

Deep Learning-Based Estimation of Specific Absorption Rate Induced by High-Field MRI RF Head Coils

Xi Wang⁽¹⁾, Xiaofan Jia⁽¹⁾, Shao Ying Huang⁽²⁾, and Abdulkadir C. Yucel⁽¹⁾

(1) School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore 639798 (xi002, xiaofan002}@e.ntu.edu.sg, acyucel@ntu.edu.sg)

(2) Engineering Product Development Department, Singapore University of Technology and Design, Singapore 487372 (huangshaoying@sutd.edu.sg)

Magnetic resonance imaging (MRI) is a versatile imaging modality that shows good soft tissue contrast yet without ionizing radiation. MRI images can assist in diagnosing illnesses or injuries and locating tumors and cancer cells. To generate higher resolution images via MRI, significant research efforts have been invested into the development of high-field MRI scanners ($> 3\text{T}$), which yield an uneven distribution of electric fields and power/heat within the human body, quantified by local specific absorption rate (SAR). To ensure MRI safety, the local SAR induced in the human body should comply with the high-tier SAR limitations from IEEE Std C95.1-2019. However, it is difficult for radiographers/researchers to predict local SAR values before each scan as these values are subject-specific and vary due to anatomical differences and the electrical properties of tissues, permittivity (ϵ) and conductivity (σ), and the calculation of SAR is not real time. To assess the subject-specific SAR, physics-based simulators appear to be the currently viable solution. For head imaging, these simulators take the subjects' head models derived from MRIs as inputs and provide the distributions of induced electric fields (E-fields) and SAR within human heads as outputs. However, the physics-based simulators require substantial computational time (far from real-time) for outputting subject-specific SAR as they rigorously solve Maxwell's equations. To this end, innovative approaches for computing the subject-specific SAR in (near-) real-time are called for. For this purpose, recently, a deep learning scheme utilizing 2D U-Net architectures has been developed for estimating the MRI-induced SAR (S. Gokyar, F. J. L. Robb, W. Kainz, A. Chaudhari, and S. A. Winkler, "MRSaiFE: An AI-based approach towards the real-time prediction of specific absorption rate," *IEEE Access*, vol. 9, pp. 140824–140834, 2021). However, the scheme is limited to 2D SAR and does not incorporate variability in the electrical properties of tissues.

This study proposes a 3D deep learning-based scheme to estimate subject-specific SAR for near-real-time calculation. In particular, the scheme leverages a 3D U-net, a convolutional neural network consisting of an encoder and decoder with skip connections. It takes permittivity and conductivity maps of the subject as well as the transmit E-fields from a high-field MRI (7T and 300 MHz) birdcage head coil as inputs. It outputs the 3D E-field distributions and consecutively SAR distributions in a region of interests of 20 cm of diameter of spherical volume for head. For a fixed head model and varying ϵ - and σ -maps, the scheme achieved a mean relative error of 5.07% for the predicted local SAR throughout the head, while requiring 183 ms for one prediction. This corresponds to 10,672 times acceleration compared to the widely-used physics-based MARIE simulator, which requires 1,953 seconds to compute local SAR on a commodity desktop computer. In the talk, the details of the proposed scheme, training strategy, as well as the scheme's accuracy when trained with a large population of head models will be provided.