



RESEARCH ARTICLE

IoT-based intelligent system For Alzheimer's Disease Detection & Monitoring

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Abstract

This research is based on two areas related to Alzheimer's disease, the first is the early detection and diagnosis of Alzheimer's disease using deep learning techniques and its various algorithms, and the second relates to how to monitor and follow up on Alzheimer's disease using the Internet of Things (IoT). In this paper, a new diagnosis based on deep machine learning and monitoring of diseases similar to Alzheimer's is proposed. Diagnosis of Alzheimer's-like diseases is achieved through deep learning magnetic resonance imaging (MRI) analysis followed by an activity tracking framework to monitor people's activities in daily life using wearable inertial sensors. Activity monitoring provides a framework for assistance in activities of daily living and assessment of patient deterioration based on activity level. The results of Alzheimer's diagnosis show an improvement of up to 86.34% with respect to current known techniques. Furthermore, greater than 95% accuracy was achieved for classifying activities of daily living, which is very encouraging in terms of looking at the activity profile of the subject.

Keyword: IoT, Deep Learning

Introduction:

The process of diagnosis and monitoring is very important in the healthcare system for both patients and healthy people. It is important to note that clinicians do not require diagnostic certainty before starting treatment; The goal of collecting information in the diagnostic process is to reduce diagnostic uncertainty sufficiently to make optimal subsequent care decisions. In addition, the provision of treatment can also help to inform and improve diagnostic work, which is indicated by the feedback loop from treatment to the information-gathering step in the diagnostic process. This also demonstrates the need for doctors to diagnose health problems that may arise during treatment. [2]

Diagnosis is the basis of any treatment a patient may receive, from medication to surgery. Accurate diagnosis is critical to avoid wasting precious time on the wrong course of treatment. The patient plays a fundamental role in helping to establish the correct diagnosis. While health surveillance is very important in terms of prevention, especially if early detection of diseases can reduce suffering and medical costs. [1] Rapid diagnosis and treatment of various diseases can radically improve the alternatives to medical treatment for a patient.

[3] The neediest for diagnosis and monitoring are those who suffer from dementia and Alzheimer's disease. Due to their health problems, they are always at risk as they would suffer from agitation, lack of nutrition, and lack of suitable treatments. From this point, The Internet of Things (IoT) has played a leading role in transforming how would they live today. The Internet of Things transforms medical data into insights to improve Alzheimer's patients' care. By leveraging devices like those used to connect sensors and other types of things that people can use, all of this information can be stored in the cloud and doctors/caregivers can easily monitor patient data in real-time.

That's why the IOT has so many characteristics concerning Alzheimer's disease patients: The Internet of Things allows doctors to easily monitor and manage the health of their patients, saving them precious minutes every day. In the telehealth monitoring system, the public IoT tracks the patient's vital signs in real time and responds if there is a problem with the patient's health.

The patient must be equipped with a device that transmits vital signs data from the patient's location. The transmitter is connected to a hospital through a communications network. It has improved the quality of life for many Alzheimer's patients who suffer from absent-mindedness, dementia, and severe memory loss.

Here, my role is to alleviate the suffering of Alzheimer's patients through two steps, the first is the diagnosis and early detection of the disease, and the second is the monitoring stage, using the Internet of Things and the use of deep learning techniques. This would be discussed later in the framework of the proposed system.

The research is intended to be organized as follows: First, the Introduction and it submits the importance of diagnosis and monitoring for both sick and healthy people, especially for

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those who suffer from Alzheimer disease, followed by the Internet of Things and its importance and impacts on people's lives and how it made it easy for Alzheimer disease patient to follow up their lives. Then comes the Basics section, where the technique being used in this research and its science being discussed.

The fourth section is the Literature review where different studies and previous proposed systems were reviewed. Then the proposed methodology is being submitted to discuss the proposed system due to defects in previous systems. Result analysis and discussions were being submitted pre-final to show-up what we reached to. Finally, the conclusion section where we gave a short brief for what the research paper concluded.

