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Efficient Simulation of Magnetic Resonance Imaging

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Cristoffer Cordes

Referees:
Prof. Matthias Günther
Prof. Tobias Preußer

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Abstract

Efficient Simulation of Magnetic Resonance Imaging

Simulation of Magnetic Resonance Imaging (MRI) is based on the Bloch equation. Solving the Bloch equation numerically is not difficult, but realistic imaging experiments bear a high computational burden. The prevalent approach requires highly resolved sampling of the object and an individual calculation of each sample's behavior for the duration of the imaging sequence. The intrinsic complexity of this approach can be remedied through more computational resources or by application-specific approximations, which both restrict the usefulness and versatility of MRI simulation.

This work presents methods that simplify the problem by exploiting hardware restrictions and the structure of common MRI sequences while not enforcing any approximations. The presented simulation strategies use the reoccurrence of radiofrequency pulses, partial availability of analytical solutions, a reformulation of the problem in Fourier space and finally an inclusion of the reconstruction process to perform MRI simulation in image space, titled Sequence Response Kernel approach.

The algorithmic efficiencies of the methods are investigated and applied to realistic imaging experiments. The particular properties and potential of the algorithms are exemplified, with an emphasis on the Sequence Response Kernel approach and its applications. Depending on the simulation problem, choosing the optimal strategy can greatly decrease computational effort. The Sequence Response Kernel approach opens a new perspective of MRI simulation that can be understood intuitively, even without knowledge of MR physics, and augment image processing techniques.

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