Advanced Monte Carlo Simulations for Optical Imaging Modalities

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Development of novel optical techniques for biomedical diagnostics and treatment requires for models of light propagation in tissues. Due to significant optical heterogeneities of biological tissues, the application of analytical models is quite limited, since they basically consider uniform turbid medium. Monte Carlo technique have become a gold standard in such simulations, since it provides the possibility to account for anatomical and morphological features in simulations. This technique is based on simulation of a large number (usually up to 10^{12}) of random photon trajectories that allow to analyze three dimensional distribution of light field in the medium and separate contribution of particular photon fractions. The main limitation of the Monte Carlo simulations consisting in huge computational workload could be overcome due to recent advances in computational hardware. Modern trend toward multicore processors in especially beneficial due to easy parallelization of Monte Carlo computations.

In this paper we report on our recent achievements in Monte Carlo technique aiming at simulation of signal formation in spectral and fluorescence imaging modalities. Employment of modern processors with parallel architecture allows to efficiently increase the computational time, while triangulation of structural boundaries within medium allows for accurate account of light transport in complex objects mimicking morphological structure of biotissues. The ability to trace individual photons trajectories allows to separate photons the suit detection conditions and analyze typical probing depth of different techniques, including its spectral dependence for spectral imaging modalities. Massive Monte Carlo simulations also allow to generate large synthetic datasets that could be successfully employed for training neural networks aimed at reconstruction of physiological parameters based on optical measurements.

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