

Detection of Alzheimer's Disease with Shape Analysis of MRI Images - A Glance

Adith Shaji*, Nikhil Mathew #, Abhijith Krishnan&, Midhun Rajendran@, Saran K S +, Shandry k k *

Department of Computer Science and Engineering, College of Engineering Kidangoor, Kottayam, Kerala, India

*adithshaji07@gmail.com, #nikhilmathew876@gmail.com, &abhijithkrishnanak123@gmail.com, @midhunrajendran94@gmail.com, +saran +shandryl@ce-kgr.org

Abstract—Alzheimer's disease (AD) is a progressive neurodegenerative disorder and the leading cause of dementia worldwide, making early and accurate diagnosis a critical clinical challenge. In recent years, artificial intelligence (AI)-based techniques have gained significant attention for assisting clinicians in the automated detection and staging of Alzheimer's disease. Numerous studies have explored deep learning approaches, particularly Convolutional Neural Networks (CNNs), for analyzing brain magnetic resonance imaging (MRI) data, as well as alternative biomarkers such as eye-movement patterns for early cognitive decline detection. Parallel advancements in transfer learning, hyperparameter optimization, and lightweight neural architectures have further improved diagnostic accuracy while reducing computational complexity.

This literature survey reviews and analyzes key research contributions in AI-driven Alzheimer's disease detection, focusing on MRI-based deep learning models, optimization strategies, multiclass disease classification, and non-invasive eye-tracking techniques. The surveyed works are examined in terms of datasets used, learning architectures, evaluation metrics, and reported performance. While many studies demonstrate high accuracy and promising clinical applicability, challenges remain regarding dataset imbalance, model generalization, interpretability, and real-world deployment. The survey highlights emerging trends such as explainable AI, mobile-based screening tools, and optimized deep learning frameworks as potential solutions to these limitations. Overall, this study emphasizes the need for robust, interpretable, and scalable AI-assisted diagnostic systems to support early Alzheimer's detection and improve clinical decision-making.

Index Terms—Artificial Intelligence (AI), Deep Learning, Clinical Decision Support System, Explainable AI (XAI), Predictive Analytics, Medical Imaging, Risk Prediction

I. INTRODUCTION

Alzheimer's disease (AD) is a progressive neurodegenerative disorder and the most common cause of dementia, leading to severe cognitive decline and functional impairment. The increasing prevalence of AD among the aging population has intensified the demand for early, accurate, and cost-effective diagnostic methods. Conventional diagnostic techniques, including clinical assessments and neuroimaging analysis, are often time-consuming, expensive, and reliant on expert interpretation, which may limit their effectiveness in early-stage detection.

Recent advancements in artificial intelligence (AI) have significantly transformed Alzheimer's disease diagnosis by enabling automated analysis of medical data. Deep learning

models, particularly Convolutional Neural Networks (CNNs), have demonstrated strong performance in extracting discriminative features from brain magnetic resonance imaging (MRI) scans for both binary and multiclass AD classification. In parallel, techniques such as transfer learning, hyperparameter optimization, and lightweight neural architectures have improved model accuracy and generalization. Additionally, non-invasive approaches based on eye-tracking and behavioral biomarkers have emerged as promising alternatives for early cognitive decline detection.

Despite these advances, challenges persist in terms of dataset imbalance, interpretability of deep learning models, and real-world clinical deployment. A structured analysis of existing research is therefore essential to understand current capabilities, limitations, and emerging trends in AI-driven Alzheimer's disease detection. **Highlights of this study are as follows:**

- This survey reviews recent AI-based approaches for Alzheimer's disease detection, focusing on MRI-based deep learning models and non-invasive eye-tracking techniques.
- The analyzed studies primarily employ CNN architectures, transfer learning, and optimization strategies for binary and multiclass AD classification.
- A comparative analysis of datasets, learning frameworks, and evaluation metrics used across existing studies is presented
- Key challenges such as model interpretability, dataset generalization, and deployment feasibility are identified.

The following section presents a review of existing literature in the proposed domain:

II. LITERATURE SURVEY

A. MRI-Based Alzheimer's Disease Detection Using Deep Learning

AbdulAzeem et al. proposed a CNN-based end-to-end framework for automated Alzheimer's disease classification using brain MRI images. Their approach avoided traditional machine-learning pipelines by directly learning features from raw MRI scans. The framework incorporated adaptive thresholding, data augmentation, Glorot uniform initialization, and the Adam optimizer, achieving high accuracy for both binary

and multiclass classification on the ADNI dataset. The study demonstrated the effectiveness of deep learning in capturing structural brain changes but required substantial computational resources.

Ajagbe et al. explored multiclass Alzheimer’s disease classification using deep convolutional neural networks and transfer learning models such as VGG16 and VGG19. Their work evaluated performance using multiple metrics, including accuracy, AUC, precision, recall, and F1-score. The results showed that VGG19 achieved superior overall performance, highlighting the effectiveness of deep pretrained networks for disease staging. However, the approach relied heavily on high-quality MRI data and sufficient annotated samples.

Dardouri introduced a deep CNN architecture with multiple convolutional branches for early Alzheimer’s disease detection. Using the OASIS dataset, the study employed extensive data augmentation to address class imbalance and achieved high accuracy in classifying four disease stages. The work emphasized the suitability of deep CNNs for real-time diagnostic applications, though the model’s size may limit deployment in resource-constrained environments.

