SSRG International Journal of Electrical and Electronics Engineering
ISSN: 2348-8379/ https://doi.org/10.14445/23488379/IJEEE-V12I10P113
Volume 12 Issue 10, 170-185, October 2025

Original Article

Smart Dementia Care: IOT-Based Location Tracking and Medication Reminder System

Novi Azman[1], Cepi Sukmayara[2]

[1,2]*Electrical Engineering Department, Universitas Nasional, Jakarta, Indonesia.*

[1]*Corresponding Author : novi.azman@civitas.unas.ac.id*

Received: 09 August 2025 Revised: 11 September 2025 Accepted: 14 October 2025 Published: 30 October 2025

Abstract - *The increasing proportion of elderly individuals in Indonesia has contributed to a significant rise in dementia cases, projected to escalate from 1.2 million in 2015 to 3.9 million by 2050. This study aims to address key challenges in dementia care-particularly poor medication adherence and disorientation-through the development of a real-time monitoring system. The proposed system utilizes an Internet of Things (IoT)-based architecture that integrates Global Positioning System (GPS), geofencing, Google Maps, and Telegram for continuous patient tracking and communication. Materials used include a GPS-enabled wearable device, a microcontroller unit, and a communication module configured to interface with a cloud-based notification system. The method involves defining a 240-meter geofence radius as a safe zone for patients and triggering alerts when this boundary is crossed. Medication adherence is supported through automated voice reminders and Telegram message notifications. Experimental results demonstrate an average localization error of 6.6 meters. The system achieves a response time of 23 seconds for voice alerts and 34 seconds for Telegram notifications. These findings indicate that, despite minor communication delays, the system is capable of enhancing patient safety and facilitating timely intervention by caregivers. This research implies the feasibility of low-cost, scalable IoT solutions for dementia care, and future work will explore system scalability, integration with electronic health records, and adaptive learning algorithms for personalized care patterns.*

Keywords - *Dementia, Monitoring, Geofencing, Internet of Things, Telegram.*

1. Introduction

According to the 2022 census, Indonesia's population reached 274.20 million, with projections estimating an increase to 328.93 million by 2050. This growth includes a significant rise in the elderly population, particularly individuals aged 60 and above, expected to increase from 6.07% in 2022 to 21.90% by 2050 [1]. Such demographic shifts pose various challenges, particularly in managing the health and well-being of aging individuals. One critical issue is dementia, a condition characterized by cognitive decline and memory loss that significantly affects daily living, social interactions, and independence [2-4]. Studies show that dementia not only affects cognitive functions but also leads to disorientation, wandering behavior, and poor adherence to medication, which in turn increases the risks of injury, hospitalization, and caregiver burden [5-7]. Dementia is a global concern, especially in low- and middle-income countries where aging populations are growing rapidly. In Indonesia, the number of individuals living with dementia is projected to rise from 1.2 million in 2015 to 3.9 million by 2050 [8-11]. Likewise, in the Asia-Pacific region, dementia cases are expected to increase from 55.2 million in 2019 to 152.8 million by 2050 [12, 13]. This trend highlights the urgent need to address dementia-related challenges. Inadequate care and support can result in severe health deterioration and social risks, such as a higher incidence of disoriented or missing individuals. To mitigate these risks, innovative solutions are needed to enhance the quality of life for dementia patients and ease the burden on caregivers [14]. This study focuses on the development of an Internet of Things (IoT)-based system to assist in dementia care [14, 15]. The proposed system incorporates geofencing technology to monitor patients' locations, ensuring they remain within safe zones, and provides automated reminders to support routine activities like medication intake [16, 17]. By leveraging IoT capabilities, this system aims to reduce caregiver workload while enhancing safety and well-being for dementia patients [16, 18]. It is also aligned with previous studies exploring IoT solutions for various health-related problems [19-25]. This study addresses the lack of an accessible, reliable, and low-cost mechanism for monitoring people living with dementia in home-like settings within the Indonesian context. Caregivers require a system that can (i) detect safe-zone breaches via geofencing, (ii) deliver actionable real-time alerts through familiar channels, and (iii) support routine adherence (e.g., medication reminders) to reduce wandering risk and caregiver burden. In response, this study develops an IoT-based prototype that integrates an Arduino Mega 2560, a GPS module, and a cloud-based platform. The resulting system provides practical and user-friendly monitoring and assistance, addressing both immediate and long-term healthcare challenges. Despite substantial progress in IoT-based dementia care, several gaps remain. First, many systems prioritize location tracking and visualization without integrating routine-support functions such as medication reminders and caregiver-facing messaging [26-30]. Second, GPS- and cloud-based solutions frequently depend on bespoke mobile apps or relatively costly wearables, with limited transparency regarding bill of materials and operating costs for low-resource settings [30-32]. Third, prior work seldom details an end-to-end, implementable geofencing pipeline grounded in the Haversine formulation, covering purpose, variables, assumptions, and limitations, coupled with lightweight alert delivery (e.g., Telegram) suitable for caregivers [16, 30, 32]. Finally, challenges in standardizing GPS-derived trajectories hinder integration into routine care pathways [29]. These gaps motivate a simple, deployable, and low-cost solution that unifies geofencing, real-time alerts, and routine support with explicit cost reporting and implementation details.

This study offers four main contributions. First, it designs and implements a low-cost IoT prototype built on an Arduino Mega 2560 with a GPS module and a cloud back end, tailored for dementia care in home-like settings. Second, it specifies an explicit geofencing pipeline grounded in the Haversine formula, clarifying its purpose, variables, assumptions, limitations, and implements a radius-based decision routine for safe-zone monitoring. Third, it delivers real-time caregiver notifications via Telegram with localized (Indonesian) prompts, alongside scheduled reminders to support daily routines such as medication intake. Fourth, it provides an intuitive caregiver-facing interface and message design that reduces workload while preserving patient safety.

2. Related Work

This study utilizes data collection, data processing, and information dissemination techniques to develop a monitoring and care system for dementia patients. Several previous studies have proposed IoT-based solutions to address dementia-related challenges, particularly in location tracking and real-time alerts. These studies are summarized below to establish the context of this research. A prototype IoT system designed for both indoor and outdoor tracking, as well as activity monitoring of dementia patients, has been developed, employing the Global Navigation Satellite System (GNSS) for outdoor localization and a symbolic infrared-based location system for indoor positioning. The system provides positional information to caregivers or healthcare staff through an accessible web platform, enabling the visualization of patients' movement trajectories over several weeks and data on room occupancy and physical activity. Such information can be utilized to detect anomalies in patients' daily routines or to locate disoriented individuals [26].

The application of Internet of Things (IoT) technologies in dementia care has demonstrated significant potential in monitoring and improving patients' quality of life, particularly in location tracking and the prevention of wandering [27, 28]. GPS-based solutions have been widely adopted to assist caregivers in locating missing dementia patients and in non-invasively monitoring their mobility patterns [27, 29]. Research has identified various IoT and GPS applications in dementia care, including real-time location monitoring systems integrated with mobile applications [27, 28].

Wearable GPS devices combining an ESP32 microcontroller, a u-blox NEO-6M receiver, and a SIM800L modem enable continuous tracking and automated alerts; geofencing enforces virtual safety boundaries with notifications upon boundary violations [30]. These systems have been shown to enhance autonomy while alleviating caregiver concerns about wandering. Another study proposed a real-time health monitoring system using the Global Positioning System (GPS) and Haversine distance calculations to classify individuals as normal, with Mild Cognitive Impairment (MCI), or dementia. This system can be connected to an Arduino Mega 2560 with nRF24L01 or ZigBee modules [33]. Wearable devices have emerged as a promising solution for continuous data collection, addressing the limitations of conventional methods [34].

To address the challenges of dementia care, cloud-based intelligent sensing systems have been proposed for real-time health management of dementia patients. These systems integrate wearable and ambient sensing devices to monitor health indicators such as heart rate and motion, transmitting the collected data to a cloud server for analysis. Cloud-based solutions enhance collaborative care and patient support by enabling continuous communication among caregivers, physicians, nurses, and family members. Alerts can be triggered by predefined thresholds or abnormal events, allowing rapid intervention during emergencies [31].

Further research has focused on developing IoT prototypes capable of locating Alzheimer's patients in real-time and reminding them to take medication through scheduled alarms. This prototype employs a NodeMCU-23DSP board, a Neo-06 GPS module, and a wireless modem/Wi-Fi router. Remote monitoring via the Blynk 2.0 application allows caregivers to track patients' medication adherence and daily activities [16]. Similarly, a dementia GPS tracker based on the A9G IoT device, incorporating GPS, GPRS, and GSM technologies, has been designed to track patients, enable voice calls, and send alerts to caregivers via messages or calls when a button is pressed for more than five seconds [32]. Further advances in IoT-based systems extend beyond location tracking to include wearable devices capable of monitoring vital signs and delivering medication reminders. Recent studies have also explored the use of GPS trajectory analysis combined with machine learning to detect atypical wandering behaviors and provide real-time alerts to caregivers [35]. However, challenges remain, particularly regarding the need for standardization and harmonization of GPS-derived data to facilitate stronger integration into clinical trials [29]. Overall, such IoT-driven solutions aim to alleviate both the financial and emotional burdens on caregivers, while enhancing patient safety and quality of life.