Machine learning (ML) is a field of research dedicated to understanding and building methods that "learn"—that is, ways that leverage data to improve performance on a set of tasks. It is seen as part of artificial intelligence. Machine learning algorithms build a model based on data samples, known as training data, to make predictions or decisions without being explicitly programmed to do so. [5] Machine learning algorithms are used in a wide variety of applications, such as medicine, email filtering, speech recognition, agriculture, and computer vision, where it would be difficult or infeasible to develop traditional algorithms to perform the required tasks.

A subset of machine learning is closely related to computational statistics, which focuses on making predictions using computers, but not all machine learning is statistical learning. The study of mathematical optimization provides methods, theory, and application areas in the field of machine learning. [8] Data mining is a related field of study, with an emphasis on exploratory data analysis through unsupervised learning. [12] Some machine learning applications use data and neural networks in a way that mimics how a biological brain works. In its application through business problems, machine learning is also known as predictive analytics.

Deep learning (also known as deep structured learning) is part of a larger group of machine learning methods or a subfield of machine learning concerned with algorithms inspired by the structure and function of the brain called artificial neural networks. Deep learning can be supervised, semi-supervised or unsupervised. [9]

[4] Deep learning architectures such as deep neural networks, deep belief networks, deep reinforcement learning, recurrent neural networks, convolutional neural networks, and switches have been applied in areas including computer vision, speech recognition, natural language processing, machine translation, bioinformatics, and drug design. , medical image analysis, climatology, material examination, and board game software have achieved results comparable to, and in some cases superior to, the performance of human experts.

Deep learning techniques:

Some powerful techniques that can be applied to deep learning algorithms to reduce training time and improve the model are discussed as following:

1. **Backpropagation:** While solving an optimization problem using a gradient based method, backpropagation can be used to calculate the gradient of the function for each iteration.
2. **Stochastic Gradient Descent:** The use of the convex function in the gradient descent algorithms ensures finding the optimal minimum without falling into a local minimum. Depending on the values of the function and the learning rate or step size, it can reach the optimal value in different ways and methods.
3. **Learning rate decay:** Adjusting the learning rate increases the performance and reduces the training time of the stochastic gradient descent algorithms. The most commonly used method is to gradually reduce the learning rate. Bigger changes can be at the beginning and then gradually reduce the learning rate in the training process.
4. **Skip-gram:** Word embedding algorithms can be modeled using Skip-gram. In the skip-gram model, two vocabulary terms share a similar context; Then these terms are identical. **For example, the sentences "cats are mammals" and "dogs are mammals" are meaningful sentences that share the same meaning "they are mammals."** Skip-gram can be implemented by looking at a context window containing n terms, training the neural network to skip one of those terms and then using the model to predict which term was skipped. [10]

Deep learning applications:

Deep learning networks can be used in a wide variety of applications, such as self-driving cars, natural language processing, the Google virtual assistant, visual recognition, fraud detection, healthcare, detecting developmental delays in children, adding sound to silent movies, automated machine translation and subtitles. Text-to-image, image-to-image synthesis, automatic image recognition, image colorization, earthquake prediction, market price prediction, news aggregation, and fraudulent news detection. Moreover, deep learning can be used in the healthcare system to detect and recognize different diseases and treatments.[11]

Literature Review:

1. **Odusami et al. (2022):** In this study, "An intelligent system for the early detection of Alzheimer's disease using neuroimaging." The researchers used two pre-trained models to simultaneously extract features from the MRI images and then combined the extracted features for Alzheimer's disease classification. During the classification process, the feature sequence accessed distant or irregular information in fully connected layers, so they expected that the use of weight randomization would bridge the gap between the feature maps. Using the ADNI data set as a standard, they ran full experiments to test our hypothesis. They used 25 subjects from each of the five categories: AD, MCI, EMCI, LMCI, and NC (a total of 125 subjects). Their findings showed that, compared to four-way multilayer classification, the proposed model sequence of MRI features improves stratification in five-way multilayer classification.
2. **Sharma S et al. (2022):** "A Deep Learning-Based Convolutional Neural Network Model with VGG16 Feature Extractor for Alzheimer's Disease Detection Using Magnetic Resonance Imaging." The researchers used two image datasets containing 6,400 and 6,330 images, and also used the deciliter algorithm software by applying a neural network classifier with VGG16 feature extractor to set the first AD, to help generate early recognition morphologies through image processing. Throughout this article, for early diagnosis of Alzheimer's disease. In addition, the results are squared

compared to previous studies, which in all expected models give more results. Finally, this article is applicable to detect various machine learning (ML) approaches and deciliters to be used to verify AD stage determination.

