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Using IoT technology for monitoring Alzheimer's and elderly patients

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ABSTRACT

Alzheimer's disease (AD) is a neurological disorder that results in the death of brain cells, causing memory loss, behavioral changes, and cognitive impairment. It drastically affects the individual's work and social life, often leading to death, and is now the sixth leading cause of mortality worldwide. AD patients have limited mobility, which restricts their movement outside their homes. Thankfully, new internet of things (IoT) applications have made it possible to monitor people with various illnesses in their everyday lives, providing valuable assistance to caregivers. This study aims to create an IoT prototype that can locate an AD patient in real time and remind them to take their medication on schedule via an alarm. The small, lightweight, portable patient carrier has a NodeMCU-23DSP board, a Neo-06 global positioning system (GPS) module, and a wireless modem/Wi-Fi router. Remote patient follow-up through the Blynk 2.0 application on computers and Android devices allows for monitoring of the patient's medication regimen and daily activities. As AD patients struggle with memory and organization, the prototype's design enables monitoring of a patient's course of medication, making it easier for caregivers to provide the necessary assistance. The prototype was tested to demonstrate its efficiency and performance.

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1. INTRODUCTION

Alzheimer's disease (AD) is still considered a fatal condition for both patients and families [1]–[8]. According to reports, Alzheimer's progresses in three phases over 12 years. The first stage, which lasts one to three years, begins with abnormal biomarkers and mild to moderate cognitive difficulties that repeat. Temporal memory loss, recurrent mild cognitive impairment, and the existence of pathophysiological biomarkers characterize the second stage of AD (three to 10 years). The third stage, usually known as dementia, can last anywhere from eight to twelve years [9]. Unfortunately, Alzheimer's patients (AP) will most likely have obvious memory loss, cognitive impairment, and a high frequency of unanticipated abnormal biomarkers [10]. According to a new study, cognitive, behavioral, sensory, and motor alterations may develop several years before clinical signs of AD manifest. Unfortunately, the incidence of AD is predicted to affect roughly 74.7 million individuals by the end of the year [11]. Internet of things (IoT) technology is a network of connected devices that collect, transmit, and analyze data. It provides an opportunity to monitor patients remotely, and in real time, which is particularly useful for patients with cognitive impairment who may forget to report their symptoms or may not be able to communicate effectively [12]–[16]. Wearable devices are an important component of IoT technology for monitoring Alzheimer's and elderly patients. These devices can monitor vital signs, such as heart rate, blood pressure, and oxygen saturation, and can detect falls and other accidents. They can also track the patient's location, which is useful for patients who wander due to cognitive impairment [17]–[20]. Smart home technology is another IoT application that can benefit Alzheimer's and elderly patients [21]. IoT has become one of the most popular subjects in all subfields, thanks to readily available communication technologies and smart mobile devices, especially in healthcare, where 40% of all IoT devices were used in healthcare by Sadoughi *et al.* [22]. Smart home devices can monitor the patient's activities, such as when they enter and exit a room, and can detect unusual behavior patterns, such as leaving the stove on or not taking medications. Smart home devices can also provide reminders for tasks, such as taking medication or attending appointments [23]–[26].

IoT technology can also provide caregivers with real-time information about the patient's condition. Caregivers can monitor the patient's vital signs, location, and activities, and can receive alerts if there is a problem. This allows caregivers to intervene quickly and provide the necessary care, which can prevent emergencies and hospitalizations. While IoT technology has great potential for monitoring Alzheimer's and elderly patients, there are also some challenges and limitations. One of the challenges is privacy and security. IoT devices collect sensitive data, such as health information, and there is a risk of data breaches and unauthorized access [27], [28]. Another challenge is the need for standardization and interoperability. There are many different types of IoT devices and platforms, which can make it difficult to integrate them into a single system. This can lead to data silos and make it challenging to obtain a complete picture of the patient's condition [29].

