알츠하이머병 예후 예측: MRI 및 메타데이터를 활용한 MMSE 점수 예측 모델

조채은[1], 문소연[2], 송여경[3], 장지우[3]
[1]고려대학교 의과대학 의학과 학부생
[2]경성대학교 컴퓨터공학과 학부생
[3]성신여자대학교 AI융합학부 학부생
chochaeeun@korea.ac.kr, opir0oui@gmail.com,
challengef0802@gmail.com, jangjang0022@naver.com

Prognosis Prediction of Alzheimer's Disease: Multi-Horizon MMSE Prediction from MRI and Metadata

Chaeeun Cho[1], Soyeon Moon[2], Yeogyeong Song[3], Jiwoo Jang[3]
[1]Dept. of Medicine, Korea University College of Medicine
[2]Dept. of Computer Engineering, Kyungsung University
[3]School of AI Convergence, Sungshin Women's University

Summary

This study aims to predict MMSE scores in Alzheimer's disease (AD) patients using a CNN-LSTM model that processes MRI images and metadata. The OASIS-2 dataset was used, with MRI slices (central, ±10mm, and ±15mm) and metadata. Two datasets were created: one with central and ±10mm slices (10mm dataset), and another with central, ±10mm, and ±15mm slices (combined dataset).

The CNN-LSTM model extracted features using VGG16 and combined them with metadata to predict MMSE scores. The 10mm model outperformed the combined model, achieving an MSE of 0.527 and MAE of 0.509. This study highlights the potential of predicting MMSE scores using MRI and metadata for early diagnosis of AD.

1. Introduction

Alzheimer's disease (AD) is a neurodegenerative disorder where early diagnosis is critical to improving patient outcomes. With an aging population, accurate prognosis prediction is increasingly important for timely intervention. Current research focuses on MRI-based diagnostics combined with metadata to improve predictive accuracy[1].

The Mini-Mental State Examination (MMSE) is a widely used tool for detecting cognitive decline, with studies showing that a drop in MMSE scores often precedes frontal lobe atrophy, making it valuable for diagnosing AD[2].

This study aims to develop a model that forecasts MMSE scores at the next clinical visit by combining metadata with multiple MRI slices. Our model outperforms those relying solely on MRI, offering more accurate prognosis predictions and supporting early interventions. Ultimately, this approach aims to improve early diagnosis and patient outcomes in clinical practice.

2. Method

The aim of this study is to predict future MMSE scores using MRI images and metadata from previous clinical visits. A CNN-LSTM model was developed, with VGG16 used for feature extraction from MRI images, and the combined features and metadata processed in a time-series structure to predict MMSE scores.

2.1. Data Collection and Preprocessing

The OASIS-2 dataset was used, and MRI slices (central, ±10mm, and ±15mm) were resized to 256x256 pixels and converted into RGB for CNN input. Two datasets were created: one containing the central slice and slices from the ±10mm range(10mm dataset), and another including slices from both the ±10mm and ±15mm ranges (combined dataset). Metadata, including age, sex, education level, SES, and CDR scores, was normalized and matched with MRI for each visit.

2.2. Model Architecture

The CNN-LSTM model processed both MRI images and metadata for MMSE score prediction. Features from MRI images were extracted using a pretrained VGG16 model with imagenet weights, where the top classification layers were removed, and a Flatten layer was added to convert the features into 1-dimensional vectors. These features were passed through a Time Distributed layer to handle the sequential nature of the data. Metadata, including age, sex, and CDR scores, was processed in parallel and combined with the image features through a Concatenate layer. The combined data was then passed to an LSTM layer with 50 units, using the ReLU activation function to capture temporal dependencies. The final prediction layer, with a single neuron, employed a linear activation function to output the predicted MMSE score.

2.3. Model Training and Evaluation

The model was trained using the Adam optimizer with a learning rate of 0.0001, and Mean Squared Error (MSE) was used as the loss function. Early stopping and ModelCheckpoint callbacks were applied to store the best-performing model. The 10mm and combined datasets were split 80-20 for training and testing. The performance of both models was evaluated using MSE and Mean Absolute Error (MAE).

3. Results

We developed and evaluated an MMSE score prediction model for early diagnosis of Alzheimer's disease by combining two different MRI multi-slice configurations with metadata. The model using central slices at ±10mm from the midline (10mm model) achieved an MSE of 0.527 and an MAE of 0.509. The model using slices at ±10mm and ±15mm (combined model) showed an MSE of 0.849 and an MAE of 0.562.

The 10mm model showed greater accuracy, with most residuals within ±1 of the actual MMSE scores. In contrast, the combined model had larger errors, especially in lower MMSE scores.

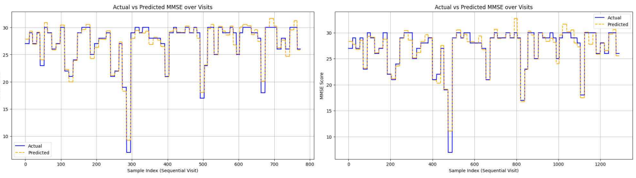

Fig 1. 10mm(left) and combined(right) model MMSE prediction at each visit

4. Conclusions

This study demonstrates the potential of predicting MMSE scores using multi-slice MRI images and metadata, indicating the possibility of early diagnosis and intervention for Alzheimer's disease. The 10mm model showed more stability and consistency, especially at extreme MMSE scores, while the combined model was more accurate in the mid-range but had larger errors in specific areas, performing better for particular patient groups. These findings suggest that both the patient's condition and the balance between consistency and precision should be considered when selecting a model. Metadata and MRI images remain critical predictors of Alzheimer's progression, and future studies will focus on collaborating with clinicians to refine datasets and further improve model performance for clinical application.

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