Light scattering model of the human retina

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Abstract

Optical coherence tomography (OCT) [6] is a noninvasive imaging modality increasingly popular in the field of ophthalmology due its unique ability of noninvasive structural imaging of the ocular fundus, allowing to assess the structure of the human retina in vivo. The overall goal of our project is to develop a model of the human retina, in respect to light scattering, able to justify OCT changes associated with blood-retinal barrier breakdown. In fact, previous studies have established a link between changes in the blood-retina barrier and in optical properties of the retina [1]. To pursue our objective, it is crucial to study in detail the behavior of the electromagnetic wave as it travels through the sample.

Simulating the full complexity of the retina, in particular the variation of the size and shape of each structure, distance between them and the respective refractive indexes, requires a rigorous approach that can be achieved by solving Maxwell's equations.

In this work we discuss the numerical discretization of the time-dependent Maxwell's equations using a leap-frog type discontinuous Galerkin (DG) method. We have chosen to use the nodal DG method [4] for the integration in space due to the fact that it is a high-order accurate method that can easily handle complex geometries. Moreover, local refinement strategies can be incorporated due to the ability of the method to deal with irregular meshes with hanging nodes and local spaces of different orders. We focus on deriving stability and convergent estimates of fully discrete schemes. In the model we consider anisotropic permittivity tensors which arise naturally in our application of interest. An important aspect in computational electromagnetic problems is the implementation of the boundary conditions. In our simulations we have considered the Silver-Müller

boundary condition [3] and the well established uniaxial perfectly matched layer (UPML) [5].

We present some numerical examples to illustrate the theoretical results and also in the context of modeling scattered electromagnetic wave's propagation through human eye's structures. Finally, we also briefly discuss the multi-scale nature of the problem. In a small scale, we use Maxwell's equations to compute parameters that could be used as inputs to larger scale simulations namely using Monte Carlo methods ([2]).

Keywords: Maxwell's equations, optical coherence tomography, discontinuous Galerkin method, leap-frog method, multi-scale.

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