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Posture-free numerical dosimetry by space mapping

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1 Introduction

In order to evaluate the electric field induced in the human body by electromagnetic fields it is crucial to take into account the posture of the body. Posturing computational phantoms, is a very complex and error-prone task.In this work a different approach is proposed: the space is mapped in such a way that in the new coordinate systems the human body is undeformed. In particular, this avoid to have to deal with the burden of deforming the human body by respecting the anatomical constraints.

2 Space mapping

In the case of low-frequency magnetic field exposure, by using the Finite Integration Technique (FIT) the equation to be solved writes (see [1] for details):

$$\mathbf{G}^{\mathrm{T}}\mathbf{M}_{\sigma}\mathbf{G}\varphi = -j\omega\mathbf{G}^{\mathrm{T}}\mathbf{M}_{\sigma}\mathbf{a} \tag{1}$$

With the classical approach (1) must be solved in the postured phantom Ω_p. The idea of space mapping is to apply a coordinate change $\mathscr{P} : \mathbb{R}^3 \mapsto \mathbb{R}^3$ which takes the computational phantom to the unpostured (standing) one: $\mathscr{P}(\Omega_p) = \Omega_u$. By applying this mapping, (1) is unchanged, apart from the material properties and the source term:

$$\mathbf{M}_{\sigma_p} = \mathbf{J}_p^{-1}\mathbf{M}_{\sigma}\mathbf{J}_p^{-\mathrm{T}}|\det \mathbf{J}_p| \qquad ; \qquad \mathbf{a}_p = \mathbf{J}_p^{\mathrm{T}}\mathbf{a} \tag{2}$$

where $\mathbf{J}_p$ is the Jacobian matrix of the map $\mathscr{P}$. It has been suggested [1] that $\mathscr{P}$ can be reasonably approximated by a combination of several isometries which have to be applied locally, for which $\mathbf{J}_p^{-1}\mathbf{J}_p^{-\mathrm{T}}|\det \mathbf{J}_p| = \mathbf{I}$. Hence the approximation $\mathbf{M}_{\sigma_p} \simeq \mathbf{M}_{\sigma}$ could be used in (1) for isotropic tissues.

3 Results

A worker with the arm stretched in from of the trunk exposed to the magnetic field generated by a circular coil (radius = 40 cm, current $I = 100$ A, frequency $f = 50$ Hz) located at 60 cm from the trunk. The phantom (Hanako, resolution = 2 mm) has been postured by using the software NICTPOSETOOL. It is found that the difference between the results obtained by the classical and the space mapping approach are practically negligible (Figure 1).

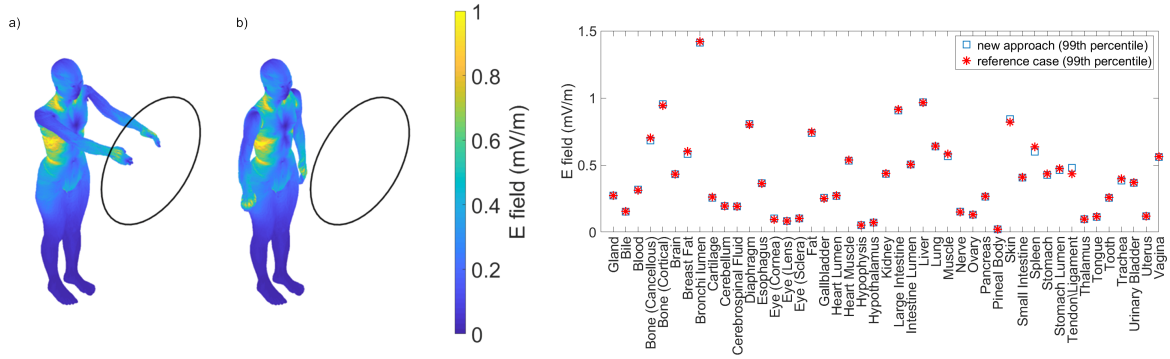

Figure 1. Left: E-field at the surface of the computational phantom computed by using the classical approach (a) and the space mapping technique (b). Right: comparison between 99% E-field computed with the two methods.

References

[1] A. C. Gubernati, F. Freschi, L. Giaccone, R. Scorretti, L. Seppecher, and G. Vial, “Modeling of Exposure to Low-Frequency Electromagnetic Fields of Workers in Arbitrary Posture”, IEEE Transactions on Magnetics, vol. 56, no. 2, pp. 1–4, Feb. 2020, doi: 10.1109/TMAG.2019.2949391.