3. **Mehmod et al. (2020):** "A Deep Siamese Convolution Neural Network for the Multiclass Classification of Alzheimer's Disease." The researchers used the Siamese Convolutional Neural Network (SCNN), a CNN-based model, developed to divide dementia into four separate stages: Alzheimer's disease (AD), mild dementia (MD), very mild dementia (VMD), and no dementia. (ND). The model was trained using a modest data set, but the researchers' studies showed that accurate results can still be obtained. The proposed model was then compared to five other models of the most recent models, and it was shown to perform better than any of them.
4. **Feng et al. (2020):** "MRI-based machine deep learning model for the detection of Alzheimer's disease process." The researchers proposed a 3D-CNN-SVM model for the diagnosis of Alzheimer's disease based on MRI. They start by extracting features from the input MRI images using the 3D-CNN model, and then use SVM to classify the MR images based on the features identified by the 3D-CNN model. In the end, the authors compared the performance of the proposed model with the 2D-CNN and 3D-CNN models and found that the 3D-CNN-SVM model performed better.
5. **Ben Yousef et al. (2019):** "3D MRI Classification Using KNN and Deep Neural Network for Diagnosis of Alzheimer's Disease". Based on MRI data, a hybrid model using KNN (K-Nearest Neighbor) and DNN classified participants as having no dementia (ND), MCI, or Alzheimer's disease (AD). The researchers developed a model incorporating KNN and DNN that facilitated identification among difficult-to-diagnose patients. The DNN was made up of two hidden layers, each with 100 nodes. Finally, their experimental findings validated the effectiveness of the suggested model in differentiating between the various stages of Alzheimer's disease (without dementia) (ND), MCI, and Alzheimer's disease (AD).
6. **Garam Lee et al. (2019):** "Prediction of Alzheimer's disease progression using a multimodal deep learning approach". The researchers recommended predicting likely MCI to AD conversion, applied a deep learning approach, a multimodal perennial neural network. They developed an Associate in Nursing integrative framework that combines not only cross-sectional neuroimaging biomarkers at baseline, but also longitudinal mood biomarkers (CSF) and psychological characteristics performance biomarkers obtained from the Neuroimaging Initiative cohort of Alzheimer's disease (ADNI). Their findings showed that their framework has integrated longitudinal multi-domain knowledge, and this led to better results ate the end.

Reference	Author	Year	Alzheimer disease biomarker	Deep learning technique	Alzheimer disease database	Model performance
1	Odusami et al.	2022	MRI	Implemented a model called the randomized concatenated model	25 subjects from each of the five categories of AD, MCI, EMCI, LMCI, and NC (a total of 125 subjects)	In the form of precision, recall the accuracy as 0.9894, 0.9889, and 98.86%, respectively.
2	Sharma et al.	2022	MRI	DL algorithm is utilized by applying a CNN with a VGG16 feature	MRI datasets containing 6400 and 6330 images	AUC and F1-score as (90.4%, 0.905, 0.904, 0.969, and 0.904), and (71.1%, 0.71, 0.711, 0.85, and 0.71) for dataset 1 and dataset 2, respectively.
3	Mehmod et al.	2020	MRI	CNN	OASIS-382 images (No Dementia: 167, Very Mild Dementia-87, Mild Dementia 105, Moderate AD-23)	Accuracy (No Dementia/Very Mild Dementia/Mild Dementia/Moderate AD): 99.05%
4	Feng et al.	2020	MRI	CNN	ADNI-469 subjects (AD- 153, MCI- 157, CN 159)	Accuracy (NC/MCI/AD): 92.11% ± 2.31 Accuracy (NC/AD): 99.10% ± 1.13 Accuracy (NC/MCI): 98.90% ± 2.78 Accuracy (MCI/AD): 89.40% ± 6.90
5	Ben Yousef et al.	2019	MRI	DNN	OASIS-416 subjects	Accuracy (NC/AD): 86.66%
6	Garam Lee et al.	2019	CSF, CT	multi-modal deep learning approach to study the prediction of MCI to AD conversion	Alzheimer's Disease Neuroimaging Initiative cohort (ADNI)	MCI conversion to AD yielded up to 75% accuracy, area under the curve (AUC) = 0.83 prediction model achieved the best performance with 81% accuracy, AUC = 0.86