IoT-based remote physiological monitoring systems have demonstrated feasibility and acceptable compliance among dementia patients and their caregivers, supporting the development of technologies, care pathways, and policies for IoT-enabled remote monitoring [36]. Other studies emphasize the importance of intelligent solutions that integrate both wearable and non-wearable technologies while considering multiple dementia risk factors as promising directions for future research [37]. Collectively, the surveyed studies demonstrate that IoT-based geofencing and location monitoring can enhance safety and oversight in dementia care. Building on these insights, this study integrates geofencing with real-time alerts, automated reminders, and a caregiver-oriented interface tailored to dementia care, with a focus on deployability in home-like, resource-constrained settings.

Compared with indoor-outdoor tracking and multi-week trajectory visualization in [26], this study contributes an actionable geofencing pipeline and caregiver-facing alerts integrated with routine reminders. Relative to GPS-based wearables and ESP32/Neo-6M/SIM800L trackers with geofencing notifications [30], the design targets lower system complexity, introduces Telegram-based alerts to minimize app dependencies, and reports a transparent cost breakdown. In contrast to NodeMCU/Blynk solutions emphasizing medication reminders and remote monitoring [16], the system unifies safe-zone monitoring and routine support within one end-to-end pipeline and details the Haversine-based decision routine. Systems using A9G devices that enable calls and button-triggered alerts [34] are complementary; unlike those systems, the alerts here are automatically triggered on geofence breaches and localized for caregiver use. Cloud-centric sensing frameworks [33] provide broad physiological monitoring; the scope here is narrower but offers a deployable, low-cost blueprint for geofencing-centric safety with explicit implementation details. Finally, whereas prior studies apply GPS/Haversine for classification or mobility analysis [31, 35], this study operationalizes Haversine explicitly for real-time safe-zone enforcement with caregiver-oriented messaging. A critical appraisal of the surveyed literature reveals practical constraints for home-like deployments. Indoor-outdoor tracking with multi-week trajectory visualization emphasizes trajectory insight rather than an actionable, caregiver-facing alert pipeline [26]. GPS wearables and ESP32/Neo-6M/SIM800L trackers commonly deliver app-based notifications but can increase system complexity and depend on bespoke apps, with limited emphasis on an implementable radius-based geofencing routine [30]. NodeMCU/Blynk solutions foreground reminders and remote monitoring, yet do not unify routine support with an explicit Haversine-based decision pipeline for safe-zone enforcement [16]. A9G-based trackers enable calls and button-triggered alerts, but alerts are user-initiated rather than automatically fired on geofence breaches [34]. Cloud-centric sensing frameworks broaden physiological monitoring but are not geofencing-centric and report fewer details on an end-to-end distance-threshold pipeline [33]. Studies leveraging GPS/Haversine for classification or trajectory analytics prioritize inference or behavior detection over an operational geofence routine with caregiver-oriented messaging [31, 35]. In addition, standardization and harmonization issues in GPS-derived trajectories remain open for routine care pathways [29]. These observations motivate the operationalization of an explicit Haversine pipeline with Telegram-based alerts and integrated routine support, targeting low-complexity, deployable use in home-like settings.

3. Materials and Methods

This section outlines the methodology used to design and develop the system, as shown in Figure 1. The research follows a structured workflow beginning with problem identification, literature review, and data collection, followed by the design, integration, and development of hardware and software components. The process includes flowcharts and system diagrams that describe both architectural and functional aspects. The system underwent rigorous testing and iterative refinement to ensure reliability and user-centered performance, ultimately supporting improved monitoring and care for dementia patients.

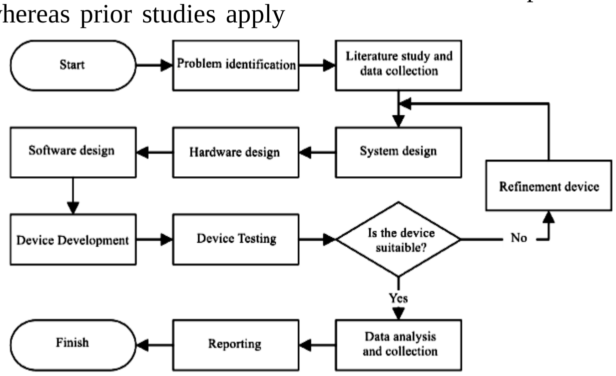

Fig. 1 Research flowchart

3.1. Overall System Block Diagram

Figure 2 illustrates Smart Dementia Care: IoT-Based Location Tracking and Medication Reminder System. The system consists of three main components: the device block, the network interface block, and the caregiver-monitoring block. These interconnected units work together to enable real-time tracking and medication alerts while keeping caregivers informed of the patient's status and location. The device block is the core of the system, incorporating essential hardware for real-time tracking and scheduled medication reminders.

An Arduino Mega Pro processes input from the GPS Neo-M8N and RTC DS3231 modules. Data is transmitted via the GSM SIM800L V2 module to a web interface, enabling caregivers to receive updates through Telegram and Google Maps. When a patient exits the geofenced area, the system sends alerts automatically. Caregivers can also manually request updates. Scheduled voice alerts and reminders are delivered using the DFPlayer Mini module. The system is powered by a rechargeable 18650 lithium battery, ensuring continuous operation and enhancing patient safety through timely, automated alerts.

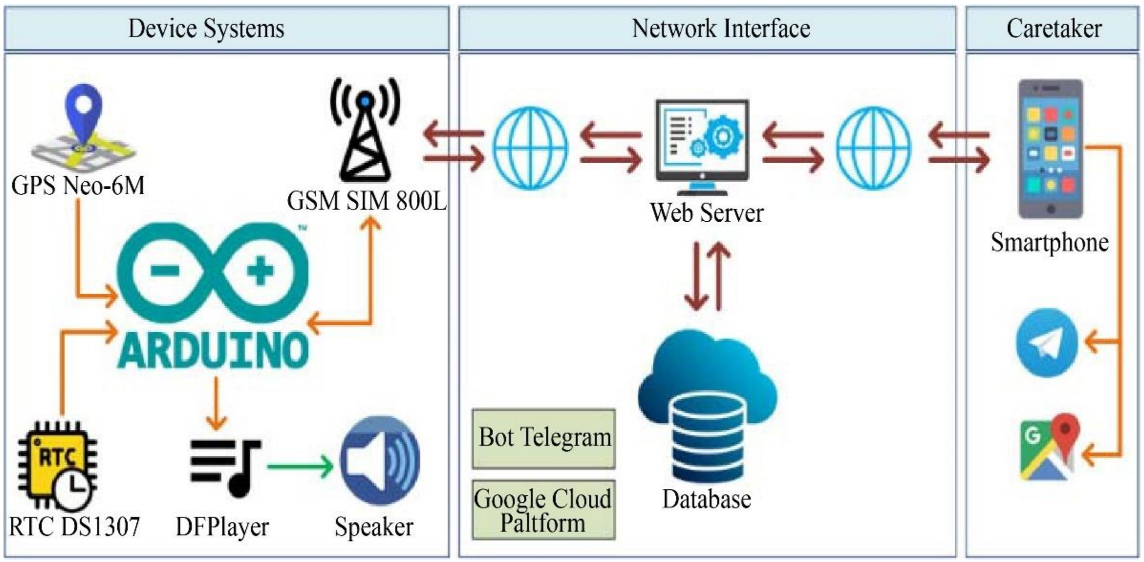

Fig. 2 System block diagram

3.2. Electrical Design

The electrical design involves the integration of key hardware components to implement the IoT-based monitoring and reminder system. The main components include an Arduino Mega Pro, GPS Neo-M8N, GSM SIM800L, RTC DS3231, DFPlayer Mini, 18650 lithium-ion battery, charging module, status indicators, and a mini speaker.

The Arduino Mega Pro (ATMega2560) coordinates communication among modules, all powered through a common 5V supply and ground. This configuration ensures efficient system operation for geolocation, alert transmission, and scheduled medication notifications. Table 1 summarizes the hardware components, roles, interfaces, and integration notes.

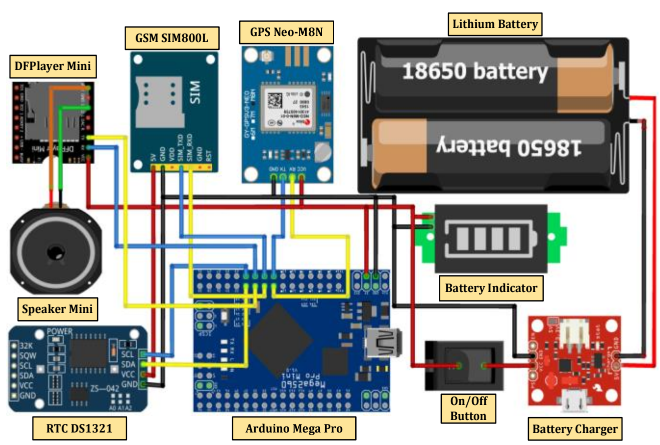

Fig. 3 System hardware schematic

Table 1. Detailed electrical specification

Subsystem	Component (Model)	Primary role	Interfaces / Pins	Supply	Integration notes
MCU/Controller	Arduino Mega Pro (ATmega2560)	Central coordination of sensing, geofencing, alerts, and reminders	UART (multiple), I²C (SDA/SCL), SPI, GPIO	5 V (regulated)	Hosts Haversine/geofence logic and messaging routines; bridges GPS, GSM, RTC, audio, and indicators.

