

FAST AND FLEXIBLE HIGH RESOLUTION FIELD OPTIMIZER FOR SAR AND TEMPERATURE DISTRIBUTIONS

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Hyperthermia treatment planning attempts to improve treatment outcome by using simulations and optimization to reduce exposure of healthy tissue (hotspots) and to focus the energy deposition into the tumor. Various studies (e.g., [1]) have shown that it is crucial to work at high spatial grid resolution to correctly capture all effects. While electromagnetic fields and in some models even thermal fields can be precomputed, it would be highly valuable to be able to quickly produce a new optimized treatment based on patient feedback during the actual treatment. A useful optimization tool would furthermore allow the specification of multiple, arbitrarily shaped targets. Furthermore, special care should be taken to reduce the exposure of sensitive tissues.

A new, fast optimizer has been designed on the basis of the generalized eigenvector method developed by Koehler [2]. It reduces the possible choice of the optimization functional but offers a fast, non-iterative method of optimizing the antenna parameters (phases and amplitudes). The method can be used for both temperature and SAR (specific absorption rate) field optimization. It requires a set of matrices of integrals to be computed. We propose to precompute these matrices for various subregions of the optimization domain. Based on patient feedback during treatment, these subregion matrices can then be weighted, combined and used for quick reoptimization. Furthermore, storing the matrices allows quick reevaluation of the functional. This can be used to perform a fast Monte Carlo analysis to study the sensitivity of the proposed treatment to uncertainties in phase and amplitude of the individual antenna excitations.

The novel implementation allows the user to specify multiple targets that can be assigned different heating priorities and that do not have to correspond to specific tissues. Instead, arbitrarily shaped target volumes can be specified such as the tumor plus 2 cm safety margin. The user can fix maximal thresholds for individual tissues or subregions and specify sensitivity factors. An iterative hotspot reduction as proposed in [2] can be used to assign additional weight to hotspots thereby allowing the generation of an improved, hotspot suppressing protocol.

The optimization tool has been integrated into the SEMCAD X [3] simulation environment, allowing various visualization and postprocessing options. It has been tested using data from a series of patients and produces considerably improved treatment protocols.

[1] Van de Kamer et al., High-resolution SAR modelling for regional hyperthermia: testing quasistatic zooming at 10 MHz. *Phys. Med. Biol.* 2001, 46(1):183ff

[2] Koehler et al., A fast algorithm to find optimal controls of multiantenna applicators in regional hyperthermia, *Phys. Med. Biol.* 2001, 46(9):2503ff

[3] SEMCAD X, Schmid & Partner AG, Zurich, Switzerland, www.semcad.com