

An Integrated AI and IoT-Based System for Early Detection and Continuous Monitoring of Alzheimer's Disease

Mohammed A. Riad* and Hazem M. El-Bakry

Faculty of Computers & Information, Mansoura University, Egypt

*Corresponding author Email: m.alaa.riad@gmail.com

Abstract: Millions of people worldwide endure Alzheimer's disease, a degenerative neurological disorder that needs to be detected early and observed continuously to improve care of patients and results. This study offers an comprehensive system that merges Internet of Things (IoT) technology for continuous patient monitoring with deep learning-based diagnosis utilizing magnetic resonance imaging (MRI) images. Convolutional neural networks (CNN) with smart sensors allows real-time monitoring and identifies the stage of Alzheimer's disease, helps enhance clinical decisions and emergency intervention. The significance of IoT to enhance patient safety and well being, lower risks and help experts successfully control Alzheimer's disease is highlighted in the article. This study is based on two areas related to Alzheimer's disease: the first area or stage is to discover and diagnose Alzheimer's disease using Deep Learning (DL) methods and its models, and the second stage is to how can we keep monitoring and follow-up our patients movement using IoT. In our paper, a developed diagnosing framework based on DL also real time monitoring of Alzheimer's is proposed. Diagnosis stage is achieved through DL MRI analysis, then we followed it by a vital signs, sleep, and activity monitoring framework to monitor patients' all-day activity in daily life using wearable sensors. the Activity monitoring provides a comprehensive framework for assistance in activities of daily living and evaluation of patient decline based on movement level and sleeping pattern and vital signs. When compared to existent methods, the results of Alzheimer's diagnosing suggest an improve of up to 86.34% disease detection accuracy. Additionally, over 95% accuracy was attained in categorizing activities of daily living, which is extremely promising when considering the subject's activity profile.

Keywords: Alzheimer's Disease, Deep Learning (DL), Internet of Things (IoT), MRI image, Monitoring, Healthcare Decision Support ,WebSocket , ocelot gateway

I. INTRODUCTION

Alzheimer's disease is one of the most difficult hindrances to overcome in the modern healthcare landscape, which is one of the degenerative diseases that affects the brain functions, which leads to severe effects on the patient's behaviors, memory, and overall well-being. It's widely accepted in the healthcare community that early detection of the disease can lead to enhanced well-being of the patient and slow and even reduce the severe symptoms for a significant period of time; correct detection and diagnosis of the disease are of great importance [8, 9].

Detection and diagnosis approaches are usually tiresome and typically do not offer the ongoing supervision required for high-impact medication. As a consequence, the necessity for utilizing technological advancements to support better disease detection and continuous monitoring of patient status is rapidly rising [10].

The latest advancements in the fields of Internet of Things (IOT) and Artificial Intelligence (AI) have provided new possibilities to enhance healthcare at large and especially healthcare for Alzheimer's disease. One of the most promising AI technologies is Deep Learning (DL) which can be combined with IoT to establish a smart system that can help in the early detection of disease and ongoing monitoring of patient statuses in real time [3,6,7].



One of the most essential DL approaches is the convolutional neural network (CNN), which can be utilized in the early detection of Alzheimer's based on MRI images of patients at very early phases of the disease [11, 12]. At the same time, IoT sensors and devices can perform the task of continuous patient monitoring of different vital functions of the patient; not only this, but they also provide a warning system of anomalous activities of the patient in case of emergency [4, 5].

Caretakers do not demand perfect detection certainly before the start of the first stages of disease treatment. But the main goal is to minimize the vagueness of the detection of the disease as much as possible to make perfect care decisions based on current circumstances. Furthermore, detection of the disease is not a separate act, but it is tightly linked with the treatment of the disease and feedback from the patient. In the case of Alzheimer's disease treatment and care, monitoring is an essential pillar and an expansion of the treatment process as a means of adapting the treatment plan based on feedback from the monitoring process. Having a means to reduce patient turmoil and unrest and help overcome cases of obliviousness and wandering, real-time monitoring is as important as early disease detection [1].

