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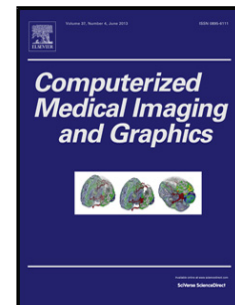
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Segmentation of White Matter Hyperintensities using Convolutional Neural Networks with Global Spatial Information in Routine Clinical Brain MRI with None or Mild Vascular Pathology

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Abstract

We propose an adaptation of a convolutional neural network (CNN) scheme proposed for segmenting brain lesions with considerable mass-effect, to segment white matter hyperintensities (WMH) characteristic of brains with none or mild vascular pathology in routine clinical brain magnetic resonance images (MRI). This is a rather difficult segmentation problem because of the small area (*i.e.*, volume) of the WMH and their similarity to non-pathological brain tissue. We investigate the effectiveness of the 2D CNN scheme by comparing its performance against those obtained from another deep learning approach: Deep Boltzmann Machine (DBM), two conventional machine learning approaches: Support Vector Machine (SVM) and Random Forest (RF), and a public toolbox: Lesion Segmentation Tool (LST), all reported to be useful for segmenting WMH in MRI. We also introduce a way to incorporate spatial information in convolution level of CNN for WMH segmentation named global spatial information (GSI). Analysis of covariance corroborated known associations between WMH progression, as assessed by all methods evaluated, and demographic and clinical data. Deep learning algorithms outperform conventional machine learning algorithms by excluding MRI artefacts and pathologies that appear similar to WMH. Our proposed approach of incorporating GSI also successfully helped CNN to achieve better automatic WMH segmentation regardless of network's settings tested. The mean Dice Similarity Coefficient (DSC) values for LST-LGA, SVM, RF, DBM, CNN and CNN-GSI were 0.2963, 0.1194, 0.1633, 0.3264, 0.5359 and 5389 respectively.

Keywords: Alzheimer's Disease, convolutional neural network, deep learning, global spatial information, segmentation, white matter hyperintensities

1. Introduction

White matter hyperintensities (WMH) are brain regions that exhibit intensity levels higher than those of normal tissues on T2-weighted magnetic resonance images (MRI). These regions are of utmost importance because they have been reported

to be associated with a number of neurological disorders and psychiatric illnesses, are also a common finding in brain MRI of older individuals, and known to have a modest association with age-related cognitive decline (Wardlaw et al., 2013). For example, In Alzheimers disease (AD) patients, higher load of WMH has been associated with higher amyloid beta deposits, presence of markers of small vessel disease and reduced amyloid beta clearance, all these contributing to an overall worsening of the cognitive functions on these patients (Birdsill et al., 2014).

WMH are considered a feature of small vessel disease (Wardlaw et al., 2013), partly because in many occasions they have been reported as having vascu-

¹Data used in preparation of this article were obtained from the Alzheimers Disease Neuroimaging Initiative (ADNI) database (adni.loni.usc.edu). As such, the investigators within the ADNI contributed to the design and implementation of ADNI and/or provided data but did not participate in analysis or writing of this report. A complete listing of ADNI investigators can be found at: http://adni.loni.usc.edu/wp-content/uploads/how_to_apply/ADNI_Acknowledgement_List.pdf

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