A single-stage detector of cerebral microbleeds using 3D feature fused region proposal network (FFRP-Net)

Conference Paper · June 2022

DOI: 10.1109/AICAS54282.2022.9869855

Mohammed A. Al-masni
Sejong University

Haejoon Lee
Carnegie Mellon University

A single-stage detector of cerebral microbleeds using 3D feature fused region proposal network (FFRP-Net)

Jun-Ho Kim
Department of Electrical and Electronic Engineering
Yonsei University
Seoul
rla803wns@yonsei.ac.kr

Mohammed A. Al-masni
Department of Electrical and Electronic Engineering,
Yonsei University
Seoul
m.almasani@yonsei.ac.kr

Hae-Joon Lee
Department of Electrical and Electronic Engineering,
Yonsei University
Seoul
haejoon.lee @yonsei.ac.kr

Yoon-Seok Choi
Department of Electrical and Electronic Engineering,
Yonsei University
Seoul
yunseok4444@yonsei.ac.kr

Dong-Hyun Kim
Department of Electrical and Electronic Engineering,
Yonsei University
Seoul
donghyunkim@yonsei.ac.kr

***Abstract*— Cerebral Microbleeds (CMBs) are chronic deposits of small blood products in the brain tissues, which have explicit relation to cerebrovascular diseases including cognitive decline, intracerebral hemorrhage, cerebral infarction. However, manual detection of the CMBs is a time-consuming and error-prone process. In this paper, we propose an efficient single-stage deep learning framework for automatic detection of the CMBs. The framework consists of a 3D U-Net and a region proposal network employing a feature fusing method (FFRP-Net) for detecting small objects. This model utilizes Susceptibility-Weighted Imaging (SWI) and phase images as 3D input to efficiently capture 3D contextual information. The performance of the proposed FFRP-Net records a sensitivity of 94.66% and an average number of false positives per subject (FP_{avg}) of 8.82.**

Keywords*— Cerebral Microbleeds; Deep Learning; Region Proposal Network; Feature Fusion

I. Introduction

Cerebral Microbleeds (CMBs) are chronic deposits of small blood products in the brain tissues and are generated due to the damage of the vessel walls. So, CMBs usually occur close to the arteries and capillaries [1, 2]. Microbleeds are commonly detected in individuals of advancing age and patients with cerebrovascular disease [3]. Especially Microbleeds are more prevalent in patients with Alzheimer's disease (AD), dementia, ischemic, and hemorrhagic stroke. Recently, CMBs are reported to be related to cognitive decline, intracerebral hemorrhage, cerebral infarction, recurrence of transient ischemic attack [4, 5].

Magnetic Resonance Imaging (MRI) is the most widely used modality for CMBs detection. Bleeding in vessels as small as 200 um in diameter can be screened utilizing the Susceptibility-Weighted Images (SWI) generated from Gradient-Recalled Echo (GRE) MRI pulse sequences [6]. However, there are challenging factors in CMBs detection. Firstly, CMBs, which are a round or elliptical lesion with a size of 2-10 mm, is very sparse and small compared to the whole brain [7, 8]. Another challenging factor is that there are many CMB mimics that appear with hypointensities like CMBs in SWI images. For example, the blood flow of the pial vessels is seen with the same intensity and shape of CMBs at some slices. Therefore, CMBs and pial vessels are discriminated by consecutive slices [7]. For these reasons, manual detection is time-consuming, and inspection results are subjective between neuroradiologists. These problems can be alleviated using an automated detector as an auxiliary tool, which assists to increase the time-efficiency of microbleeds detection and agreement between raters [9].

Early works in CMBs detection mainly employed hand-crafted features to distinguish CMBs from CMB mimics. For example, Barnes et al. proposed a semi-automated method based on the statistical thresholding and Support Vector Machine (SVM) classifier to identify CMBs [10]. Kuijf et al. utilized the 3D Fast Radial Symmetry Transform (FRST) to detect CMB candidates [11]. Ghafaryasal et al proposed a computer-aided system using simple intensity, size, and shape features and local image descriptors [12]. Fazlollahi et al. proposed a cascaded model utilizing cascaded random forest classifiers trained on radon- based features [13].

The main drawback of these conventional methods is that it is difficult to extract the effective features that differentiate between CMBs and CMB mimics effectively. This can be solved by applying deep learning Convolutional Neural Network (CNN). CNN models have shown great progress not only in the computer vision field, but also in medical imaging filed, including the detection of cerebral small vessel diseases [14-20]. Indeed, most of the existing approaches in the literature developed two-stage frameworks to automatically detect CMBs from MR images. The first stage is usually used for screening (i.e., potential candidate detection), while the second stage is responsible to distinguish true CMBs and CMB mimics (i.e., False-Positive (FP) reduction). The 3D Fully Convolutional Network (3D-FCN) [17], 2D-FRST [19], 3D-FRST [18], and You Only Look Once (YOLO) [15, 20] are examples of the first stage detectors, while the 3D-CNN [15, 17, 20] and 3D Residual Network (3D-ResNet) [18, 19] are commonly utilized for the FP reduction stage.

In this paper, we propose a single-stage 3D deep convolutional neural network for automatic CMBs detection. The proposed work utilizes both the SWI and phase images as 3D input to capture 3D contextual information efficiently. The followings are the main two contributions of this work.