The merging and integration of both IoT and DL can lead to improved and enhanced disease detection and give caretakers a smart decision support system that can reduce the burden on doctors, nurses, and scientists integrated into the process of treatment. Smart systems and sensors, like smartwatches with motion sensors, can monitor and send data to the cloud platform, which is processed and analyzed, and initiate an alerting system when needed. The integration of both technologies leads to improved intervention and enhanced well-being of patients [2,3].

Research Question

How can a system which combines the pattern recognitions and automated feature selection capabilities of DL for Alzheimer's early detection and IoT continuous data collection through sensors and devices for patient monitors improve the detection and wellbeing of patient and help enhance therapeutic assessment ?

Answer

By the creation of a two stages framework that consists of first stage which utilized the MRI DL models for early detection of the Alzheimer disease, after that take advantage of IoT sensors for the ongoing monitors for patient statuses in real time. Monitors stage can provide alerting and warning on timely manner to the caretakers and other concerned parties like relatives of patients. This improve and enhance wellbeing of the patient.

The first stage early detection of the disease provides accurate detection of the Alzheimer's based on CNNs model, on other hand the second stage monitors stage provide statuses updated of the patient activities and statuses continuously which help caretakers take enhanced decisions based on current circumstances.

Objectives

- To build a DL model that can detect Alzheimer's different stages based on MRI image of the patient's brains with high degree of confidence.
- To develop an IoT approach that includes monitoring of patients' activities (sleeping, walking etc) and statuses using movement and vital signs sensors.
- To build a secure data acquisition and analysis framework, which establishes end to end system for sending, analysis and recording for patient data using tokens for authentication and authorization.
- To develop early warning and alerting systems that alert caretakers or other concerned parties like relatives and family members on timely manner about anomalies and emergencies and record data of events for future use.
- To improve clinical decisions process based on analysis and detection models, reduce the overall response time and provide enhanced care
- Enhance wellbeing of patients and caretakers alike by reduce the burden of work, and enhanced homecare for patient utilizing remote medicine.



II. BACKGROUND AND LITERATURE REVIEW

In literature most research focuses on only one aspect of Alzheimer's disease, first focusing on the early detection of the disease using medical images like MRI and utilizing DL or AI in general for the detection of the different stages of the disease, and second focusing on ongoing monitoring of patient status based on utilizing IoT sensors and devices like smartwatches and other wearables. Rarely in literature do you find studies and research that focus on both aspects of the disease. This research fills the gap in literature by providing a complete integrated solution merging the strengths of both early detection and constant patient monitoring [3,4,6].

Previous research shows high accuracy of CNNs for early detection of Alzheimer's using MRI and other medical imaging approaches [8,9,11,12]. On the other hand, IoT integration in healthcare shows great potential in remote medication and constant monitoring of patient status but does not have analytic and diagnostic process integration [5, 10].

The proposed framework merges both detection and constant monitoring into one complete package, which establishes an end-to-end solution that moves between detection of the disease and constant monitoring of patients' vital signs and statuses, as Alzheimer's patients require constant monitoring and intervention in a timely manner.

1. Alzheimer's Patient Support System Based on IoT and Machine Learning

Authors: S. Swapna Kumar, Vismaya N Sasi, Vaanisha Murali

Published: 2024

Overview: this paper proposed a novel framework built for improving the well-being and safety of patients suffering from Alzheimer's disease. The proposed framework consists of two main modules: a smart wearable, which is an armband with a set of sensors (heart rate, accelerometer, and GPS) for constant patient monitoring, and a face recognition module that utilizes machine learning models like (CAFFE and :BPH) to detect familiar faces and help the patient recognize family members. The combination of two modules provides the patient with constant monitoring and a warning and alerting function for caretakers and family members in case of emergencies. Providing care and assistance in a timely manner.

