AI4MS - Artificial Intelligence for Multiple Sclerosis

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Collaborative project between [1]Institut de Neurosciences de la Timone (INT), [2]Centre de Résonance Magnétique Biologique et Médicale (CRMBM), [3]Laboratoire d'Informatique et Systèmes (LIS)

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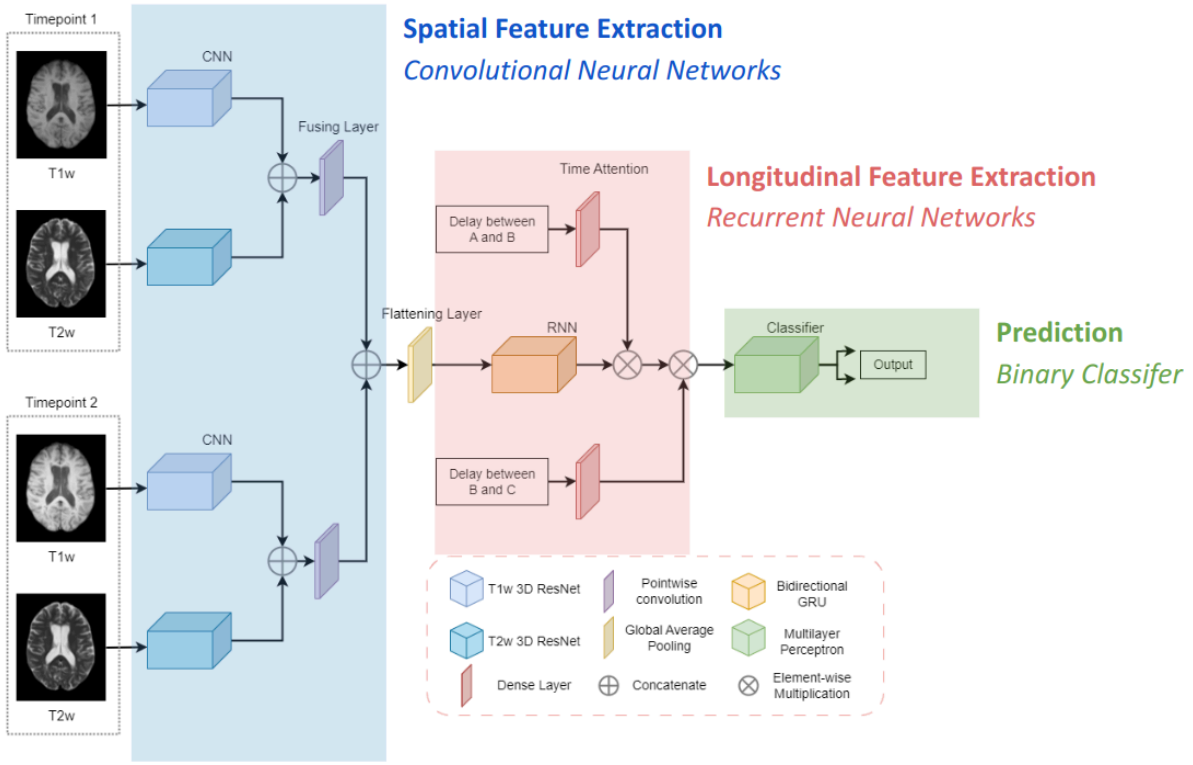
Multiple Sclerosis (MS) is the most widely prevalent chronic disabling disease affecting the central nervous system in young adults. The diagnosis of MS remains largely guided by clinical expertise, as opposed to laboratory findings. Investigations via magnetic resonance imaging (MRI) help by providing diagnostic support and deeper insights. The use of MRI has been particularly important with regards to establishing prognosis and treatment response. The current treatment for MS consists of a multifaceted approach consisting of disease-modifying therapies (DMTs), symptomatic treatment, lifestyle changes, psychological support, and rehabilitation interventions. Thus, patient care largely involves tailoring the individualized treatment plans not only based on the immediate needs of the patient, but taking into account the likely prognosis and expected changes in the foreseeable future. It is therefore evident that being able to predict the progression of the disease in MS patients with great precision and confidence is invaluable for their medical care.

AI-based approaches are increasingly being employed in addressing the need for early prognosis of various neurological disorders. Recent studies, such as that by Campanioni et al., (2024), have shown how AI methods are superior to traditional computational algorithms in predicting MS disease progression. We envision a huge potential for obtaining better predictions of disease progression in MS by adopting a truly multimodal approach to train our AI-based model. By employing a variety of clinical data, such as the MSFC scores (in addition to EDSS scores and other metadata) for the patients on each visit, our models would be trained to capture both physical as well as cognitive disability accumulation. This would provide a much-needed holistic representation of the patient's state on each visit, enabling the model to extract meaningful biomarkers more effectively.

We have access to a large cohort of MS patients included and followed at CRMBM: 300+ patients followed over 10+ years. This would enable the model to learn more effectively, without the inherent bias introduced by smaller cohorts, resulting in more generalizable and reliable models. We also have access to even larger datasets of healthy controls that could potentially be employed in training the model to recognize brain scans of healthy individuals, which could, in turn, potentially assist in better interpretation of progressive changes in those from MS patients.

The proposed model will employ Convolutional Neural Networks (CNNs) in the form of '3D ResNet' for extracting spatial features from the MRI images, and bidirectional Gated Recurrent Units (GRU) for capturing temporal dynamics. We plan to also implement Time-aware Attention (TA) mechanisms to handle any variability in time intervals between MRI scans, as the time intervals between clinical visits are often inconsistent. In such cases, it is crucial to account for these differences in temporal distances.

The project will be implemented in two parts. In the first part we shall train CNNs using multimodal neuroimaging data, alongside other clinical/cognitive data, to be able to associate spatial features with EDSS and MFSC scores. In the second part, this trained CNN will be incorporated as part of the larger model architecture, with the focus shifting towards the temporal aspects, thereby training the model to predict prognosis. The proposed internships will align with these two parts of the project.



An illustration of the current model architecture

AI4MS Primary Objective:

- Develop and validate a deep-learning based model using multimodal data to predict the prognosis of MS in patients. The performance of the models will be evaluated via metrics such as the Mean Absolute Error, R-squared, and Area Under the ROC Curve, and compared with existing state of the art models.

AI4MS Secondary Objectives:

- Develop models for predicting both short-term (1-2 years) and long-term (5+ years) prognosis
- Evaluate the predictive power of different neuroimaging modalities (T1w, T2w, FLAIR)
- Examine the synergistic value provided by clinical metadata
- Implement visualization techniques (e.g., Grad-CAM) to highlight regions of interest in MRI scans
- Explore how control datasets could improve the predictive power of the model
- Develop a user-friendly interface that could allow clinicians to readily test the model