GNSS	GPS Neo-M8N	Position fix for geolocation and geofence evaluation	UART (TX/RX to MCU) *(alt.: I²C if supported by module)*	(Module-rated; regulated)	It requires a clear sky view and a dedicated antenna; it should be placed away from the GSM antenna to reduce interference.
Cellular/ Comms	GSM SIM800L	Uplink/downlink for alerts (e.g., Telegram gateway/SMS)	UART (TX/RX to MCU), PWRKEY (GPIO)	Dedicated rail per module specs	Provide adequate bulk decoupling; account for TX current bursts; and provide level-shift logic if required by the module.
Real-time clock	RTC DS3231	Stable time base for scheduled reminders and timestamps	I²C (SDA/SCL), INT/SQW *(optional)*	3.3–5 V (module-rated)	Keep coin-cell backup installed; route I²C with short traces; optional alarm pin to MCU.
Audi	DFPlayer Mini	Local audio prompts/alerts to the patient	UART/Serial to MCU, SPK+/SPK– to speaker	Module-rated	Uses microSD for audio assets; ensure proper speaker impedance and enclosure for clarity.
Power source	18650 Li-ion (1S)	Main energy storage	-	3.0–4.2 V (cell)	Use a protected cell; monitor voltage if needed; isolate high-current paths from GNSS lines.
Charging/PMIC	Charging module (1-cell Li-ion)	Battery charging and protection	VIN/USB, BAT+, BAT–, OUT+ / OUT–	As per the module	Ensure thermal relief and correct charge current; common ground with the system.
Indicators	Status LEDs (power, GPS lock, network, alert)	User feedback on system states	MCU GPIO (with resistors)	5 V (via GPIO)	Assign distinct blink patterns for diagnostics; keep current limiting per LED.
Audio output	Mini speaker	Audible prompts to the patient	From DFPlayer SPK+/SPK–	As per DFPlayer	Mount away from the mic (if any) to avoid acoustic feedback.

3.3. Mechanical Design

Following the schematic design, the mechanical design ensures ergonomic integration of the hardware. Figure 4 shows the enclosure created using Tinkercad and Microsoft Visio for accurate spatial planning.

The final device is housed in a belt-mounted case measuring 120 mm × 80 mm × 60 mm, offering portability and comfort for the patient. This wearable design promotes ease of use while maintaining secure module placement.

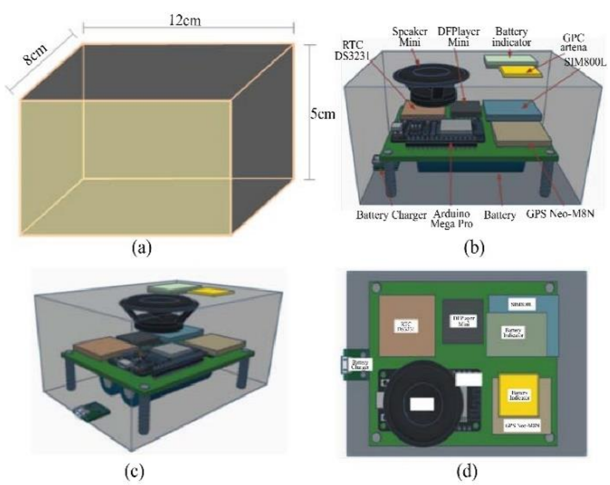

Fig. 4 Mechanical design: (a) System equipment box design, (b) Front view, (c) Side view, and (d) Top view of component layout within the enclosure.

3.4. Software Design

The software integrates multiple tools and platforms, including Arduino IDE (C programming), Visual Studio Code (PHP), Autodesk Eagle, Telegram Bot API, Google Cloud Platform, and a web interface for caregivers.

- Arduino IDE: Programs the microcontroller to manage the GPS Neo-M8N, RTC DS3231, GSM SIM800L, and DFPlayer Mini.
- Visual Studio Code (PHP): Hosts the web application and database to handle user requests and communicate with Telegram.
- Telegram Bot API: Sends real-time alerts for geofence breaches and medication reminders.
- Google Cloud Platform: Utilized for the Maps API to display patient location.
- Web Hosting: Manages data storage and remote access for caregivers.

This architecture ensures seamless hardware control, real-time communication, and intuitive interaction for remote dementia care.

3.5. System Workflow and Radius Calculation

Figures 5 and 6, Workflow and radius calculation system. The GPS module provides latitude and longitude coordinates to support the geofencing feature. The Haversine formula calculates the distance between the patient's current location and a predefined reference point (e.g., the patient's home), as presented in Equations (1) and (2).

The conversion of the Haversine formula is also implemented as a subprogram for geofencing radius calculation, as shown in Figure 7. Specifically, the Haversine formula is applied to determine the great-circle distance on the Earth's surface with the aim of detecting whether the patient remains within the safe radius. The variables used include the latitude and longitude coordinates of both the patient's position and the reference point, as well as the Earth's Radius (R). The underlying assumption is that the Earth is a perfect sphere, which simplifies computation and ensures efficiency. However, its limitation is that accuracy may decrease over very long distances or at high latitudes, in which case ellipsoid-based methods offer greater precision.

$$a = sin^2\left(\frac{\Delta Lat}{2}\right) + \cos(Lat_1).\cos(Lat_2).sin^2\left(\frac{\Delta Long}{2}\right) \quad (1)$$

$$d = 2r.\arcsin(\sqrt{a}) \quad (2)$$

Where:

- Lat_1 & $Long_1$ are the reference coordinates
- Lat_2 & $Long_2$ are the actual coordinates
- $\Delta Lat = Lat_2 - Lat_1$
- $\Delta Long = Lat_2 - Long_1$
- d is the calculation radius value
- r (Earth's Radius) = 6371 km
- 1° = 0,01745329 radians

If the calculated distance exceeds the 240-meter threshold, a voice alert instructs the patient to stop moving, while a Telegram notification with the patient's coordinates is sent to the caregiver. The system also triggers medication reminders using a timer-based schedule, with alerts set at 08:00 AM, 01:00 PM, and 08:00 PM. These reminders are delivered via audio and Telegram messages to ensure adherence.