AD is a progressive and irreversible neurological disorder affecting millions worldwide. Early detection and management of the disease are crucial for improving patient outcomes and quality of life. Recent studies have shown that the IoT can be critical in detecting and controlling AD. In this article, we will review six recent studies that explore the potential of IoT in AD detection and management. One of the major benefits of using IoT in AD management is the ability to collect large amounts of data on patients' behavior and cognitive function. These data can be used to detect early signs of cognitive decline, enabling prompt medical intervention and improving patient outcomes. Furthermore, IoT-based systems can provide patients with cognitive rehabilitation exercises to slow the progression of the disease and improve their quality of life. On the other hand, a 2019 study published in the Journal of AD investigates the potential of smart home technology in AD management. The study describes a system that uses IoT devices to monitor patients' activities of daily living and alert caregivers when patients display abnormal behavior [30]. In the same year, a study published in the Journal of Medical Systems explores the use of wearable technology in AD detection. The study describes a system that uses wearable sensors to monitor patients' gait and movement patterns and detect early signs of cognitive decline [31]. Another study published in the Journal of Healthcare Engineering in 2020 investigates the use of IoT-based cognitive assessment in AD patients. The study describes a system that uses IoT sensors to collect data on patients' cognitive functions and analyzes the data using machine learning algorithms to detect early signs of cognitive decline [32]. Recently, a study published in the Journal of Healthcare Engineering in 2021 explores the use of IoT and deep learning techniques to detect early-stage AD. The study focuses on analyzing the behavioral patterns of patients using IoT sensors to develop a machine-learning model that can predict the likelihood of AD [33]. Another study published in the Journal of Medical Systems in 2021 discusses the potential of IoT in AD diagnosis and treatment. The study highlights IoT devices, such as wearable sensors and smart home technology, to collect data on patients' behavior and monitor their cognitive function [34]. These recent studies demonstrated the potential of IoT in detecting and managing AD. IoT devices, such as wearable sensors, smart home technology, and fall detection systems, can collect data on patients' behavior and monitor their cognitive function, enabling early detection of the disease. Furthermore, IoT-based systems can provide patients with cognitive rehabilitation exercises and improve their quality of life. As the field of IoT continues to evolve, we can expect to see more innovative solutions for AD detection and management.

Meanwhile, Lavrukhin *et al.* [35] investigated cloud computing, fog computing, big data analytics, IoT and mobile applications, and emerging technologies to address the challenges of building a healthcare system for early disease identification and providing secure online health-related medicines. They emphasized the need for high-quality, accurate eHealth platforms. Boksnati *et al.* [36] studied the Alzheimer's disease knowledge test (ADKS) to determine Australian physicians and clinicians' knowledge and history of therapeutic practice. They found that most had a modest understanding of the factors affecting wireless communications and mobile computing in AD, while those who had neuroscience training or experience working with patients and attending related workshops were well-informed about the condition. Fardou *et al.* [37] created a prototype device that uses facial recognition to help access points identify people with AD. However, the system is not suitable for older people with Alzheimer's who may have trouble reading the information on the smartwatch's small screen. Naf *et al.* [38] developed an inexpensive robotic interface with haptic feedback to detect visual-motor deficits in AD patients. They found that response times and tracking errors differed between the cognitively healthy group and the AD group. Finally, Costanzo *et al.* [39] discussed how telemedicine could assist in the treatment and diagnosis of AD and mild cognitive impairment (MCI), highlighting the need for technology services such as email and video conferencing to identify and track patients and physicians. The various studies mentioned here all relate to personalized healthcare systems for AD and mild cognitive impairment. These systems aimed to use emerging technologies to provide accurate and high-quality healthcare to patients. The use of mobile applications, cloud computing, IoT, and other technological advancements are being investigated to create efficient eHealth platforms. Additionally, various devices such as cell phone software, facial recognition systems, and robotic interfaces with haptic feedback are being developed to aid patients with daily activities and help healthcare providers diagnose and treat the condition. Finally, the potential of telemedicine to identify and track patients and physicians has also been explored. Overall, these studies highlight the importance of utilizing technology to improve the quality of life for those affected by AD and mild cognitive impairment.