B. Multiclass Classification and Alzheimer’s Disease Severity Analysis

Dar et al. focused on multiclass Alzheimer’s disease stage classification using transfer learning-based CNN models. Pretrained architectures such as MobileNet, VGG16, and ResNet50 were fine-tuned on MRI datasets, with MobileNet achieving the best balance between accuracy and computational efficiency. The study highlighted the applicability of lightweight models for practical diagnostic systems, though dataset dependency remained a limitation.

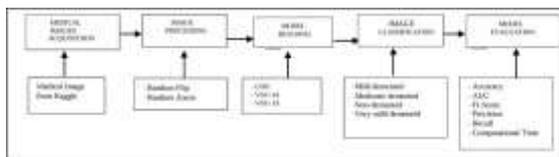


Fig. 1: []

Dardouri’s work further reinforced the feasibility of multiclass disease staging by employing deep CNNs with data augmentation to mitigate class imbalance, achieving strong classification performance across four Alzheimer’s disease severity levels.

C. Transfer Learning and Optimized CNN Architectures for Alzheimer’s Detection

Ajagbe et al. similarly employed transfer learning approaches using VGG-based architectures to enhance multiclass classification performance. Their findings indicated that deep pretrained models outperform conventional CNNs when trained on limited MRI datasets.

Kaya and Çetin-Kaya proposed a Particle Swarm Optimization (PSO)-based framework to automatically optimize

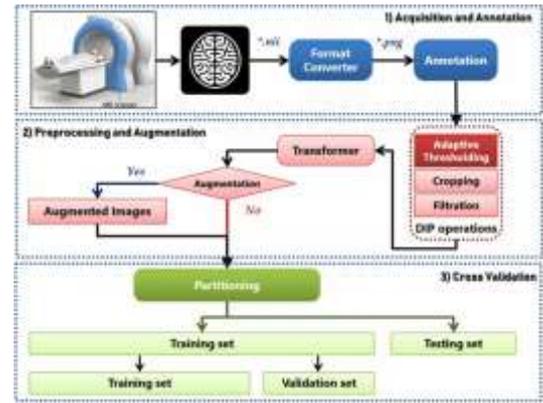


Fig. 2: [?]

CNN architecture parameters, including the number of convolutional layers and filters. The optimized lightweight CNN achieved high accuracy while reducing overfitting. However, the optimization process increased training complexity and computational cost.

III. NON-INVASIVE ALZHEIMER’S DISEASE DETECTION USING EYE-TRACKING TECHNIQUES

Tokushige et al. investigated early Alzheimer’s disease detection using eye-tracking during visual memory and search tasks. Their analysis of gaze fixation, saccade behavior, and pupil responses revealed significant differences between Alzheimer’s patients and healthy controls, enabling early cognitive decline detection with high sensitivity and specificity.

Li et al. extended eye-tracking-based diagnosis by developing an AI-driven framework using mobile device cameras. Machine-learning models trained on eye-movement features achieved strong diagnostic performance, demonstrating the feasibility of low-cost and accessible screening tools. However, both studies highlighted limitations related to sample size, device variability, and environmental factors..

IV. SURVEY AND REVIEW STUDIES ON AI-BASED ALZHEIMER’S DISEASE DETECTION

Altinkaya et al. presented a comprehensive survey of deep learning approaches for Alzheimer’s disease and dementia detection using MRI images. The study reviewed CNN-based classification methods, super-resolution techniques, and computer-aided diagnosis systems, emphasizing the growing role of deep learning in medical imaging. The survey also identified key challenges such as long MRI acquisition times, data quality issues, and lack of interpretability, underscoring the need for robust and explainable AI-based diagnostic frameworks.

V. CONCLUSION

This survey presented a comprehensive review of recent artificial intelligence-based approaches for Alzheimer’s disease detection and classification. The analyzed studies demonstrate that deep learning techniques, particularly Convolutional Neural Networks (CNNs), have become the dominant methodology

for automated analysis of brain MRI images, consistently outperforming traditional machine learning approaches. Both end-to-end CNN frameworks and transfer learning-based models have shown strong capability in capturing structural brain abnormalities associated with Alzheimer's disease, enabling accurate binary and multiclass disease classification.

The survey also highlights the growing importance of multiclass Alzheimer's disease staging for early diagnosis and disease progression monitoring. Optimized and lightweight CNN architectures, along with hyperparameter optimization strategies, have improved model generalization while reducing overfitting. However, challenges related to dataset imbalance, limited demographic diversity, and lack of cross-dataset validation remain significant barriers to clinical translation.

In addition to neuroimaging-based methods, emerging non-invasive diagnostic approaches based on eye-tracking have shown promising results in detecting early cognitive decline. These techniques offer cost-effective and accessible screening alternatives, particularly when integrated with machine learning models and mobile-device platforms. Despite their potential, further large-scale validation is required to ensure robustness across diverse populations and real-world conditions.

Overall, the reviewed literature indicates a clear shift toward AI-driven, automated, and data-centric diagnostic systems for Alzheimer's disease. Future research should focus on integrating explainable AI, multimodal data fusion, and large-scale external validation to enhance clinical reliability and adoption. By addressing these challenges, AI-assisted Alzheimer's disease detection systems can evolve from experimental models to practical tools that support early diagnosis and improved patient care.

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