Abstract

Title: Automated Quantification of Ischemic Stroke and its Core-Penumbra from Multi-parametric Magnetic Resonance Imaging

Ischemic stroke injury can be characterized by a central core tissue severely deprived of blood flow and surrounded penumbra tissue with collateral blood flow. As time-window is narrow to identify ischemic territory from multi-parametric MRI and re-establish the tissue perfusion, the immediate objective of ischemic stroke therapy is automatic identification and salvaging of penumbra before it degenerates into necrotic tissue. Manual tracing of injury on multiple slices and multiple modalities is limited by varying lesion shape, observer fatigue and inter and intra-observer variabilities.

This thesis presents accurate and reproducible methods for automatic segmentation of ischemic lesion followed by core-penumbra differentiation. Two unsupervised and one supervised methodologies are developed here, which infuse biological cues adopted by human experts into automated algorithms for trustable and verifiable clinical interpretation.

Method-1: Hemispheric asymmetry of stroked-lesion is often a neuro-radiological cue as healthy brain is mostly symmetric. Hence, a symmetry determined super-pixel based hierarchical clustering (SSHC) algorithm is developed to identify stroked-lesion.

Method-2: To segment both core and penumbra from multi-parametric MRI with both diffusion and perfusion sequences, a multi-view iterative random walker (MIRW) algorithm is proposed with automated seed point detection utilizing the hierarchical decomposition of volumetric histogram. The individual lesion estimations from axial, coronal and sagittal views are conglomerated iteratively for a computationally efficient segmentation and quantification of the salvageable and necrotic tissues.

Method-3: A supervised multi-path convolution leveraged attention deep network (MCA-DN) is also proposed, which acquires attention by embedding multiple filter paths and prioritizing the selective activation of multi-parametric MRI sequences to quantify core and penumbra.

These three proposed methodologies are evaluated on three challenging adult (sub-) acute stroke datasets, two of which are publicly available and benchmarked. Proposed methods outperformed state-of-the-art methods with significant improvements in Dice similarity score (core: 4.6 – 23.57%; penumbra: 3.1 – 10.65%), sensitivity (core: 0.8 – 34.9%; penumbra: 7.1 – 14.6%), and specificity (core: 0.2 – 0.9%; penumbra: 1.8 – 8.7%). This demonstrates the promising potential of the proposed methods for computational analysis of adult stroke and to quantify salvageable penumbra for quick and enhanced candidate-selection for recanalization in stroke patients.

Keywords: Core-penumbra, Diffusion Perfusion Mismatch (DPM), Ischemia, Multi-parametric MRI, Multi-view, Brain-symmetry, Random walks, Convolutional neural network