The IoT has made significant strides in the healthcare industry, and the use of wearable sensors is a testament to this. With the use of wearable sensors and Wi-Fi technology, clinical data from patients can be gathered continuously and transmitted in real-time to medical professionals. In this article, we will explore the use of an IoT prototype with a constrained interface that employs wearable sensors to gather clinical data, and uses Wi-Fi technology to send the data to the framework's second level, and then uses an Android phone to retrieve patient data from wearable sensors. The first level of our prototype is comprised of wearable sensors that are placed on the patient's body. These sensors can include heart rate monitors, blood pressure monitors, and temperature sensors. The wearable sensors are connected to a central device that is responsible for collecting the data from each of the sensors. The second level of this prototype is the framework that receives the data from the wearable sensors. The framework can be implemented using Wi-Fi technology, which enables the data to be transmitted wirelessly to a centralized location. This level of the prototype is responsible for analyzing the data, identifying any potential health issues, and providing alerts to medical professionals if necessary. To retrieve patient data from wearable sensors, an Android phone can be used. The phone can be connected to the Wi-Fi network and used to access the patient's data from the framework's second level. This enables medical professionals to view the patient's data remotely and make informed decisions based on the patient's current health status. The constrained interface of the prototype ensures that only relevant data is transmitted to the framework. This means that the system only collects the data that is necessary for monitoring the patient's health. The interface also ensures that the data is transmitted securely and that the patient's privacy is protected [40], [41]. The proposed system is highly integrated and supports various network connectivity options, making it suitable for use in a wide range of healthcare settings. It is also designed to be low-power and highly portable, allowing patients to take it with them wherever they go. By providing patients with timely reminders to take their medication, the system can help improve medication adherence and reduce the risk of adverse health outcomes. The use of an IoT prototype with wearable sensors and Wi-Fi technology has numerous benefits for the healthcare industry. Continuous monitoring of a patient's health enables potential health issues to be identified and addressed in real-time. This can improve patient outcomes and reduce healthcare costs. Additionally, the use of an Android phone to retrieve patient data from wearable sensors enables medical professionals to access the data remotely, reducing the need for hospital visits and improving the overall patient experience.

2. METHOD

AD is a debilitating neurological disorder that affects millions of people worldwide. It is characterized by a gradual decline in cognitive function, memory loss, and changes in behavior. As the population ages, the incidence of AD is increasing, and providing care for AP is becoming more challenging. Fortunately, the development of the IoT technology provides new opportunities for monitoring and managing AP, as well as elderly patients with other conditions. The geolocation of things is becoming increasingly significant in various disciplines, including medicine, the military, and everyday life. In this work, we will create an AD patient monitoring system and track medicine dosages using a receiver global positioning system (GPS) Neo-0.6 and Node MCU-32 DSP board. The monitoring system takes current coordinates and delivers them to a server for simultaneous Wi-Fi data exchange and then from the server to the Blynk 2.0 mobile app. In Figure 1, the high-level schematic representation applied in this work is depicted.

2.1. Required materials

To implement the system, the study utilized equipment proposed in the AD monitoring diagram depicted in Figure 2, which included an input gyroscope sensor, a drug dose tracking system, a controller, batteries, and output devices. This system is designed to help patients remember to take their medication on time, by providing them with timely alerts and reminders. The controller used in the system is responsible for monitoring the medication schedule and triggering the alarm when the time is right. The alarm button, which is located on the box, can be pressed by the patient to acknowledge that they have taken their medication.