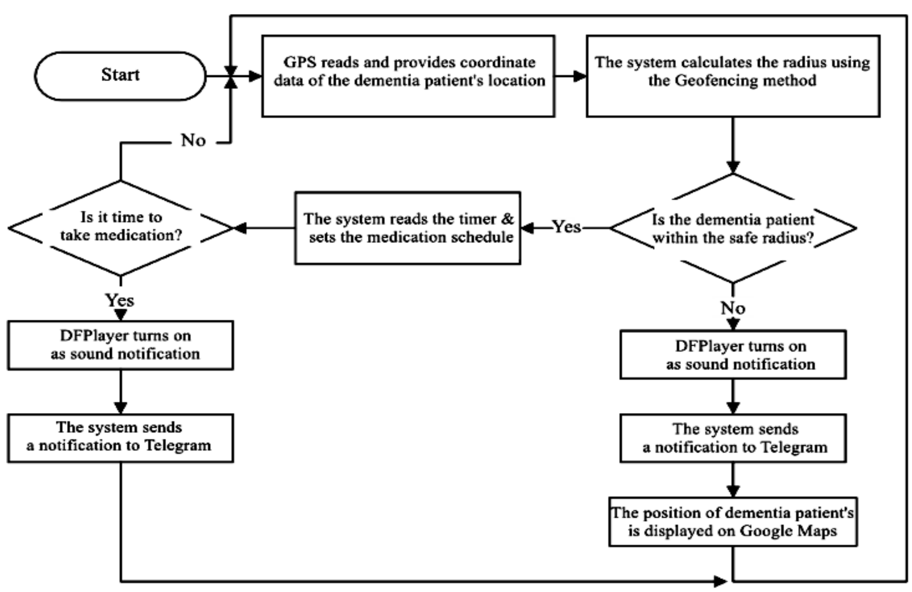

Fig. 5 Flowchart of dementia patient monitoring system

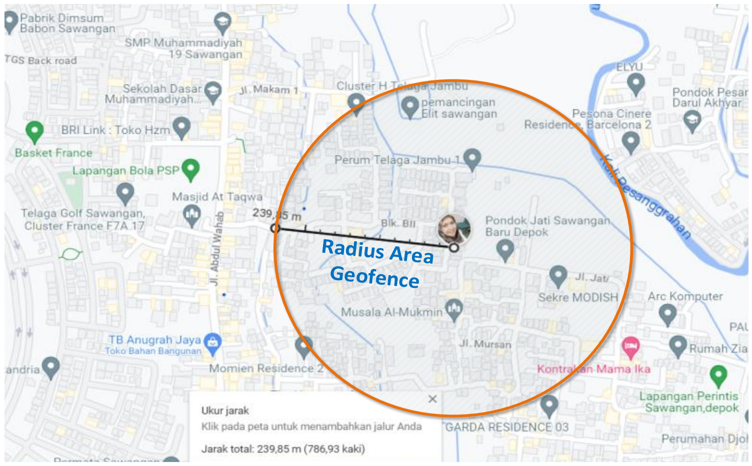

Fig. 6 Geofence area radius design

```
#include <TinyGPS++.h>

const float sp_lintang = -6.395236;  // latitude
const float sp_bujur = 106.764062;;  // longitude
const float maks_radius = 240;         // longitude
String map_url;
float radius;
float lintang, bujur;

TinyGPSPlus gps;

void setup() {
  Serial.begin(9600);
  Serial3.begin(9600);
}

void loop() {
  while (Serial3.available() > 0) {
    gps.encode(Serial3.read());
    if (gps.location.isUpdated()) {
      lintang = gps.location.lat();
      bujur = gps.location.lng();
      map_url = "https://maps.google.com?q=" + String(lintang, 6) + "," + String(bujur, 6);
      radius = getDistance(lintang, bujur, sp_lintang, sp_bujur);

      Serial.print(F("Radius: "));
      Serial.print(radius);
      Serial.print(F(" Meter, Google Map: "));
      Serial.println(map_url);
    }
  }
}

float getDistance(double lat1, double lon1, double lat2, double lon2) {
  double dLat = radians(lat2 - lat1);
  double dLon = radians(lon2 - lon1);
  double a = sin(dLat / 2) * sin(dLat / 2) + cos(radians(lat1)) * cos(radians(lat2)) * sin(dLon / 2) * sin(dLon / 2);
  double c = 2 * atan2(sqrt(a), sqrt(1 - a));
  double d = 6371000 * c;

  return d;
}
```

Fig. 7 Haversine application for geofencing sub-program

3.6. Telegram Bot Development

Due to the SIM800L module's limitation to TLS 1.0, an outdated protocol unsupported by Telegram, a PHP-based message relay was implemented. This intermediary script receives data from the microcontroller and forwards it to the Telegram Bot API via a secure server, ensuring reliable message delivery.

3.7. Testing Procedure

The system was tested for all hardware modules and functions. The RTC DS3231 was validated for accurate timekeeping; the DFPlayer Mini and the speaker for audio output; GSM SIM800L for message delivery; and GPS Neo-M8N for location accuracy. Figure 8. Neo-M8N GPS Accuracy Testing, Figure 9 monitoring system, and drug consumption schedule testing. Geofencing and medication reminder functions were also assessed. The results confirmed the system's reliability for real-time tracking, notification, and routine scheduling, indicating its readiness for deployment in dementia care settings.

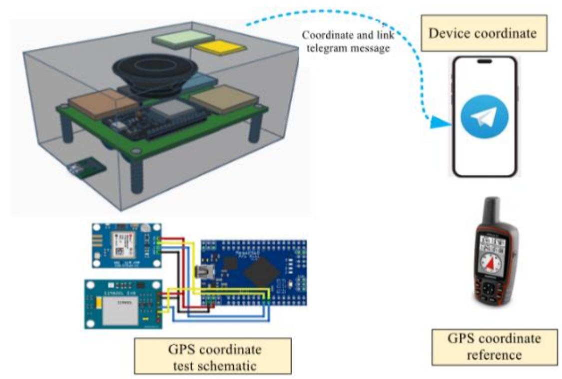

Fig. 8 Neo-M8N GPS accuracy testing

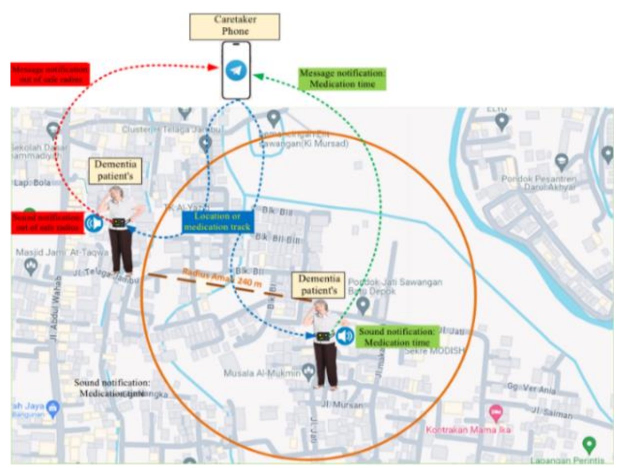

Fig. 9 Monitoring system and drug consumption schedule testing

4. Results and Discussion

The Smart Dementia Care IoT-Based Location Tracking and Medication Reminder System was successfully developed into a functional prototype, as shown in Figure 10. Panel (a) displays the front view, highlighting the compact and user-friendly interface equipped with an LED indicator and power switch. Panel (b) shows the right view, featuring the communication antenna for stable connectivity. Panel (c) illustrates the internal layout, optimizing space for the GPS, RTC, and GSM modules. Panel (d) demonstrates the ergonomic design mounted on a belt for patient comfort, while Panel (e) presents the device in actual use. The design prioritizes both functionality and discretion, ensuring efficient location and medication schedule monitoring.

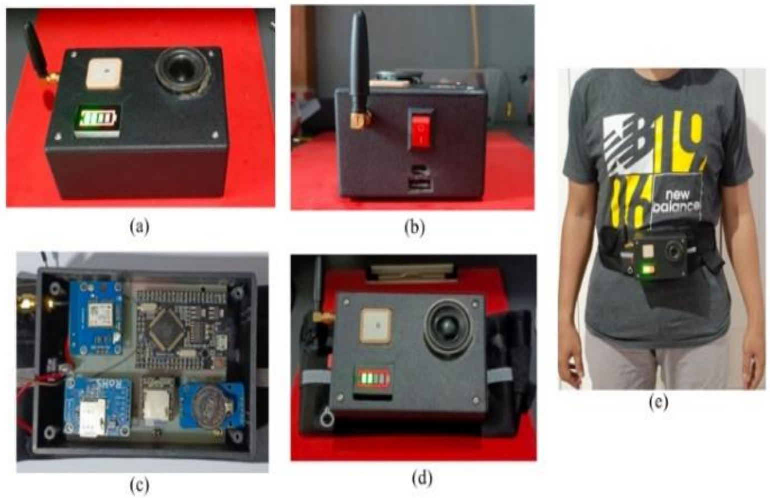

Fig. 10 Device result design: (a) Front view, (b) Right view, (c) Component layout, (d) Belt-mounted, and (e) Device implementation on the user.

4.1. GPS Neo-M8N Performance Testing

The GPS Neo-M8N module was tested to evaluate its performance and accuracy by comparing its output with that of a high-precision reference device, the Garmin Oregon 650. The test involved 20 trials at various locations. The Haversine formula was used to calculate the distance between GPS readings from the Neo-M8N and the Garmin device. The average localization error was found to be 6.1 meters, with variations due to environmental factors such as satellite visibility, obstructions, and signal stability. Table 2 presents the detailed test results, showing consistent spatial accuracy within the acceptable range for healthcare-related applications.

Table 2. Neo-M8N GPS module test results

Test No	Coordinate Reference		GPS Neo-6M		Garmin Oregon 650		Radius (m)		Distance Error (m)
	Lat	Long	Lat	Long	Lat	Long	GPS Neo-M8N	Garmin Oregon 650	
1	-6,3955	106,7619	-6,3951	106,7641	-6,3952	106,7641	247	246,3	0,7
2	-6,3955	106,7619	-6,3951	106,7638	-6,3951	106,7637	218,9	199,7	19,2
3	-6,3955	106,7619	-6,3954	106,7635	-6,3954	106,7636	172,2	182,5	10,2
4	-6,3955	106,7619	-6,3954	106,7629	-6,3954	106,7629	110,5	112,3	1,8
5	-6,3955	106,7619	-6,3949	106,7627	-6,3949	106,7627	110,4	109	1,5
6	-6,3955	106,7619	-6,3944	106,7627	-6,3944	106,7627	150,3	147,8	2,5
7	-6,3955	106,7619	-6,3948	106,7633	-6,3948	106,7632	170,8	166,2	4,5
8	-6,3955	106,7619	-6,3948	106,7645	-6,3949	106,7638	241,2	223,3	17,8
9	-6,3955	106,7619	-6,3942	106,7642	-6,3943	106,7641	271	267	4
10	-6,3955	106,7619	-6,3949	106,7622	-6,3949	106,7623	75,1	80,3	5,2
11	-6,3955	106,7619	-6,3948	106,7616	-6,3948	106,7616	86,1	84,3	1,8
12	-6,3955	106,7619	-6,3944	106,7611	-6,3943	106,7611	157,3	159,2	1,9
13	-6,3955	106,7619	-6,3927	106,7585	-6,3927	106,7586	493,3	487,6	5,7
14	-6,3955	106,7619	-6,3941	106,7583	-6,3941	106,7584	431,9	424,6	7,3
15	-6,3955	106,7619	-6,3992	106,7564	-6,3992	106,7565	731,5	725,5	6
16	-6,3955	106,7619	-6,4024	106,7552	-6,4024	106,7553	1063,50	1054,70	8,8
17	-6,3955	106,7619	-6,4041	106,7544	-6,4041	106,7544	1262,90	1262,90	0,1
18	-6,3955	106,7619	-6,4048	106,7537	-6,4048	106,7537	1373,50	1368,70	4,9
19	-6,3955	106,7619	-6,4058	106,7524	-6,4058	106,7524	1552,00	1545,80	6,2
20	-6,3955	106,7619	-6,4002	106,7557	-6,4004	106,7549	928,3	940,6	12,3
Average									6,1

4.2. System Response to Safe Radius Violation

The system was evaluated under two scenarios: (1) when the patient exceeds the 240-meter safe radius, and (2) when the patient remains within the radius during scheduled medication times.

