency for these single-board computers. Raspbian Bookworm ships with the Linux 6.1 LTS kernel, bringing improved device support, power management, and performance tweaks specific to ARM architectures. Optimized primarily for ARMv7 and ARMv8 architectures, compatible with both 32-bit (armhf)

and 64-bit (arm64) Raspberry Pi devices. Raspbian Bookworm relies on APT (Advanced Package Tool) for package management, accessing a modified Debian repository with packages compatible with ARM architecture. The distribution includes access to Raspbian's Bookworm repositories, containing thousands of precompiled ARM-compatible packages, with additional back ports available for community-supported software.

- OpenCV (cv2) Python Module is used in Computer Vision Applications like Face Classifier and Detector along with multiple Image Processing Algorithms. It is installed using "sudo pip3 install opencv-python" with dlib along with it. It supports various operations like filtering, edge detection, face recognition, and object tracking.
- Max30100 python module allows configuration settings of the sensor such as LED current adjustment, maximum buffer length, pulse width, FIFO Interrupt, sample rate and sensor mode (spo2 and heartrate).
- Firebase_admin library offers connectivity to Firebase services by utilizing credentials and access to services like realtime database by using the references, url and json private key and token.
- PySerial provides access to the serial / tty ports of Raspberry Pi which is used to extract data from UART devices and USB devices. It allows both Read and Write functions over serial port.
- PyTTS is used for voice assistant which gives Text-To-Speech engine, configure volume rate and voice.
- Kodular is used to create Android Apps easily with Block-type editor with a Material Design UI. The apps in Kodular are backed with Blocks which provide Logic for every component which allows integration of various features like cloud, appealing interface and animations.

C. Methodology

The System consists of an embedded system which utilizes a Raspberry Pi microcomputer with multiple sensors and modules sending data to a Firebase Realtime Database which receives data from Pi from different modules connected to it. This data is extracted by the Kodular application which displays it for the user. The patient wearing CogniAid is offered with a voice assistant which interacts with the face detector and communicates the information about the person in front of the patient and their relation to them. The caregivers are provided with mobile application which constantly informs them about the patient's heart rate and SpO2 which plays key role during medical emergencies and are the primary parameters that are affected. In case of a spike in any of the parameters, the caregivers are alerted with an emergency reminder for quick action. The application also offers Geofencing service where the patient's continuous location is accessed in real-time, along with a safe zone. When the patient moves out of this safe zone, an alert is sent immediately to the caregiver to take action and ensure patient safety.

The initial stage of planning the system includes gathering components through consideration of power specifications and pre-evaluated budget. This should also include any adapters or ADC module or UART buses for multiple devices etc. Since the project involves Face recognition feature, picking appropriate algorithms also plays a major role in reliability and efficiency of the code. OpenCV comes with wide range of algorithms like Deep Neural Networks, Haar Cascading, Linear Binary Pattern Histogram, Convolutional Neural Networks and Single Shot Multibox Detector. Since we required code efficiency and limited budget, Haar Cascading seemed like a good choice for Classifier along with a LBPH Face detector.

Haar Cascading – This involves initially capturing a lot of samples of an individual's face which is used to train the classifier. This is done using the Haar Cascade XML files in Open CV library which is a dataset of pretrained models for haar cascade classifier. The way this algorithm works is by differentiating images as non-face images which are negative and face-containing images which are positive and the features are differentiated by subtracting sum of pixels under white rectangle from sum of pixels under black rectangle. The advantage of this algorithm is that, instead of applying all multiple features on a window, the features are grouped into different stages of classifiers and applied one-by-one. (Normally the first few stages will contain very many fewer features). If a window fails the first stage, discard it. We don't consider the remaining features on it.

LBPH – Linear Binary Pattern Histogram algorithm is applied after classification and differentiating face images from non-face images. LBPH is then used to recognize faces of the individuals in the classified images. The idea behind this algorithm is to summarize local structure of an image by comparing each pixel with its neighborhood. A central pixel is taken as a threshold intensity and is compared with its neighbors. If the intensity is higher than the threshold it is denoted as 1, else 0. This gives a binary sequence which can have 2^n combinations, where n is the number of neighbors considered which will give us Linear Binary Codes (LBP). These binary sequences are converted to a decimal in the range of 0-255 and respective grayscale is placed. This creates LBP for the entire image by repeating this for every cell. This histogram varies from person-to-person and hence Face recognition can be achieved.

The Haar cascade classifier is initially run to capture multiple samples of different faces and is labelled individually. These samples are stored in a folder. This dataset is trained by an LBPH trainer which stores it in lbph.yml database. The Face Recogniser utilizes the trained dataset and recognizes the faces in real time. This is done using a Bounded Box which displays Confidence level, the name and their relation to the patient. The name and relation are announced through Speakers using TTS whenever a face is recognized.