Method

Existing systems:

Before we go through our system, we need first to go through the existing systems and see the disadvantages of these systems that led us to work on the output of our proposed system. Some of these disadvantages are: some of the studies have only diagnosis methods for Alzheimer disease, others only discussed the monitoring stage. The existing systems have small sample size which is a big challenge to achieve good classification accuracy. They also detect more noise, and the data may contain missing values which will cause uncertainty.

Proposed System:

The objective of this proposed system is simply to go through two stages; the first stage is to detect or diagnose the phase of Alzheimer's disease (AD) patients through deep learning models. The second stage is to facilitate monitoring of the disease and allows measures to be taken to provide optimal treatment and prevent complications.

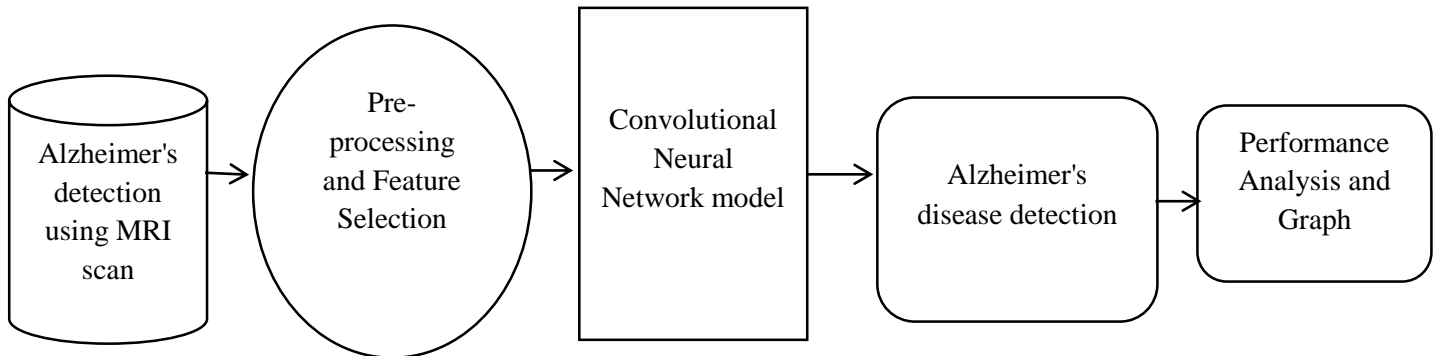


Fig 1. Proposed System Architecture.

The design of the proposed system architecture goes through 5 steps as following:

- 1) **Alzheimer's detection using MRI scan:** In this step, which called "Acquisition step" as we can get the MRI Images, then these images can be formatted according to the ADNI datasets using medical image convertor.
- 2) **Pre-processing and Feature Selection:** In this step, the images go through some techniques MRI registration, filtering, and normalization for the resampling methods for the next stage.
- 3) **Convolutional Neural Network model:** In this step, which called the "Augmentation step" Data is applied by traditional techniques such as reflection, flipping horizontal or vertical and rotation to show more details of the images.
- 4) **Alzheimer's disease detection:** This step is called the "Classification step" which apply medical image classification by deep learning, also it could be classified through by simple Neural Network architecture through a multi-class and binary medical image classifier that deals with 2D and 3D MRI. In this step, it's detected and classified which stage of the AD is!
- 5) **Performance Analysis and Graph:** This step is called "Application step" as we are now sure that there is a patient with Alzheimer disease. So, we need to go to the other stage "Monitoring stage" which is concerned about following-up the patient through wearable devices and sensors to give more data about the vital signs of the patient. It also gives data about the patient while sleeping, walking, nutrition process, agitation, and falling.