In the first scenario, the system issued real-time alerts via voice and Telegram messages when the patient moved beyond the designated geofenced area. Table 3 summarizes the test results, showing an average distance deviation of 6.6 meters and a response accuracy of 2.77%. These findings indicate that the geofencing and alert mechanisms function reliably under real-world conditions.

The system output, generated in response to a dementia patient exiting the safe radius, is also delivered via Telegram. The message 'Warning! The dementia patient has exited the safe radius (On figure: *Peringatan! Penderita demensia sudah keluar radius aman*), indicating that the patient is outside the designated safe zone, as shown in Figure 11.

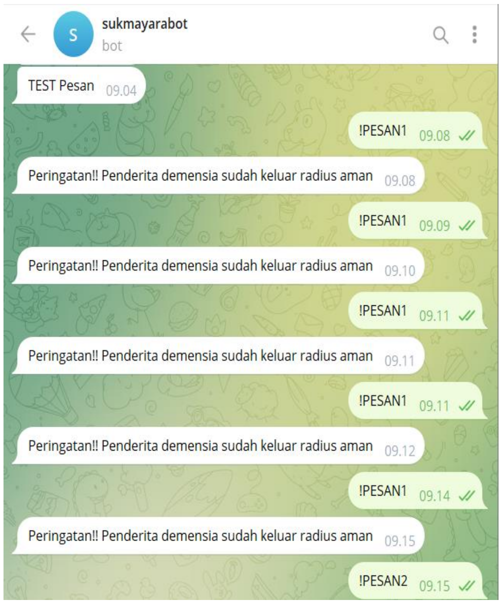

Fig. 11 Telegram notification

Table 3. System response test results with geofency method

Test No	Reference Coordinate		Actual Coordinate		Radius (m)		Distance Difference (m)	Accuracy
	Lat	Long	Lat	Long	Set Point	Testing		
1	-6,395541	106,76191	-6,395209	106,76417	240	252,2	12,2	5,10%
2	-6,395541	106,76191	-6,395158	106,76414	240	249,9	9,9	4,11%
3	-6,395541	106,76191	-6,395154	106,76415	240	251	11	4,59%
4	-6,395541	106,76191	-6,395156	106,76412	240	247,7	7,7	3,22%
5	-6,395541	106,76191	-6,395143	106,76414	240	250,1	10,1	4,23%
6	-6,395541	106,76191	-6,395177	106,76411	240	246,2	6,2	2,60%
7	-6,395541	106,76191	-6,395163	106,76412	240	247,6	7,6	3,16%
8	-6,395541	106,76191	-6,395176	106,76411	240	246,4	6,4	2,65%
9	-6,395541	106,76191	-6,395205	106,76414	240	249	9	3,76%
10	-6,395541	106,76191	-6,395177	106,76411	240	246,2	6,2	2,60%
11	-6,395541	106,76191	-6,395185	106,76409	240	243,9	3,9	1,63%
12	-6,395541	106,76191	-6,395211	106,76414	240	249,1	9,1	3,79%
13	-6,395541	106,76191	-6,395162	106,76412	240	247,6	7,6	3,17%
14	-6,395541	106,76191	-6,395171	106,76411	240	246,4	6,4	2,65%
15	-6,395541	106,76191	-6,395162	106,76411	240	246,5	6,5	2,71%
16	-6,395541	106,76191	-6,395161	106,76406	240	241,1	1,1	0,45%
17	-6,395541	106,76191	-6,395185	106,76405	240	239,5	-0,5	-0,19%
18	-6,395541	106,76191	-6,395196	106,76406	240	240,4	0,4	0,18%
19	-6,395541	106,76191	-6,395186	106,76411	240	246,1	6,1	2,53%
20	-6,395541	106,76191	-6,395194	106,76411	240	245,9	5,9	2,47%
Average					240	246,64	6,64	2,77%

4.3. System Response to Medication Schedule

In the second scenario, the system was tested to verify its ability to issue timely medication reminders. Alerts were programmed for 08:00 AM, 01:00 PM, and 08:00 PM. As shown in Table 4, the average delay for audio alerts was 23 seconds, while Telegram message delays averaged 38 seconds. These delays are considered acceptable for real-time healthcare notifications, mainly due to network latency and processing time. The system maintained consistency across all scheduled intervals, confirming its effectiveness in supporting medication adherence.

Table 4. System response results for medication schedule

Test No	Medication Consumption Schedule		Sound Notification		Telegram Notification		Time Difference	
	Time	Set Point	Output	Test	Sent	Test	Voice	Telegram
1	Morning	08:00:00	Yes	08:00:21	Yes	08:00:44	00:00:21	00:00:44
2	Afternoon	13:00:00	Yes	13:00:06	Yes	13:00:23	00:00:06	00:00:23
3	Evening	20:00:00	Yes	20:00:29	Yes	20:00:42	00:00:29	00:00:42
4	Morning	08:00:00	Yes	08:00:31	Yes	08:00:44	00:00:31	00:00:44
5	Afternoon	13:00:00	Yes	13:00:25	Yes	13:01:05	00:00:25	00:01:05
6	Evening	20:00:00	Yes	20:00:29	Yes	20:00:42	00:00:29	00:00:42
7	Morning	08:00:00	Yes	08:00:29	Yes	08:00:43	00:00:29	00:00:43
8	Afternoon	13:00:00	Yes	13:00:27	Yes	13:00:39	00:00:27	00:00:39
9	Evening	20:00:00	Yes	20:00:23	Yes	20:00:34	00:00:23	00:00:34
10	Morning	08:00:00	Yes	08:00:07	Yes	08:00:14	00:00:07	00:00:14
11	Afternoon	13:00:00	Yes	13:00:21	Yes	13:00:33	00:00:21	00:00:33
12	Evening	20:00:00	Yes	20:00:19	Yes	20:00:31	00:00:19	00:00:31
13	Morning	08:00:00	Yes	08:00:27	Yes	08:00:40	00:00:27	00:00:40
14	Afternoon	13:00:00	Yes	13:00:22	Yes	13:00:34	00:00:22	00:00:34
15	Evening	20:00:00	Yes	20:00:23	Yes	20:00:35	00:00:23	00:00:35
Average							00:00:23	00:00:38

4.4. Overall System Functionality

A comprehensive evaluation was performed to confirm the system's performance in both safe and unsafe conditions. Within the safe radius, the system successfully issued timely medication alerts. When the patient exited the safe zone, alerts were triggered to inform both the patient (via audio) and the caregiver (via Telegram and Google Maps link). Table 5 summarizes the results, confirming that the system functions as intended, providing reliable location monitoring and medication reminders. The system effectively supports caregivers by reducing the risk of wandering and ensuring timely medication administration.