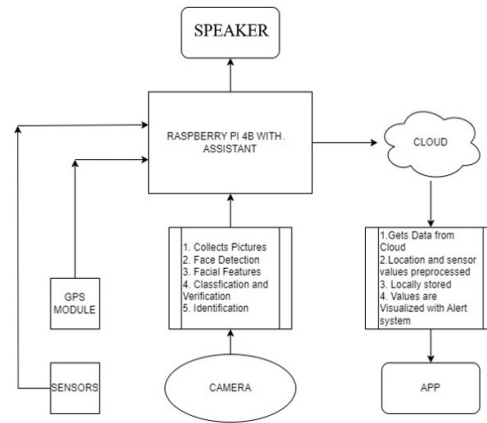


Figure 1. Block Diagram

A crucial step involves setting up Firebase and its real-time database service since cloud acts as primary database for the System apart from the memory of the Raspberry Pi. The real-time database is created with read and write rules set to True. The URL and JSON must be exported along with private key and store it inside the Raspberry pi to use it to access the Firebase remotely using Firebase-admin SDK.

Next phase involves health part of the objectives where cheap and robust sensor called MAX30100, which is an I2C module is utilized to measure Heart rate and SpO2 percent of the patient continuously. This data is fed to Firebase which is accessed by the Kodular App that helps in alerting caregivers in case of an emergency. The GPS module also is activated when the patient goes outdoors and helps in tracking real-time along with Geofencing, which is done by storing the latitude and longitude of the location in Firebase and extracting it. This ensures that the patient is not lost or getting out of the safe zone, since they have tendency to forget the roads or their home location. This allows the caregivers to take care of the patient in case they get lost or go out of the safe zone. The GSM module ensures that the caregivers get location of the patient even if the internet connection is lost through SMS and improves reliability. A detailed block diagram as shown in fig.1 explains the brief working of the CogniAid system and how each component is interfaced with each other.

IV. RESULTS AND DISCUSSION

The system achieved effective real-time tracking, health monitoring, and face recognition support for Alzheimer's patients. The GPS module, of the system-maintained accuracy in location monitoring, reliably defining and enforcing geofenced safe zones. The system generated alerts within few seconds on the mobile application, showing low latency in notification delivery. The health monitoring sensor consume low power hence making the system energy efficient. Real-time data was stored in the firebase and accessed through the mobile application, where alerts were triggered consistently when abnormalities occurred, ensuring a proactive approach to patient health.

The face recognition feature, implemented on RaspberryPi had an average confidence level of 90% after being tested under various lighting conditions. Switching between online and offline modes was also evaluated, with the system seamlessly transitioning to offline mode whenever the Wi-fi got disconnected and sent an immediate message to the caregiver saying the "Wi-Fi has been disconnected" with the last known location of the patient making it easy for the caregiver to take care of the patient more easily, thereby increasing patient safety and decreasing dependency on caregivers to some extent.

The mobile app interface as shown in Fig.2 and Fig.3 delivered efficient performance, with real-time data visualization, alert delivery, and geofencing settings accessible in a user-friendly format, supporting caregivers in managing patient care effectively and consistently.



Figure 2. Results on Mobile Application Displaying (A) Patients' Health Parameters (B) Interactive UI For Medicine Reminder and Timely Notification For Taking the Medicine (C) Interactive UI for Setting The Reminder Timings

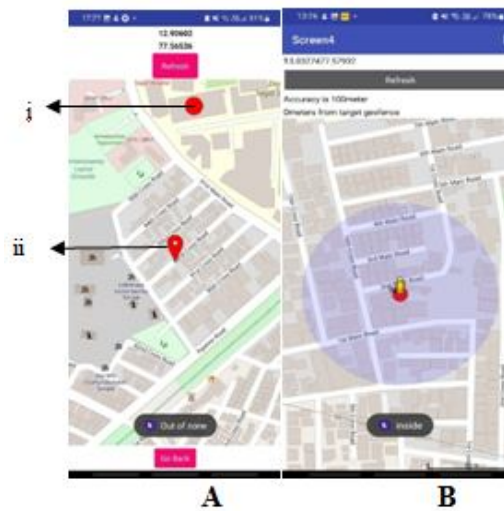


Figure 3. Results of geofencing implemented on mobile application (A) "out of zone" alert sent when patient is outside the safe zone (B) shows the patient is within the safe zone (i) Safe zone (ii) Patient's current location

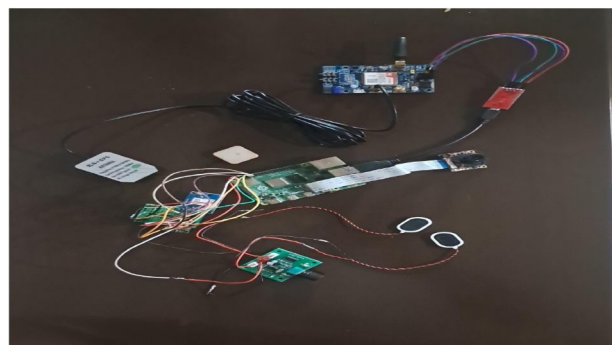


Figure 4. Hardware Prototype

V. CONCLUSION

This paper describes CogniAid as a comprehensive IoT-based system, aimed at enhancing the safety and quality of life for patients. It is centered on the Raspberry Pi. Firstly, we collect the location and health parameters of the patient continuously and store them in the cloud. This data is later used to send alerts to the patient and the caregiver whenever an abnormality occurs. Apart from this, the CogniAid system is also able to assist the patient

in maintaining the routine without any burden. The user application created using Kodular is a very user-friendly application used for giving timely alerts to both, the patient and the caregiver.

