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FUTURE NETWORKS: 5G AND BEYOND

Artificial Neural Networks for Uncertainty Quantification in RF Radiation Modeling

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Abstract:
This paper focuses on quantifying the uncertainty in the outputs of numerical simulations produced by uncertain positions of the electrodes placed on patient's scalp. In order to avoid running thousands of simulations, an architecture which combines two different artificial neural networks (ANNs) for uncertainty quantification (UQ) is proposed in this paper. The overall aim of this work is to develop a surrogate model for UQ involving high-dimensional data. The proposed method is demonstrated to be an attractive alternative to conventional UQ methods since it shows considerable advantage in the computational expense and speed.

1 Introduction

The final goal of ANSES ECLAIR project is to design a system allowing high resolution EEG recordings in the presence of an RF radiating source and taking electromagnetic field deformation into account. Achieving this goal requires understanding well the interaction between the metallic part of the EEG recordings and the RF source. Since measurement is time consuming and expensive, numerical modeling is an effective alternative method to investigate the physical properties of the proposed system. The modeling of the radiating source, head, and EEG device relies on sets of input parameters which can affect the electromagnetic field, and then affect specific absorption rate (SAR) values in brain. In practice, the exact values of the random inputs can not be found, which produces uncertainties in simulation results. Uncertainty quantification (UQ) is an indispensable part when the acceptability of the simulation results is considered. In this paper, UQ is concentrated on uncertain positions of the electrodes in a EEG helmat.

2 Design of the experiment (DoE)

The head model is a 3-layer sphere, and the electrodes is formed by triangles on the sphere. In this case, the position of each electrode can be represented by (r, θ_p, ϕ_p) $(p = 1, ..., L)$ in a spherical coordinate system and (P_p^x, P_p^y, P_p^z) in a Cartesian coordinate system, respectively, where r is the radius of the sphere, θ_p is polar angle, ϕ_p is azimuthal angle, and L is the number of electrodes. The coordinates of the two systems can be transformed into each other. The original Cartesian coordinate of a electrode (P_p^x, P_p^y, P_p^z) is obtained by a toolbox, and they are used in the numerical simulations. The uncertainties in the positions of the electrodes are modeled in a spherical coordinate system, and the coordinates with uncertainties required to be transformed into Cartesian coordinates. In a spherical coordinate system, the center of each electrode moves in a square, and the size of the square is controlled by $\triangle$. For each electrode, there are 9 possible positions represented by 9 indexes. When $\triangle$ is determined, the uncertainty of the position of an electrode can be modeled by the 9 indexes which is a discrete random variable. In the above case, the electrodes positions are changed independently of one another, and the number of combination is 9^L.

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