2. IoT Prototype for Real-Time Monitoring and Medication Reminders

Published: 2023

Overview: In this paper the authors proposed building an IoT-enabled device that can locate the patient in real time utilizing GPS sensor and alert the patient to take medication utilizing an alarm. Not only this but also at the same time give the caretakers remote monitoring of patient vital signs through sensors like heart rate and movement sensors. This is made easy by the utilization of Bkynk 2.0 application and providing remote monitoring of patients' status and condition.

3. Digital Intelligence Visualization Health Monitoring Device

Published: 2025

Overview: this paper proposed a wearable device build for constant collection of vital sign data of the Alzheimer's patients. The wearable device utilizes multiple sensors to observe and monitor movement patterns and behavior of patients. After the data collection completes, the data is then sent to the cloud for further analysis and processing and classification. The classification is based on a pretrained CNN (PRENet). The cloud platform is responsible for the creation of alerts to the caretakers and family members in case of emergency.

4. IoT-Assisted Cloud Computing Architecture for Alzheimer's Disease Detection

Published: 2023

Overview: this research proposed a framework that combines IoT, which is used for data collection, and merges it with a cloud platform for the preprocessing and storage of data. At the same time, utilizing a Long-Short Term Memory



(LSTM) network for analysis of collected data. The main objective of the proposed framework is to enhance the early detection of Alzheimer’s disease by overcoming challenges like the availability of data, long response time, and security and privacy of patient data.

5. AD Marker: A Multi-Modal Federated Learning System for Monitoring Digital Biomarkers of Alzheimer's Disease

Authors: Xiaomin Ouyang et al.

Published: 2023

Overview: This paper proposed a comprehensive framework that addresses several challenges related to Alzheimer's detection, like lack of sufficient labeled data. Limited computing processing and finally heterogeneity of data. The authors create a small-sized multi-modal hardware system. The proposed system achieved state-of-the-art performance with 93.8% accuracy in the detection of early signs of the disease. The proposed system named ADMarker which is a new platform that doctors can use to detect the progress of the disease, combines multiple markers like biomarkers, the environment, and the demographics.

6. Intelligent Assistive System Based on Augmented Reality and IoT for Alzheimer's Patients

Author: Fatemeh Ghorbani

Published: 2024

Overview: this research proposed a smart assistant system that combined three different technologies: IoT, augmented reality (AR) and finally adaptive fuzzy decision-making. The system integrated systems location and storage and AR for interacting with patients, a complete end-to-end decision-making system, and a user interface (UI) that is used by the caretakers like doctors and nurses. The system has two main modes, fully automated and semi-automated, to help improve the well-being of patients and provide real-time observation services of patients.

7. The SERENADE Project: Sensor-Based Explainable Detection of Cognitive Decline

Authors: Gabriele Civitaresse et al.

Published: 2025

Overview: This paper proposed explainable artificial intelligence for the detection of anomalous in behaviors and cognitive functions of patients that are early signs of Alzheimer’s disease. By the utilization of a smart home environment equipped with a diverse set of sensors and combined with wearables. The system collected data for human activity recognition (HAR). The data collected is used in the clinical decision-making system as an early detector of Alzheimer's disease.

Comparison of IoT-Based Alzheimer Monitoring Studies

Study Title	Year	Main Technology	Monitoring Type	Decision Support	Evaluation / Results
Alzheimer's Support System utilizing IoT and ML	2024	IoT + ML (CAFFE, LBPH)	Vital Signs + Facial Recognition + GPS	Notification to caregivers + emergency alert	Timely alerts facial recognition system emergency alerting and support system
IoT based Monitoring Alzheimer's	2023	GPS, Nedelcu, medication notifications	Medication alerting + timely Location	limited analytics support	Limited functionality Ideal for medication reminders
Digital Health observation	2025	Wearable Sensors +	Multimodal (Behavioral,	Timely visualization + notifications High	High accuracy and reactivity;