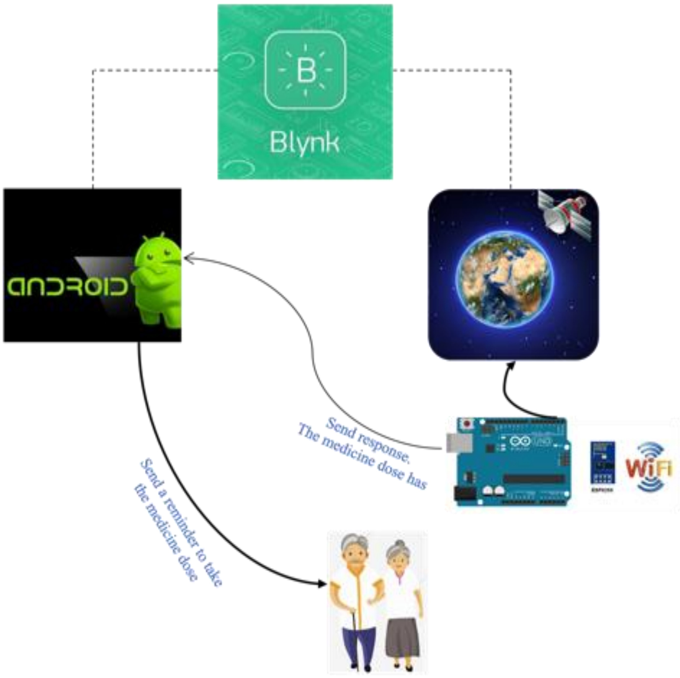


Figure 1. General principle adopted for implementing the proposed system

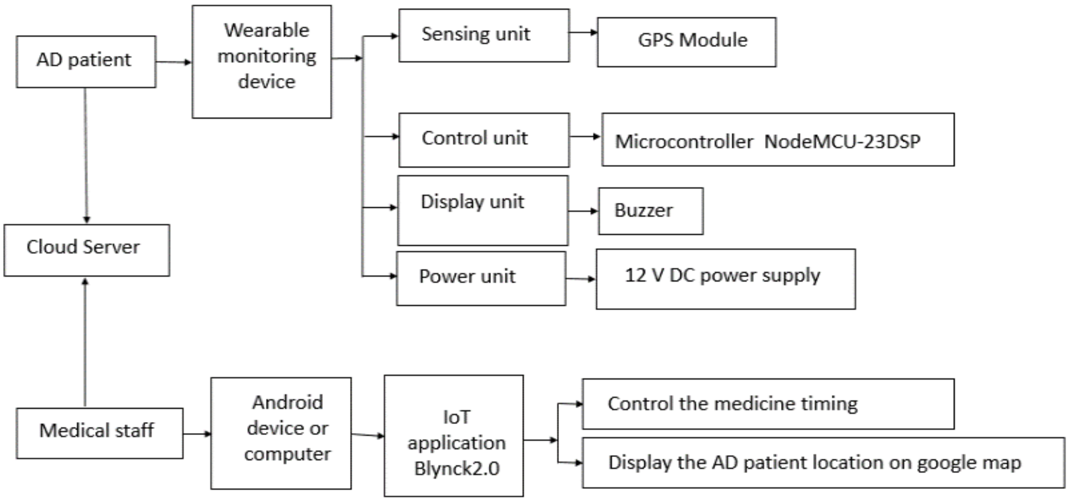


Figure 2. The proposed diagram for the AD monitoring system

The Node MCU ESP32 board, which includes an ESP-WROOM-32 module in the breadboard, was used in the system. This module has an ESP32 processor that is expandable and versatile, with a clock frequency that can be varied from 80 to 240 MHz and two central processor units (CPU) cores that can be handled independently. It also works with real-time operating system (RTOS) and supports traditional Bluetooth, Bluetooth low energy, and Wi-Fi, making it suitable for various applications. For maximum wireless communication, the module additionally supports data rates of up to 150 Mbps and an antenna output strength of 20 dBm [42]. On the other hand, the GPS NEO-06 module was used to provide patient geolocation data. This module is part of a family of standalone GPS receivers with a high-performance locating engine. It is a versatile and low-cost receiver that comes in a compact 16x12.2x2.4 mm box with many connecting possibilities. The NEO-06 GPS receivers provide remarkable navigation performance even in the most challenging settings due to groundbreaking design and technology that suppresses jamming sources and mitigates multipath effects [43]. Also, the proposed system includes a device that gives an alert to the patient in real-time when the time coincides with the set time for taking the drug. The entire system is implemented in a box containing the alarm button that is controlled by the controller used in the design under the guidance of the care unit.

2.2. Software

Blynk [44] is a powerful and user-friendly platform for building IoT projects. Its combination of ease of use and advanced features make it a popular choice for developers of all skill levels, and its support for a wide range of hardware platforms and protocols makes it a flexible solution for a variety of IoT use cases. Blynk [45] is a mobile app and platform that allows developers to build IoT projects quickly and easily. It is designed to simplify the process of connecting hardware devices to the internet and to allow developers to remotely control and monitor their projects. Blynk provides a range of tools and features to help developers create their IoT projects. These include a drag-and-drop interface for building mobile app interfaces, a cloud-based server for storing data and managing device connectivity, and a library of pre-built widgets and code snippets for commonly used IoT functions, and supports a wide range of hardware platforms, including Arduino, Raspberry Pi, ESP8266, and others. It also offers integrations with popular IoT services and protocols such as IFTTT, MQTT, and Zapier. One of the key benefits of Blynk is its ease of use. Developers with little or no experience in IoT or programming can quickly build functional projects using the app's intuitive interface and pre-built widgets. At the same time, experienced developers can leverage Blynk's advanced features and integrations to create complex and powerful IoT solutions [46]. To use Blynk, we need to first create an account on the Blynk website and then download the Blynk app onto the patient's mobile device. Once the hardware is connected to the internet, the Blynk app controls and monitors the project remotely. notice that we can create custom user interfaces using drag-and-drop widgets, such as buttons, sliders, and graphs, and map these widgets to specific functions in their code, also offers a range of advanced features, such as real-time data syncing, push notifications, and email alerts. It also provides integrations with third-party services, such as Google Sheets and Twilio, to allow developers to send data to external services or trigger events based on external events.