In this research paper, the proposed solution is for Alzheimer's patients. This system will help diagnose and monitor the activities of these people, health conditions and movements and will be responded to as quickly as possible in the event of an emergency by the concerned hospitals. In this paper, we developed an Alzheimer's disease detection system using a convolutional neural network (CNN) architecture using magnetic resonance imaging (MRI) scanning of images trained with the ADNI and NACC datasets. The models in this study were trained on the same data set in order to analyze their performance.

Result and discussion:

Data sets:

We used two of the datasets, the ADNI and NACC datasets:

1) ADNI datasets:

ADNI was introduced in 2003 and is a long-term study intended to investigate whether cerebrospinal fluid measurements, serial MRIs, clinical assessments, PET scans, and others help identify neuropsychological factors to track deterioration Mild cognitive and early development of Alzheimer's disease. ADNI data was collected from a variety of academic institutions, businesses, and subjects from more than 50 locations. ADNI data sets are classified into four categories: ADNI-1, ADNI GO, ADNI-2, and ADNI-3.

The time frame for overseeing the transition to AD was eighteen months. ADNI has previously been used in several studies to classify Alzheimer's disease and to recognize the progression of Alzheimer's disease. The primary purpose of ADNI is to see if sequential imaging, PET differential RSS display, and clinical and psychological scientific estimates can be combined to estimate the progression of primary MCI and AD.

2) NACC datasets:

The National Alzheimer's Coordination Center is home to one of the largest, oldest, and most robust Alzheimer's data sets, created in collaboration with more than 42 Alzheimer's Disease Research Centers (ADRCs) worldwide. The world over the past 20 years with funding from the National Institute on Aging (NIA). NIA has appointed the ADC Clinical Working Group to define and define an expanded and standardized clinical data set, called the Unified Data Set (UDS). The goal of the UDS is to provide ADC researchers with a standard set of evaluation procedures, grouped longitudinally, to better characterize ADC participants with mild Alzheimer's disease and mild cognitive impairment compared to unperturbed controls.

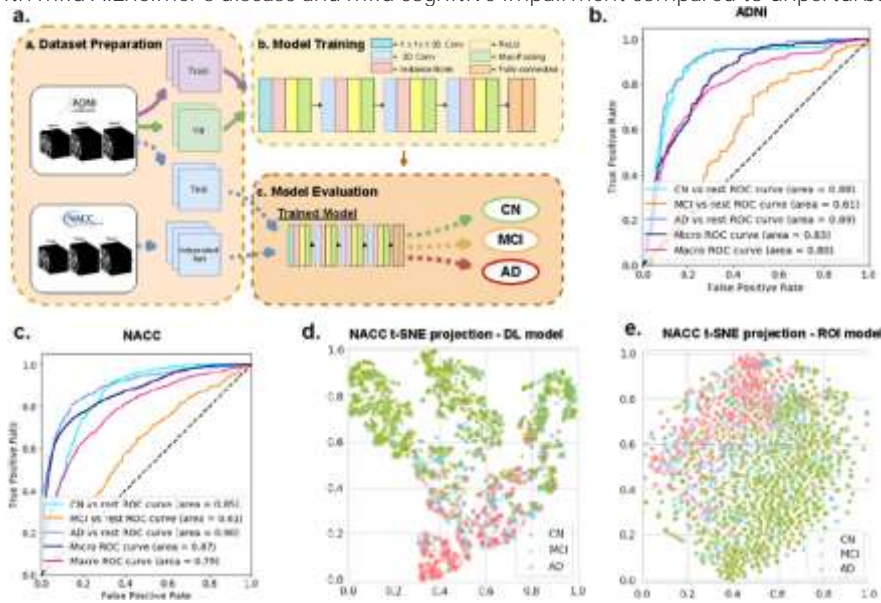


Fig 2. Diagnosis Alzheimer's disease according to datasets of ADNI and NACC.

