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Fast 3D radiative transfer tomography

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Abstract

This paper introduces a method to preform optical tomography in 3D, using radiative transfer as the forward model. We use an iterative approach to solve the optimization problem in a scalable manner. Finally we show an application in remote sensing of the atmosphere.

1 Introduction

Optical tomography is an imaging technique that uses optical measurements on the boundary of a domain, to find the spatial distribution of parameters within. It finds applications in bio-medical imaging and remote sensing of the earth atmosphere [1–4]. For a list of applications we refer the reader to [5, 6] and the references therein. Solving the inverse problem using the radiative transfer equation (RTE) as a forward model can be difficult and computationally demanding. For some applications it is possible to use an approximate model. In dense media (mean free path small compared the distance of propagation), with scattering dominant over absorption, it is possible to use a diffusion approximation of the RTE. This results in the inverse problem of *Diffuse Optical Tomography* (DOT) [7–9]. When the mean free path is large compared to the propagation distance, the measured energy is dominated by direct and single scattered intensities. The resulting inverse problem is single scattering tomography [6, 10, 11]. Other approximations and their derivations can be found in [12]. We wish to solve the inverse problem using the RTE, with neither single scattering, nor diffusion approximations. However, a numerical solution of the RTE in 3D is time consuming. Therefore, to make the inverse problem tractable, we derive an iterative optimization framework.

2 Theoretical background

2.1 Radiative transfer

Our forward model is the time-independent radiative transfer. This model is used in passive imaging, such as atmospheric tomography, or when source gating is sufficiently slow. The RTE governs propagation of light through a medium. Consider a domain Ω having boundary $\partial\Omega$ whose outward facing normal is $\boldsymbol{\vartheta}$ (Fig. 1a). The domain is indicated by position $\boldsymbol{x} \in \mathbb{R}^3$ and direction $\boldsymbol{\omega} \in \mathbb{S}^2$ (unit sphere). The radiation (light)