3. RESULTS AND DISCUSSION

As a case study, a 78-year-old patient with advanced AD who lives in Mosul city, Iraq was chosen as a subject for examining the effectiveness of the proposed system. The system was applied to the patient for over two weeks, and all data received from the system was recorded to demonstrate its efficiency during daily usage. During this time, the system collected and recorded blood pressure and heart rate information and also sent the patient's location while he was moving inside and outside of the house, using the attached GPS system. Also, the proposed system has been improved by adding a medication reminder feature.

3.1. System architecture and working procedure

The program was written in ARDUINO software. The flowchart of the whole system is shown in Figure 3, it is divided into two parts. The first one is used to monitor the GPS location of the patient; the second part is used to set the medicine schedule; when it is time to take the medication, a message will be sent via the app to remind the supervisor of the appointment. The supervisor, in turn, will send an audible alert to the patient that the medication must be taken and tap the Buzzer on the wearable monitor on the patient's wrist. By clicking on the Buzzer, a message will be sent through the application stating that the drug has been taken.

3.2. Actual tests of the system

During the period of checking the system for over a week, the system proved to be very effective by sending notifications to the person in charge of the situation if he crossed a distance of 100 meters from the position of the installer with the observer. The designed system notified the monitor when the patient moved from his neighborhood site to a point 150 meters away from the patient's location. On the other hand, the system is designed according to a specific schedule by the doctor to alert the patient to take the medication, which includes specifying the day and time and sending an alert (message) to the supervisor reminding him of the time of taking the medication. The response from the patient after taking the dose has been received via the Buzzer in the wearable system. The system records and saves the event in event 1. Then evidence of completing the task shows a phrase on the application screen, "turn on gp2". Then moving to the second appointment, the drug dose according to the schedule, is approved by the specialist doctor and installed in the application. The doses of taking the drug in the application are arranged in the form of an event for each dose. Figure 4 illustrates the programming procedure using the Blynk app where Figure 4(a) showed the evidence of completing the task and Figure 4(b) shows the doses of taking the drug in the application screen. The software utilized two languages-Arabic and English-in accordance with the local languages prevalent in the case study area. It is noteworthy that the programming language can be conveniently modified based on the preference of the user.

Ultimately, we put together the system's components inside a compact box that can be worn by the patient like a lightweight wristwatch, allowing them to move around without any hindrance. The various electronic components required for the device to function, including the microprocessor, GPS circuit, Wi-Fi circuit, and other necessary parts, are illustrated in Figure 5. It's important to mention that this device is designed to operate on low battery power, and the battery can be easily recharged.

