Joint Department of Biomedical Engineering
Marquette University / Medical College of Wisconsin

Announcement of Public Dissertation Defense

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ABSTRACT

"DEEP LEARNING FOR QUANTITATIVE SUSCEPTIBILITY MAPPING RECONSTRUCTION"

Quantitative susceptibility mapping (QSM) is a magnetic resonance imaging (MRI) technique that estimates tissue magnetic susceptibility from Larmor frequency offset measurements. The generation of QSM requires solving ill-posed background field removal (BFR) and field-to-source inversion problems. Incorrect BFR often introduces erroneous local field outputs and subsequently affects susceptibility quantification accuracy. Inaccurate field-to-source inversion often causes large susceptibility estimation errors that appear as streaking artifacts in the QSM, especially in massive hemorrhagic regions. Because current QSM techniques struggle to generate reliable QSM, the clinical translation of QSM is greatly hindered. Recently, deep Learning (DL) has achieved state-of-the-art performance in many computer vision tasks and been widely applied to medical image reconstruction. This dissertation applied DL techniques to address the aforementioned challenges of QSM reconstruction.

To address the limitations of existing BFR algorithms, a 3D deep convolutional neural network was trained to obtain the local field of interest from the total field measurement. Due to the lack of a ground-truth reference, synthetic data were simulated based on underlying physical principles and used for network training. The proposed approach was quantitatively evaluated in-silico and qualitatively examined on real data.

The field-to-source inversion problem, which estimates QSM from the local field, was addressed using two DL approaches: one supervised and the other model-based. Due to the lack of a ground-truth QSM, the supervised method was trained on synthetic data and then fine-tuned on in-vivo data. The model-based method was trained based on the well-established physical principles without the need of QSM labels. The performance was quantitatively evaluated on multi-orientation datasets and qualitatively assessed on single-orientation datasets.

Furthermore, two DL-based (supervised and weakly-supervised) techniques were developed for single-step QSM reconstruction to directly estimate QSM from the total field. The supervised method utilized simulated training data and achieved impressive qualitative performance when applied to clinical data. The weakly-supervised approach used the BFR method RESHARP results as a supervision to perform a multi-task learning of local tissue field and QSM estimate. This approach was able to recover magnetic susceptibility estimates near the brain edges and generate high-quality local field and QSM in a variety of neuroimaging contexts.

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