system		CNN	Physiological, Psychological)	precision	supports vigorous interventions.
IoT-Assisted Cloud Computing platform	2023	IoT + Cloud + LSTM	Sensors + Cloud analysis and processing	Prediction model for classification	Enhanced latency and detection accuracy Ideal for large-scale deployments.
AD Marker - Federated Learning framework	2023	IoT + Federated Learning (FL)	Digital Biomarkers and environment factors	Federated learning classification	Achieved 93.8% accuracy Enhanced privacy protection.
Aiding System Using AR and IoT	2024	IoT + AR + Fuzzy Logic	Activity Support + timely Alerts	Automatic decision support	Precise activity guidance Dynamic UI modes.
SERENADE - Explainable Cognitive observation and classification	2025	Smart Homes+ Explainable AI	HAR Monitoring + Behavioral Analysis	Explainable AI for physicians	Effective early detection of patient cognitive decline using HAR changes supports physicians understanding .

III. METHODOLOGY

The proposed system consists of two major phases:

3.1 Phase 1: Diagnosis Using Deep Learning

Data collection step : up to 6,123 images were used from ADNI dataset, following the utilizing of image we conducted preprocessing on images [11, 12, 13]

Preprocessing step : it consisted of sub steps, we first utilized image denoising and then we following that we utilized standrilization of image sizes and dimensions to ensure consistent input for our model [13].

Modeling step: we utilized a CNN DL model that is trained for detection and classification of patient's MRI images into three classes No dementia, mild dementia and moderate dementia [14, 15].

Training and evaluation step: the model achieved 86.34% accuracy in training phase and 86.45% accuracy in validation phase which is a good for early detertcion of Alzheimer's disease [14].

3.2 Phase 2: Continuous Monitoring Using IoT

Sensor utilization: Using wearable sensors and device for the collection of vital signs and other activity data like (heart rate, vital signs, sleep pattern and daily acitivities).

Data transfer: Utilizing Ocelot gateway and secure real time communication protocols such MQTT, and for ensurance of better reliability of packet transfer we used web sockets for sensors data transfer.

Data processing: The system analysis inbound real-time sensors data for the detection of abnormal and critical incidents.

Notification system: Use the websocket protocol for automated notification boracation to caretakrs and family members for instant reactions.

Dashboard:

Timely visulizations aid care takers and family members of the patient to make better decision based on current conditions and statues of the patient.



3.3 System workflow

As presented in (Figure 1), the system workflow begins with MRI images utilization and preprocessing, after that the detection phase starts with CNN model which decides if the patient has Alzheimer or not. If he has the disease the continuous monitoring and observation of patient daily live and vital signs commence, this phase is carried out by a set of sensors that collect all vital signs and daily activity, the collected data from the sensors will be sent to the server, then analysis on timely manner for detection of emergency or abnormalities. If something wrong happens an alert is broadcasted to the caretakers and family members, and the incident is stored for future analysis and utilization, after that it returns again to the continuous monitoring phase.

