OSSARTE: an Open-Source software for SAR and Temperature Estimation

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Target audience: anyone interested in RF safety in MRI, average SAR and temperature increase computation.

Introduction: To ensure safe use of MRI it is desirable to estimate and limit the Specific energy Absorption Rate (SAR) averaged over the whole body, whole head, and the maximum SAR averaged over any 1 or 10g region in the body [1]. Safety guidelines by the IEC recommend limits on the maximum values of both SAR and temperature. Specifically, limits are recommended for the maximum value of SAR averaged over the whole body, over the whole head, or over volumes having a mass of 10 grams, and also averaged over specific time intervals ranging from 10 seconds to 6 minutes, or for the maximum value of absolute temperature in different regions of the body and temperature increase in core body temperature. Several methods have been proposed recently to average SAR locally [1-3], and to compute temperature increase due to SAR absorption. In this work, we present open source software including tools to locally average SAR and to compute temperature increase with different methods, letting the user choose whether to prioritize accuracy or computation speed. It should be useful in the design of RF coils and RF pulses with consideration of SAR, temperature, or both.

Methods: The software currently offers two methods to compute n-gram local average SAR and three methods to compute the temperature increase. The two methods to compute average SAR correspond to the one described using cubical masks [1], and another using adaptive spherical masks [3].
The three methods to compute temperature increase include a full Finite Difference numerical solution of the Pennes' bioheat equation [4], a published method which approximates tissues thermal conduction with a digital filter for fast computation [3], and another where the temperature response of the body tissues to a single SAR segment is convolved with the power levels of throughout an entire exam to quickly predict the temperature throughout a series of different pulse sequences [5]. The software has been implemented in C++ and includes a 2D visualizer for the SAR and temperature distributions and tools to easily import/export data with Matlab related to the geometry and the tissue properties of the sample, or to the SAR and temperature distributions.

Results: Figure 1 shows some of the features present in the software: from the possibility to load the subject geometry, tissue properties, and the unaveraged SAR distributions in different formats, such as the output files from the numerical software XFDTD (Remcom), to the possibility to select the desired method to compute the temperature increase and the SAR distribution. The software can run on a variety of different operating systems (Windows, Linux and Mac OS). It will be available online (http://cai2r.net/resources/software), including also all the source code. A future version of the software will include the ability to determine the Virtual Observation Points of a SAR distribution, very useful tool for transmit array pulse design, and the ability to derive the SAR distribution starting from a measured temperature distribution with consideration of conduction of heat through time.

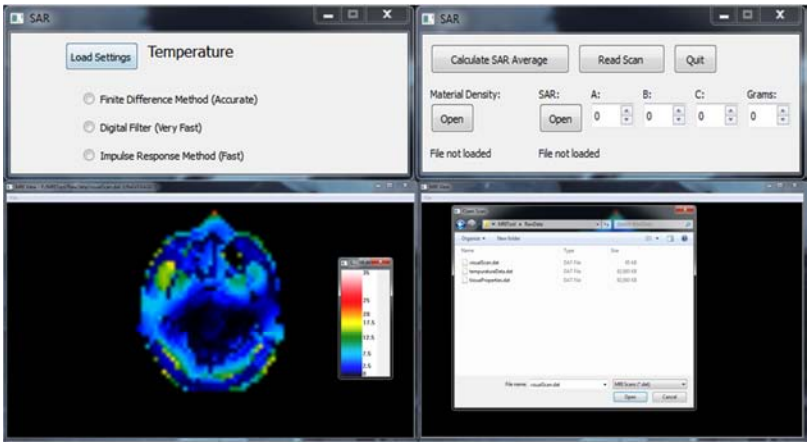

Figure 1: Screenshots of some of the tools available in the software.

References:

[1] IEC International Standard 60601, 2012. [2] Catarinucci et al., IEEE/MTT-S, June 2007, 1349, 1352. [3] Carluccio G *et al.*, IEEE TBME, 60:6:1735-1741, 2013. [4] Collins CM *et al.*, JMRI, 19:650-656, 2004. [5] Carluccio G *et al.*, Proc. 21st ISMRM, p. 4425.