The system's design prioritizes both patient independence and caregiver support. Face recognition technology aids patients in recognizing close ones, fostering social connection, and reducing confusion.

All these features make the system robust. Overall, CogniAid offers a promising solution to Alzheimer's care by merging IoT capabilities with real-time monitoring and patient specific features. This paper demonstrates the potential of IoT in healthcare, particularly in supporting patient safety. Future work could focus on enhancing geofencing accuracy, expanding alert features, and incorporating more advanced analytics, further improving CogniAid's capabilities and adaptability for widespread use in Alzheimer's patient care.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGMENT

We express our profound thanks to Dr. Suma M R, Department of ECE, DSCE, Bengaluru for all the invaluable guidance and help she gave us throughout this project. She provided us with required knowledge and also encouraged us with her suggestions.

We extend our special thanks to Dayananda Sagar College of Engineering for giving us the necessary facilities and resources needed to execute this work.

REFERENCES

- [1] P. Praveen and S. Madihabanu (2023), "A Real Time Multiple Object Tracking in Videos using CNN Algorithm", 2023 International Conference on Self Sustainable Artificial Intelligence Systems (ICSSAS), pp. 1-6, 2023.
- [2] S. Patil et al., "Medical Assistance for Alzheimer's Disease Using Smart Specs," 2022 4th International Conference on Circuits, Control, Communication and Computing (I4C), Bangalore, India, 2022, pp. 363-366
- [3] R. Chokri, W. Hanini, W. B. Daoud, S. A. Chelloug and A. M. Makhoul, "Secure IoT Assistant-Based System for Alzheimer's Disease," in IEEE Access, vol. 10, pp. 44305-44314, 2022
- [4] R. Reena, Srishti R, Harini M1, Aezeden Mohamed, ErgashevaSurayyo and Senthil Kumar R, "IoT-Based Assistant for Alzheimer's Patient with Reminder System and Tracking Using GPS"
- [5] S. Patil et al., "Medical Assistance for Alzheimer's Disease Using Smart Specs," 2022 4th International Conference on Circuits, Control, Communication and Computing (I4C), Bangalore, India, 2022, pp. 363-366
- [6] S. N. Siri, H. B. Divyashree and S. P. Mala, "The Memorable Assistant: An IoT-Based Smart Wearable Alzheimer's Assisting Device," 2021 IEEE International Conference on Computation System and Information Technology for Sustainable Solutions (CSITSS), Bangalore, India, 2021, pp. 1-6
- [7] Johnson, M., & Thompson, B. (2020). "Comprehensive IoT Systems for Alzheimer's Care: A Case Study." Journal of Healthcare Engineering, 2020, 1-12.
- [8] Ullah et al., "Effective Monitoring of Alzheimer's Patients Using IoT Based Wearable Devices", in IEEE Access, vol. 8, pp. 33716-33726, 2020
- [9] S. Al-Nuaimi et al., "IoT-Based Monitoring System for Alzheimer Patients", in Procedia Computer Science, vol. 160, pp. 38-45, 2019
- [10] C. G. De Souza et al., "An IoT-Based Healthcare Platform for Patients with Alzheimer's Disease" in IEEE Access, vol. 7, pp. 178206-178216, 2019
- [11] M. Farhan et al., "IoT-Based Cognitive Stimulation Framework for Early Detection and Prevention of Alzheimer's Disease" in IEEE Access, vol. 7, pp. 678-688, 2019
- [12] P. Mamoshina et al., "Applications of Deep Learning in Biomedicine", in Molecular Pharmaceutics, vol. 15, no. 12, pp. 4312-4319, 2018
- [13] S. K. Dash et al., "A Smart Healthcare Monitoring System for Patients Suffering from Alzheimer's Disease", Procedia Computer Science, vol. 132, pp. 1610-1618, 2018
- [14] C. Nugent et al., "IoT for Elderly Healthcare—Challenges and Opportunities", in Springer, 2018
- [15] S. M. R. Islam, D. Kwak, M. H. Kabir, M. Hossain and K. -S. Kwak, "The Internet of Things for Health Care: A Comprehensive Survey," in IEEE Access, vol. 3, pp. 678-708, 2015, doi: 10.1109/ACCESS.2015.