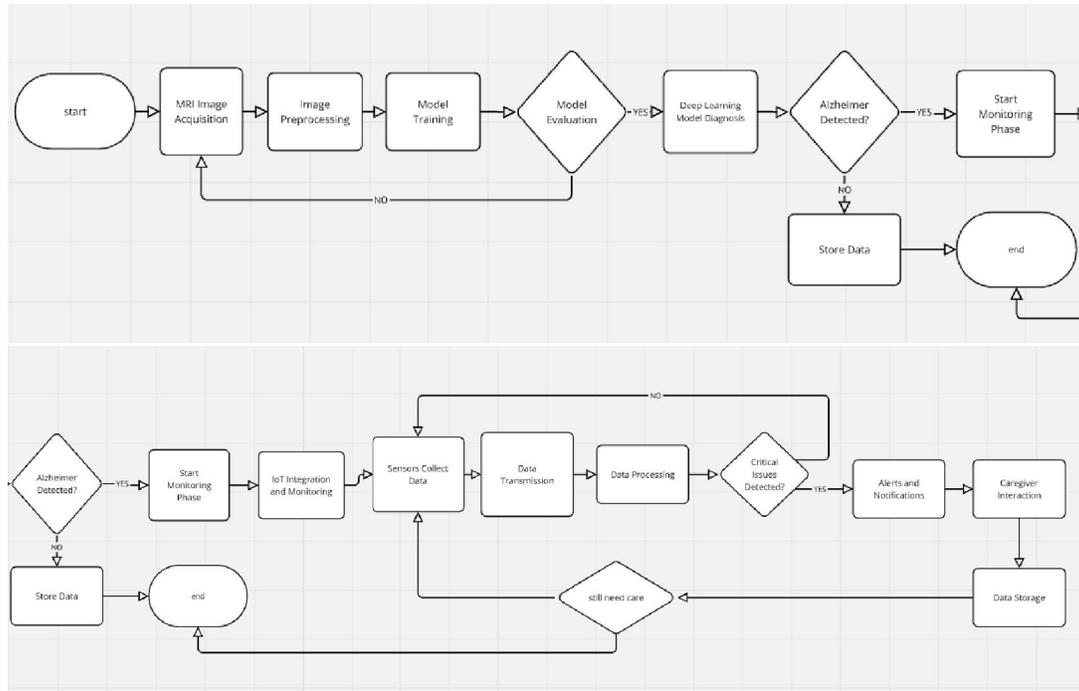


Figure 1 . Diagnostic and Follow-up Diagram.

IV. RESULTS AND DISCUSSION

Diagnosis Performance

The proposed CNN architecture shows a state-of-the-art performance in specifying the disease's current stage, which gives a vital capacity in the arsenal of clinicians in early detection of the disease and helps make informed decisions during the treatment operation.

IoT Monitoring Impact

Real-time monitoring has led to a noticeable decrease in accidents like patient wandering and forgetting of medication. These types of accidents are typical of Alzheimer's disease and can sometimes lead to missing cases and even death in road crossings. Timely notification has improved the caretakers' and family members' response to emergencies, which in turn saves the life of the patient.

Decision Support

By utilization of real-time monitoring, which collects continuous data from the patient related to vital signs and other essential measures. The system aids clinicians in gaining deeper understanding of the patient's current status and future trends. Not only this, but it also improves the response time in case of emergencies, which enhances overall patient care quality.



V. SECURITY AND PRIVACY CONSIDERATIONS

Patient data security is protected by the encryption of data during transmission to the server and after arriving to the server before storage. The proposed system utilized access control; only those who need information will be able to access it. And at the same time follows the standard privacy measure in the field of healthcare for the protection and securing of patient data [4,6,7].

VI. CONCLUSION AND FUTURE WORK

This research proposed a complete framework that takes advantage of early detection utilizing AI and real-time monitoring of patients based on IoT. This comprehensive approach improves the accuracy of early detection and the well-being of the patient. At the same time, it improves the decision-making process of the clinicians by aiding in informed decision-making.

Future improvements may focus on the utilization of a wider range dataset with more data points for improved generalization of DL model. Another focus may try to build IoT devices that are built for Alzheimer's patients and elderly patients. Improve the security of data collected by implementing more robust protocols and the integration with the electronic health record (EHR) system in hospitals. This provides improved healthcare provided by the hospitals and secures the patients at the same time.