Table 5. Overall system function test results

Test No	Radius (m)	Time	Expected Result			Result Output			Note
			Sound	Telegram	Google Maps	Sound	Telegram	Google Maps	
1	< 240	08:00	Exist	Exist	Unused	Exist	Exist	Unused	Match
2	< 240	13:00	Exist	Exist	Unused	Exist	Exist	Unused	Match
3	< 240	20:00	Exist	Exist	Unused	Exist	Exist	Unused	Match
4	>240	08:00	Exist	Exist	Exist	Exist	Exist	Exist	Match
5	>240	13:00	Exist	Exist	Exist	Exist	Exist	Exist	Match
6	>240	20:00	Exist	Exist	Exist	Exist	Exist	Exist	Match

4.5. Analysis of GPS Accuracy

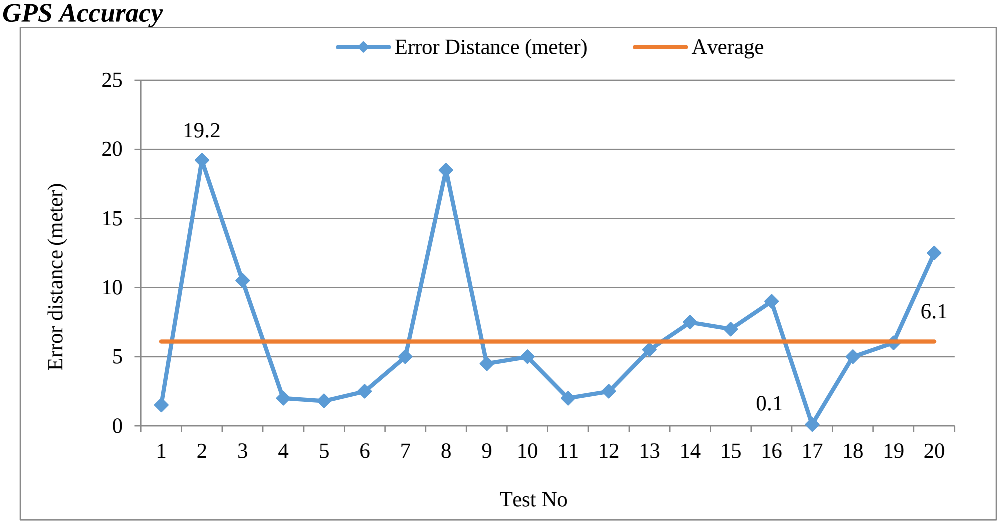

Fig. 12 Graph of GPS Neo-M8N accuracy test results

As shown in Figure 12, the GPS Neo-M8N module demonstrated strong accuracy, with most error values falling within the expected ±5 to ±7 meter range. The highest error, 19.2 meters, occurred during a test under poor satellite coverage, likely due to obstruction or weak signals. Overall, the GPS module provides sufficient accuracy for geofencing in dementia care applications, although users should be aware of potential environmental impacts on performance.

4.6. Analysis of Geofacing Response

The geofencing mechanism was found to be highly reliable. In 20 test trials, the average recorded radius was 246.6 meters, reflecting a 6.6-meter deviation from the setpoint. This aligns well with the GPS Neo-M8N's average error and confirms the system's effectiveness in accurately detecting boundary violations. Figure 13 presents the graphical summary of these results.

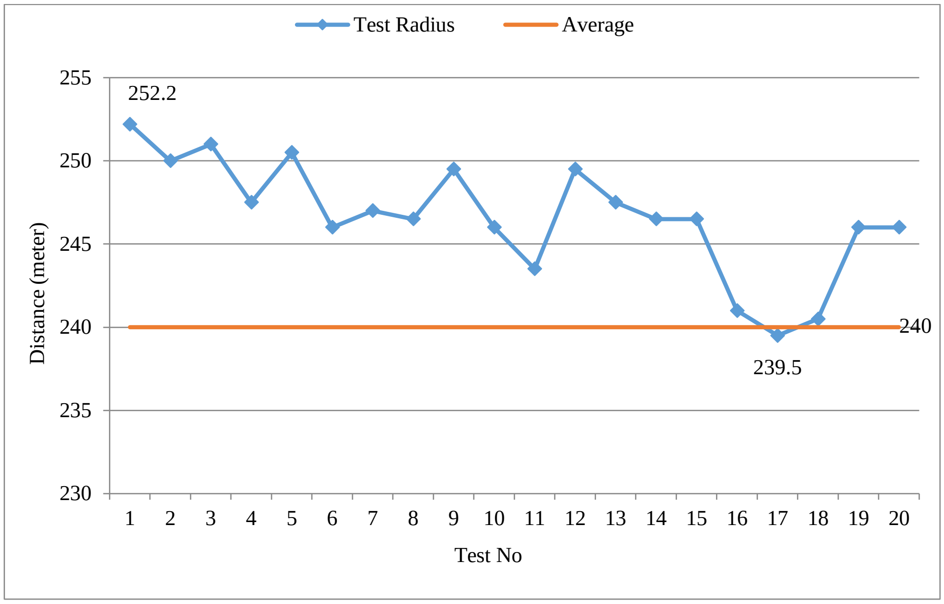

Fig. 13 Graph of system response test for exiting the safe radius

4.7. Analysis of Medication Remainder Response

Figures 14 and 15 present the response times for medication reminders. The average delay was 23 seconds for audio and 34 seconds for Telegram messages. The shortest delays recorded were 6 and 5 seconds, respectively, while the longest were 31 and 44 seconds. Variability was primarily attributed to the DFPlayer Mini and GSM SIM800L modules, which may require optimization for improved consistency. Despite these variations, the system remains within acceptable limits for healthcare applications.

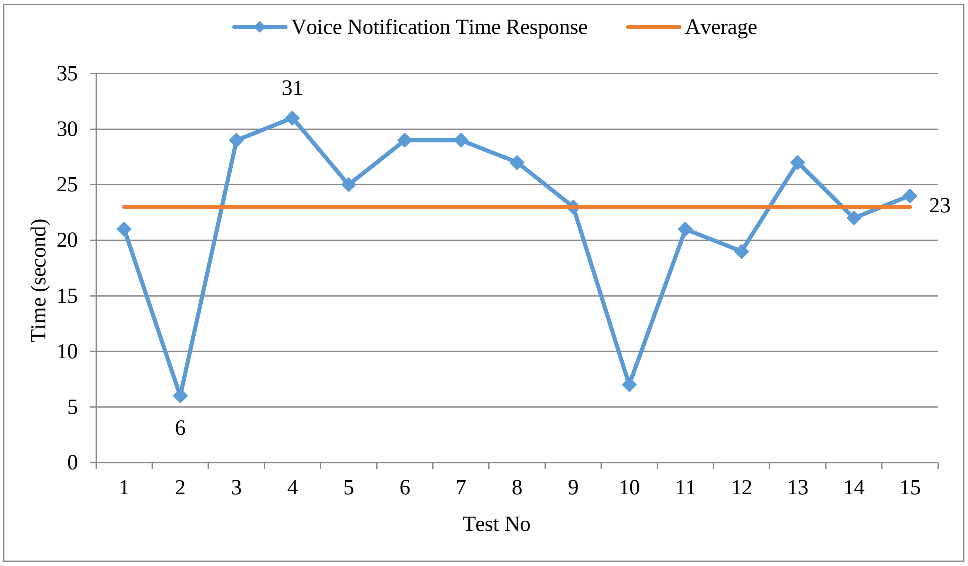

Fig. 14 Graph of system response test within safe radius – 1

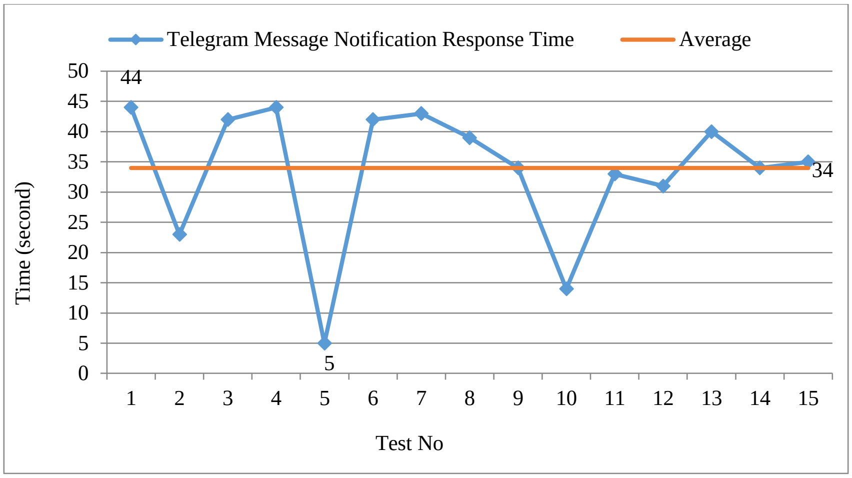

Fig. 15 Graph of system response test within safe radius – 2

4.8. Analysis of the Overall System Function Test Results

The system effectively combines geofencing and medication scheduling in a single device. It performed as expected under both test conditions, ensuring alerts are triggered when necessary and data is relayed to caregivers in real time.

This dual-mode capability supports proactive and preventive dementia care, reducing the burden on caregivers while enhancing patient safety.

These findings are consistent with previous studies highlighting the effectiveness of GPS and geofencing in dementia monitoring [38-41]. However, this research extends the contribution by integrating real-time medication reminders, an area that has received limited attention in earlier works.

4.9. Statistical Analysis of GPS Accuracy

To further evaluate the GPS performance, the test results in Table 2 were subjected to statistical analysis. From 20 test trials comparing GPS Neo-M8N against Garmin Oregon 650, the following results were obtained as Table 6.

