Utilizing Monte Carlo method for light transport in quantitative photoacoustic tomography

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In photoacoustic tomography (PAT), images of an initial pressure distribution generated by absorption of and externally introduced light pulse are estimated [1]. The method combines unique contrast of optical absorption and high resolution of ultrasound. In quantitative photoacoustic tomography (QPAT), the aim is to estimate concentrations of light absorbing molecules, chromophores, from photoacoustic images [2].

Image reconstruction problem of QPAT is an ill-posed inverse problem, which requires modeling the light transport inside the imaged target. A widely accepted method for light propagation in scattering medium, such as biological tissue, is Monte Carlo (MC) method for light transport. It is based on simulating stochastic paths for photon propagation in a medium in the presence of absorption and scattering. Simulating a large number of photons enables modeling light transport accurately, but on the other hand, fast and efficient reconstruction methods are crucial in practical applications. Therefore, optimizing the number of simulated photon packets used in model based inversion is necessary to obtain estimates in a reasonable amount of time while concurrently simulating light propagation accurately.

In this work, the optical inverse problem of QPAT, i.e. estimation of optical parameters from the absorbed energy density, is approached in a Bayesian framework [3, 4]. Light transport is modeled using a MC method implemented with ValoMC software [5]. *Maximum a posteriori* estimates are computed using a Gauss-Newton method. We optimize the computation cost of the method by adapting the number of photon packets used by the forward model in each Gauss-Newton iteration step utilizing a so-called norm test [4]. The approach is studied using numerical simulations.

References

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