Factors on which ADNI and NACC datasets are measured:

For advances in the diagnosis of Alzheimer's disease, the evaluation ADNI and NACC datasets of quantitative biomarkers (medical measures that can indicate the disease) in addition to cognitive tests is of great value. The five most common biomarkers examined were recently included in the revised diagnostic criteria for Alzheimer's disease and mild cognitive impairment due to Alzheimer's disease. These five biomarkers can be divided into two categories: measures of beta-amyloid protein and measures of nerve cell damage. For the first category, beta-amyloid can be measured by cerebrospinal fluid (CSF) aspiration or positron emission tomography (PET) scan. For the second category, damage to neurons can be measured indirectly by quantifying the fraction of tau protein in cerebrospinal fluid or using tau-PET, or directly by measuring brain metabolism with fluorodeoxyglucose (FDG) or atrophy using MRI (magnetic resonance imaging).

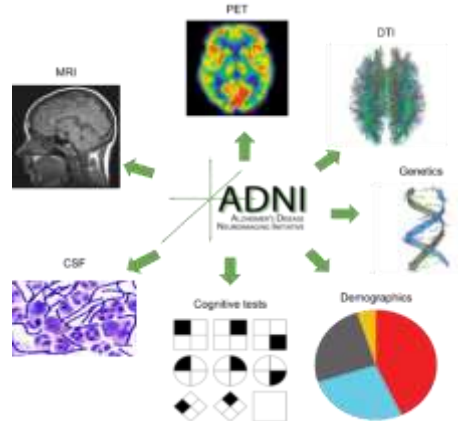


Fig 3. ADNI dataset to inform the prediction of AD.

Population: Patients with various stages of Alzheimer's and dementia were included.

Control: All studies were reviewed with or without control groups.

Outcome: All outcomes reported in papers, such as activity of daily living, medication intake, follow-up, and physical status determination of older adults were reviewed.

The proposed System testing:

System testing ensures that the entire integrated software system meets the requirements. It tests a configuration to ensure known and predictable results. An example of system testing is the configuration-oriented system integration test. System testing is based on process descriptions and flows, emphasizing pre-driven process links and integration points.

Integration test:

Software integration testing is the incremental integration testing of two or more integrated software components on a single platform to produce crashes caused by interface defects. The task of integration testing is to verify that components or software applications, for example components in a software system or - one step - company-wide software applications - interact without errors.

Test results: All of the above test cases passed successfully. There are no accidental defects.

Acceptance test:

User acceptance testing is a critical stage in any project and requires significant participation from the end user. It also ensures that the system meets functional requirements.

Test results: All of the above test cases passed successfully. There are no accidental defects.

The proposed system analysis:

- (1). To predict diseases such as Alzheimer's disease, the application of high-precision computational tools - automated machine learning - will help diagnose the disease at the same early stage and provide better clinical, social and economic outcomes.
- (2). In the proposed system, based on the accuracy of classification and prediction responses, the architecture of the convolutional neural network comes as the most suitable system for pattern recognition and prediction problems such as Alzheimer's disease detection system.
- (3). This model can help improve prediction performance by clinicians and cover limitations indicated in previous research.

In this work, we used the basic Convolutional Neural Network (CNN) architecture model to classify Alzheimer's disease from magnetic resonance imaging (MRI) images based on deep learning. A convolutional neural network (CNN) architecture model is used to avoid costly training from the start and to get higher efficiency with a limited number of datasets. The proposed system was able to give good accuracy with training accuracy of 86.34% and validation accuracy of 86.45% on test data with very small false ratings on normal and very moderate case.

Conclusion:

This paper presented a comprehensive framework for the diagnosis and monitoring of Alzheimer's disease using deep learning mechanism through IoT platforms. Prediction and analysis systems based on deep learning are widely used to diagnose Alzheimer's disease (AD). However, the low resolution of current techniques and the lack of post-diagnostic follow-up systems limit the scope of such studies.

The results for the diagnosis of Alzheimer's disease show an improvement of up to 86.34% with respect to the known current techniques. Furthermore, over 95% accuracy was achieved for classifying activities of daily living, which is very encouraging in terms of looking at the subject's activity profile.

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