Table 6. Summary statistics for GPS error (in meters)

Metric	Value
Mean Error	6.1
Standard Deviation	4.64
Min Error	0.1
Max Error	19.2
95% Confidence Interval	[4.0, 8.2]

A Shapiro-Wilk test ($p = 0.17$) showed no significant deviation from normality. A one-sample t-test comparing the GPS error against a 10-meter benchmark resulted in $t(19) = -3.78$, $p < 0.01$, indicating that the module performs significantly better than the threshold commonly used in healthcare applications. Figure 16 illustrates the distribution of localization errors recorded during 20 field trials using the GPS Neo-M8N module, benchmarked against a Garmin Oregon 650. The histogram shows a moderately right-skewed distribution, with most errors falling between 2 and 10 meters. The presence of a clear peak near the mean and a relatively narrow spread indicates that the GPS module performs reliably within acceptable error margins for healthcare applications such as dementia monitoring. A Kernel Density Estimate (KDE) line is overlaid to visualize the probability density function.

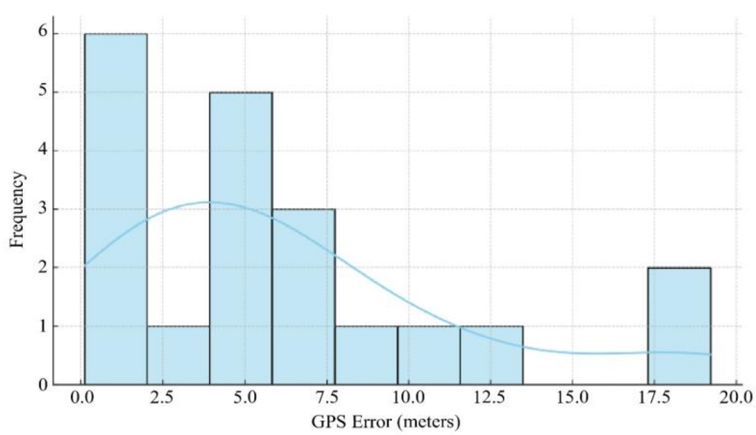

Fig. 16 shows a histogram of the GPS localization errors

4.10. Statistical Analysis of Geofencing Accuracy

The geofencing feature was tested in 20 trials, and the deviation from the 240-meter setpoint was recorded. The key findings include:

- Mean deviation: 6.64 meters
- Standard deviation: 3.93 meters
- Deviation range: -0.5 m to 12.2 m

A paired t-test comparing actual radius detection vs. the expected 240-meter threshold yielded $t(19) = 7.48$, $p < 0.001$, indicating a statistically significant but small average deviation within acceptable limits. Figure 17 presents a control chart of geofencing deviation from the fixed 240-meter safe radius. Each point corresponds to the deviation recorded during 20 trials. All data points fall within the $\pm 3\sigma$ control limits, demonstrating statistical process control and confirming that the geofencing functionality operates within a stable and predictable range. This finding supports the reliability of the system's boundary violation detection mechanism in real-world environments.

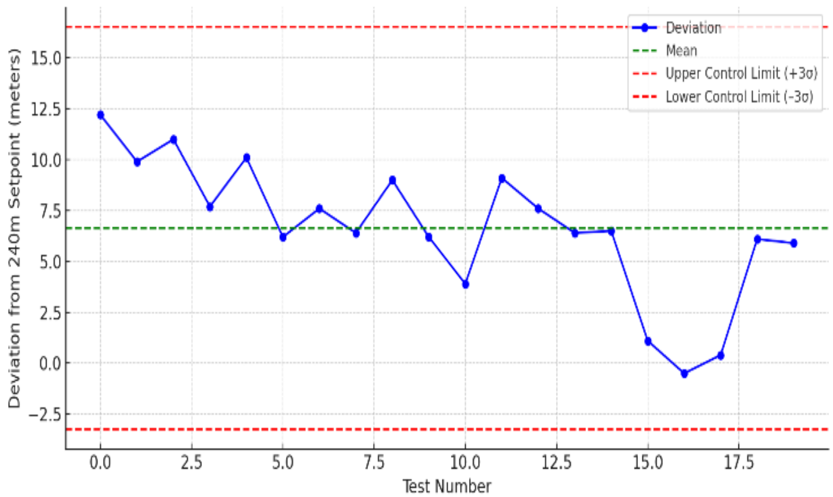

Fig. 17 presents a control chart of geofencing deviation

4.11. Statistical Evaluation of Notification Delays

Delays for voice and Telegram notifications were analyzed across different time slots (morning, afternoon, evening) using ANOVA tests, as shown in Table 7. ANOVA test showed no statistically significant difference among time groups ($p > 0.05$), suggesting consistent notification performance throughout the day.

Table 7. Summary of notification delays

Notification Type	Mean Delay (s)	Std Dev (s)	Min (s)	Max (s)
Voice	23.1	8.3	6	31
Telegram	34.7	9.6	14	44

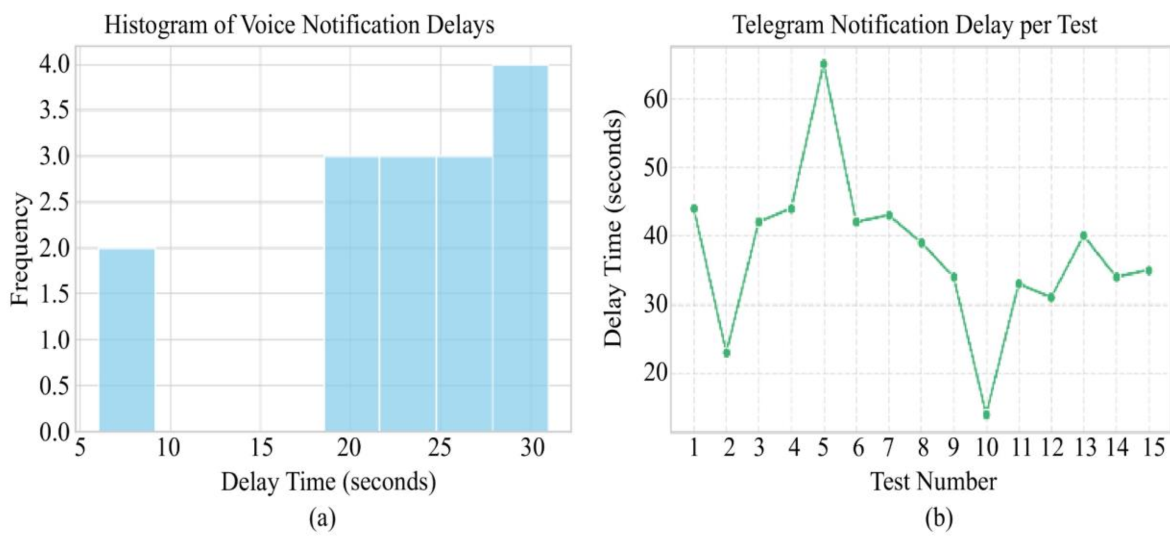

Fig. 18 Notification delay visualizations: (a) Histogram of voice notification delays, and (b) Telegram notification delays per test.

Figure 18 displays two visualizations representing delays in both voice- and Telegram-based medication notifications.

Panel (a) shows a histogram of voice notification delays from DFPlayer Mini, with most values falling between 20 and 30 seconds.

Panel (b) presents the delay times for Telegram notifications across 15 trials, indicating some variation but still within an acceptable range for healthcare applications. These visualizations help illustrate the overall consistency and performance of the system in delivering timely reminders.

5. Conclusion

This study developed and evaluated the Smart Dementia Care system, an IoT-based solution combining GPS tracking, geofencing alerts, and medication reminders to address dementia-related wandering and medication non-adherence. Field tests showed reliable performance: GPS error averaged 6.1 meters ($p < 0.01$), geofencing deviations stayed within ±3 SD, and medication alerts were timely with no significant time-based variation ($p > 0.05$). These findings were confirmed through statistical analysis (Shapiro–Wilk, t-tests, ANOVA), supporting robustness and reproducibility. The system meets IEEE evaluation standards and is viable for deployment. Wearable hardware and cloud alerts offer a scalable, affordable tool to improve patient safety and caregiver responsiveness in both home and institutional settings.

Overall, the results confirm that the system developed in this study goes beyond existing location monitoring solutions by also enhancing medication adherence, making it one of the first IoT-based integrated approaches for dementia care in Indonesia. Planned improvements include a smaller, ergonomic device, biometric sensors, voice control, battery/signal monitoring, Telegram alerts, clinical trials, and a caregiver dashboard.

Acknowledgment

The authors would like to express their sincere appreciation to all individuals and colleagues who provided constructive feedback and valuable discussions during the development of this manuscript. Their insights and suggestions greatly contributed to improving the clarity and quality of the work.