REFERENCES

- [1]. Benyoussef, E. M., Elbyed, A., & El Hadiri, H. (2019). 3D MRI Classification Using KNN and Deep Neural Network for Alzheimer's Disease Diagnosis. *Advanced Intelligent Systems for Sustainable Development (AI2SD'2018)*, 154–158. https://doi.org/10.1007/978-3-030-11884-6_14
- [2]. Civitarese, G., Fiori, M., Arighi, A., Galimberti, D., Florio, G., & Bettini, C. (2025). The SERENADE project: Sensor-Based Explainable Detection of Cognitive Decline. *arXiv preprint arXiv:2504.08877*. Electrical Ebrahim,
- [3]. A T., Mawfaq Mohamedsheet Al-Hatab, M., Al-Jabbar, E. Y. A., Alkhaled, W. H., & Al-Sawaff, Z. H. (2023). Using IoT technology for monitoring Alzheimer's and elderly patients. *Indonesian Journal of Engineering and Computer* <https://doi.org/10.11591/ijeecs.v31.i2.pp986-994> *Science*, 31(2), 986.
- [4]. Feng, W., Halm-Lutterodt, N. V., Tang, H., Mecum, A., Mesregah, M. K., Ma, Y., Li, H., Zhang, F., Wu, Z., Yao, E., & Guo, X. (2020). Automated MRI-Based Deep Learning Model for Detection of Alzheimer's Disease Process. *International Journal of Neural Systems*, 30(06), 2050032. <https://doi.org/10.1142/s012906572050032x>
- [5]. Ghorbani, F., Farshi Taghavi, M., & Delrobaei, M. (2023). Towards an Intelligent Assistive System Based on Augmented Reality and Serious Games. <https://doi.org/10.36227/techrxiv.22678831.v1>
- [6]. Kumar, S. S., Sasi, V. N., & Murali, V. (2024). Alzheimer's Patient Support System Based on IoT and ML. *Journal of Electronics and Electrical Engineering*. <https://doi.org/10.37256/jeee.3120244607> *Data*
- [7]. Lee, G., Kang, B., Nho, K., Sohn, K.-A., & Kim, D. (2019). MildInt: Deep Learning-Based Multimodal Longitudinal Integration <https://doi.org/10.3389/fgene.2019.00617> *Framework*. *Frontiers in*
- [8]. *Genetics*, 10. Mahendran, N., & P M, D. R. V. (2022). A deep learning framework with an embedded-based feature selection approach for the early detection of the Alzheimer's disease. *Computers in Biology and Medicine*, 141, 105056. <https://doi.org/10.1016/j.compbiomed.2021.105056>
- [9]. Mehmood, A., Maqsood, M., Bashir, M., & Shuyuan, Y. (2020). A Deep Siamese Convolution Neural Network for Multi-Class Classification of Alzheimer Disease. *Brain Sciences*, 10(2), 84. <https://doi.org/10.3390/brainsci10020084>
- [10]. Odusami, M., Maskeliūnas, R., & Damaševičius, R. (2022). An Intelligent System for Early Recognition of Alzheimer's Disease Using Neuroimaging. *Sensors*, 22(3), 740. <https://doi.org/10.3390/s22030740>



- [11]. Oskouei, R. J., MousaviLou, Z., Bakhtiari, Z., & Jalbani, K. B. (2020). IoT-Based Healthcare Support System for Alzheimer's Patients. *Wireless Communications and Mobile Computing*, 2020, 1–15. <https://doi.org/10.1155/2020/8822598>
- [12]. Ouyang, X., Shuai, X., Li, Y., Pan, L., Zhang, X., Fu, H., Cheng, S., Wang, X., Cao, S., Xin, J., Mok, H., Yan, Z., Yu, D. S. F., Kwok, T., & Xing, G. (2024). ADMarker: A Multi-Modal Federated Learning System for Monitoring Digital Biomarkers of Alzheimer's Disease. *Proceedings of the 30th Annual International Conference on Mobile Computing and Networking*, 404–419. <https://doi.org/10.1145/3636534.3649370>
- [13]. Riad, M. and El-Bakry H. M. (2024) "IoT-Based Intelligent System for Alzheimer's Disease Detection & Monitoring". *IJAİM*, 12.4: 24-33. https://www.ijaim.org/administrator/components/com_jresearch/files/publications/IJAİM_674_FINAL.pdf
- [14]. Sharma, R, Goel, T, Tanveer, M & Murugan, R 2022, 'FDN-ADNet: Fuzzy LS-TWSVM based deep learning network for prognosis of the Alzheimer's disease using the sagittal plane of MRI scans', *Applied Soft Computing*, vol. 115, Elsevier . BV, p. 108099, viewed
- [15]. Zheng, M., Wu, Y., & Weng, C. (2025). A digital intelligence visualization health monitoring device for Alzheimer's disease patients based on WBAN technology. *Scientific Reports*, 15(1). <https://doi.org/10.1038/s41598-025-99637-x>