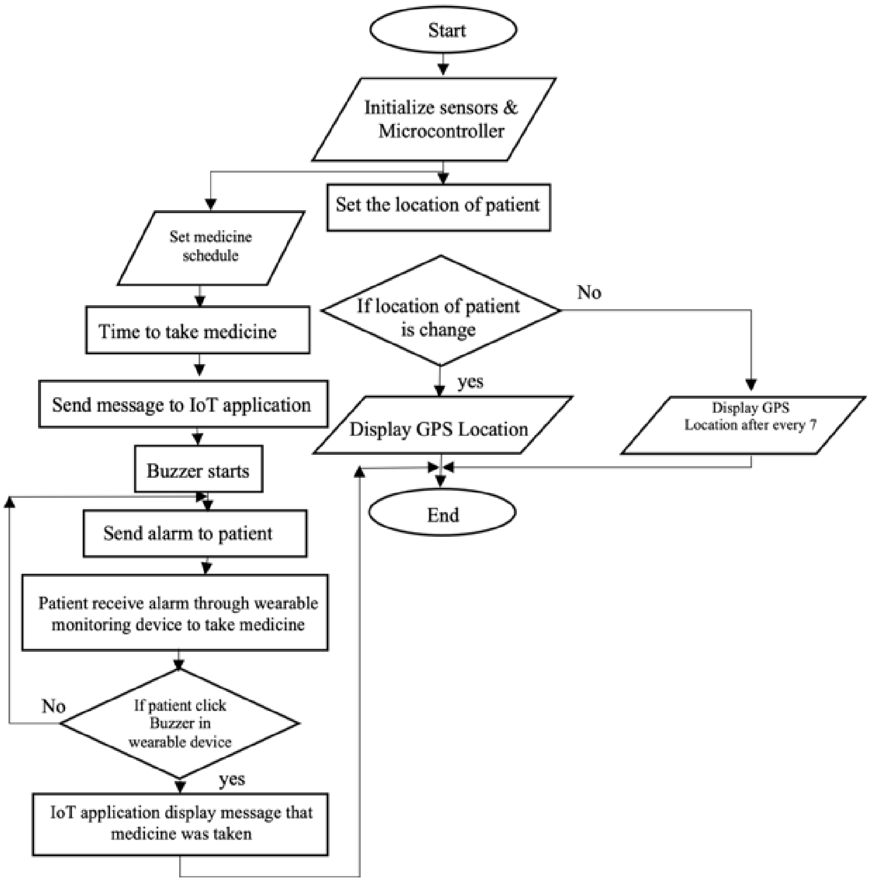
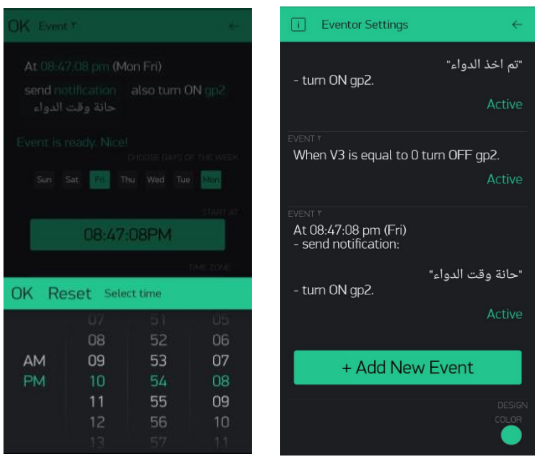


Figure 3. The proposed flowchart for the AD monitoring system



(a) (b)

Figure 4. The programming of the Blynk application (a) programming the system according to the schedule approved by the doctor and installing it in the application and (b) the order of doses in the application as an event for each dose

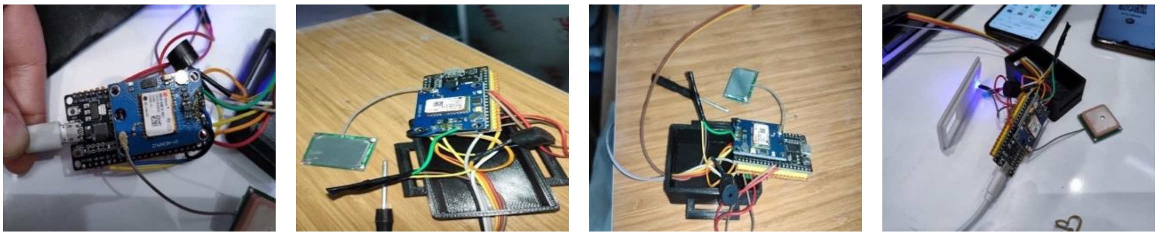


Figure 5. The proposed device components which include the microprocessor with the sensors needed for the tests

4. CONCLUSION

This article delves into a highly significant topic that pertains to society, taking into consideration the potential of the already available equipment and gadgets on the market at a reasonable cost. Through the implementation of the IoT approach, this study proposes a unique method for monitoring the activities of AP both inside and outside their homes, alerting family members and medical staff of the location, severity, and timing of any incidents. The prototype's compact, lightweight design includes a NodeMCU-23DSP board, a Neo-06 GPS module, and a wireless modem/Wi-Fi router. The Blynk 2.0 program facilitates remote patient monitoring via computers and Android devices. After testing the proposed device on a 78-year-old Alzheimer's patient, under the supervision of their specialist physician for two weeks, we observed that the device was highly efficient in providing the doctor with the necessary information within the specified timeframe. Additionally, the patient did not experience any discomfort or inconvenience while wearing the device on their wrist, validating its effectiveness and efficiency as a monitoring and alert system for AP.

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