References

[1] Central Bureau of Statistics, 2022 Senior Citizens Statistics, 2022. [Online]. Available: https://www.bps.go.id/id/publication/2022/12/27/3752f1d1d9b41aa69be4c65c/statistik-penduduk-lanjut-usia-2022.html

[2] Rammohan V. Rao et al., "Rationale for a Multi-Factorial Approach for the Reversal of Cognitive Decline in Alzheimer's Disease and MCI: A Review," *International Journal of Molecular Sciences*, vol. 24, no. 2, pp. 1-23, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[3] Matthew L. Cohen, Alexis C. Ryan, and Alyssa M. Lanzi, "Prevention of and Early Intervention for Cognitive Decline Due to Alzheimer's Disease and Related Disorders," *Delaware Journal of Public Health*, vol. 7, pp. 118-122, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[4] Ricardo Augusto Leoni De Sousa, "Reactive Gliosis in Alzheimer's Disease: A Crucial Role for Cognitive Impairment and Memory Loss," *Metabolic Brain Disease*, vol. 37, no. 4, pp. 851-857, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[5] Gregory Peters-Founshtein et al., "Lost in Space(s): Multimodal Neuroimaging of Disorientation Along the Alzheimer's Disease Continuum," *Human Brain Mapping*, vol. 45, no. 4, pp. 1-13, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[6] Sojung Park, and Yaelim Lee, "Non-Pharmacological Management of Wandering in Persons with Dementia: An Integrative Review," *Psychogeriatrics*, vol. 24, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[7] Simona Raimo et al., "The Relation Between Cognitive Functioning and Activities of Daily Living in Normal Aging, Mild Cognitive Impairment, and Dementia: A Meta-Analysis," *Neurological Sciences*, vol. 45, no. 6, pp. 2427-2443, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[8] Nicolas Farina et al., "Comprehensive Measurement of the Prevalence of Dementia in Low- and Middle-Income Countries: STRiDE Methodology and its Application in Indonesia and South Africa," *BJPsych Open*, vol. 9, pp. 1-7, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[9] Fasihah Irfani Fitri et al., "Modifiable Risk Factors for Dementia in Indonesia: Results from STRiDE Project," *Neurol Asia*, vol. 28, no. 4, pp. 1009-1017, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[10] Tri Suratmi et al., "Assistance for the Elderly with Dementia by Caregivers at the Nursing Home," *RSF Conference Proceeding Series: Medical and Health Science*, vol. 2, no. 1, pp. 55-61, 2023. [CrossRef] [Publisher Link]

[11] Fasihah Irfani Fitri, "Frequency and Characteristics of Patients with Dementia and Cognitive Impairment in Indonesia: A Hospital-Based Study," *Aging Medicine and Healthcare*, vol. 16, no. 2, pp. 173-177, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[12] Emma M. Devenney et al., "A Scoping Review of the Unique Landscape and Challenges Associated with Dementia in the Western Pacific Region," *Lancet Regional Health Western Pacific*, vol. 50, 2024. [CrossRef] [Publisher Link]

[13] Colin Binns, and Wah Yun Low, "Dementia in the Asia-Pacific Region," *Asia Pacific Journal of Public Health*, vol. 36, no. 8, pp. 661-663, 2024. [CrossRef] [Publisher Link]

[14] Sapna Juneja et al., "A Perspective Roadmap for IoMT-Based Early Detection and Care of the Neural Disorder, Dementia," *Journal of Healthcare Engineering*, vol. 2021, no. 1, pp. 1-11, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[15] Piyush Yadav et al., "Development of Pervasive IoT based Healthcare Monitoring System for Alzheimer Patients," *Journal of Physics: Conference Series*, Uttar Pradesh, India, vol. 2007, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[16] Aseel Thamer Ebrahem et al., "Using IoT Technology for Monitoring Alzheimer's and Elderly Patients," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 31, no. 2, pp. 986-994, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[17] B. Pavitra et al., "Dementia Prediction using Novel IOTM (Internet of Things in Medical) Architecture Framework," *Intelligent Data Analysis*, vol. 27, no. 1, pp. 29-45, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[18] G. Anto Gabriel, and M.N. Nachappa, "IoT Assistant-Based Secured System for Alzheimer's Disease," *International Journal of Advanced Research in Science, Communication and Technology*, vol. 4, no. 4, pp. 341-346, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[19] Deepak Saini et al., "IoT Based Health Monitoring System," *International Journal for Research in Applied Science and Engineering Technology (IJRASET)*, vol. 12, no. IV, pp. 4365-4372, 2024. [CrossRef] [Publisher Link]

[20] Novi Azman et al., "Design of Temperature and Humidity Monitoring Baby Incubator based on Internet of Things," *International Journal of Advanced Trends in Computer Science and Engineering*, vol. 9, no. 5, pp. 8390-8396, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[21] G.S. Pradeep Ghantasala et al., "Wireless Health Monitoring for Calculating Vitals Device by Using IoT," *2024 Second International Conference Computational and Characterization Techniques in Engineering & Sciences (IC3TES)*, Lucknow, India, pp. 1-4, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[22] Jaishankar B., "IoT Based Health Risk Monitoring System," *2024 Ninth International Conference on Science Technology Engineering and Mathematics (ICONSTEM)*, Chennai, India, pp. 1-6, 2024. [CrossRef] [Publisher Link]

[23] Novi Azman et al., "The Development of IoT Tele-Insomnia Framework to Monitor Sleep Disorder," *Internasional Journal of Advanced Trends in Computer Science and Engineering*, vol. 8, no. 6, pp. 2831-2839, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[24] Novi Azman et al., "Insomnia Analysis based on Internet of Things using Electrocardiography and Electromyography," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 18, no. 3, pp. 1406-1415, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[25] Hashmat Usmani et al., "IOT & GSM based- Patient Health Monitoring System," *2024 4th International Conference on Advancement in Electronics & Communication Engineering (AECE)*, GHAZIABAD, India, pp. 1012-1015, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[26] A. García-Requejo et al., "Indoor-Outdoor Tracking and Activity Monitoring System for Dementia Patients," *2022 IEEE International Symposium on Medical Measurements and Applications (MeMeA)*, Messina, Italy, pp. 1-6, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[27] Abbas Sheikhtaheri, and Farveh Sabermahani, "Applications and Outcomes of Internet of Things for Patients with Alzheimer's Disease/Dementia: A Scoping Review," *BioMed Research International*, vol. 2022, no. 1, pp. 1-17, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[28] Kavita Khatal et al., "IoT based GPS Tracking for Dementia Patient," *International Journal of Advanced Research in Science, Communication and Technology*, vol. 5, no. 4, pp. 66-74, 2025. [CrossRef] [Publisher Link]

[29] Hongan Mu et al., "Discovering and Analyzing Internet of Things (IoT) Technologies and Applications for Aged Care," *Journal of Physics: Conference Series*, Hangzhou, China, vol. 1948, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[30] Mayuri Priyadharshini Murugavel, Reshma Hari, and Murugavalli Elangovan, "Monitoring the Health of the Alzheimers Patients and Geofencing their Location," *International Journal for Research in Applied Science and Engineering Technology*, 2022. [CrossRef] [Publisher Link]

[31] R. Latha et al., "Cloud-Based Smart Sensing System for Real-Time Health Management of Dementia Patients," *2023 Second International Conference on Smart Technologies for Smart Nation (SmartTechCon)*, Singapore, pp. 923-927, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[32] Vijay Gaikwad et al., "A9G-based Dementia GPS Tracker," *2023 7th International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)*, Kirtipur, Nepal, pp. 603-608, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[33] Guillermo Prieto-Avalos et al., "Wearable Devices for Physical Monitoring of Heart: A Review," *Biosensors*, vol. 12, no. 5, pp. 1-31, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[34] Bernardo A. Vicente, Raquel Sebastião, and Vitor Sencadas, "Wearable Devices for Respiratory Monitoring," *Advanced Functional Materials*, vol. 34, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[35] Vedant Thakare, and Prateek Verma, "A Review on Applications of IoT in Healthcare," *2025 International Conference on Electronics and Renewable Systems (ICEARS)*, Tuticorin, India, pp. 793-798, 2025. [CrossRef] [Publisher Link]

[36] Michael C B David et al., "Remote Monitoring of Physiology in People Living with Dementia: An Observational Cohort Study," *JMIR Aging*, vol. 6, pp. 1-14, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[37] Sampson Addae et al., "Smart Solutions for Detecting, Predicting, Monitoring, and Managing Dementia in the Elderly: A Survey," *IEEE Access*, vol. 12, pp. 100026-100056, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[38] Neda Firouraghi et al., "The Role of Geographic Information System and Global Positioning System in Dementia Care and Research: A Scoping Review," *International Journal of Health Geographics*, vol. 21, no. 1, pp. 1-13, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[39] Torhild Holthe, Liv Halvorsrud, and Anne Lund, "Digital Assistive Technology to Support Everyday Living in Community-Dwelling Older Adults with Mild Cognitive Impairment and Dementia," *Clinical Interventions in Aging*, vol. 17, pp. 519-544, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[40] Torhild Holthe, Liv Halvorsrud, and Anne Lund, "Digital Assistive Technology to Support Everyday Living in Community-Dwelling Older Adults with Mild Cognitive Impairment and Dementia," *Clinical Interventions in Aging*, vol. 17, pp. 519-544, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[41] Waleed Salehi et al., "IoT-Based Wearable Devices for Patients Suffering from Alzheimer Disease," *Contrast Media & Molecular Imaging*, vol. 2022, no. 1, pp. 1-15, 2022. [CrossRef] [Google Scholar] [Publisher Link]