Wednesday, October 22nd :: 5:00pm :: Allen Room (36-462)

Quantum Control Problems in Magnetic Resonance Imaging

Dr. Nicolas Boulant

Unité d'imagerie par IRM et de Spectroscopie (UNIRS), NeuroSpin, CEA, Saclay, France

The field of Magnetic Resonance Imaging (MRI) most often only needs to consider isolated single spin 1/2 systems (i.e. the protons of water molecules).
Despite significant overlap between the NMR and MRI fields, the two in general exploit different formalisms (Bloch vs. Schrodinger). Although Bloch and Schrodinger equations indeed can be used interchangeably in this context, the quantum formalism can bring valuable insight and tools to tackle control problems in MRI via the use of Hamiltonians, product operator formalism and other tools developed for quantum control and quantum computing purposes.
After an introduction of the challenges in control the MRI community faces, I will present a series of concrete examples where these tools have significantly contributed recently. In-vivo and in-vitro data illustrations will be provided [1]. Examples include strongly modulating pulses (Fortunato et al.[2]), quantum process tomography and gradient ascent pulse engineering (GRAPE) (Khaneja et al. [3]) techniques.

[1] Aurélien Massire, Martijn A. Cloos, Alexandre Vignaud, Denis Le Bihan, Alexis Amadon, Nicolas Boulant, "Design of non-selective refocusing pulses with phase-free rotation axis by gradient ascent pulse engineering algorithm in parallel transmission at 7 T", J. Mag. Res. **230**, 76–83 (2013)

[2] Evan M. Fortunato, Marco A. Pravia, Nicolas Boulant, Grum Teklemariam, Timothy F. Havel and David G. Cory, "Design of strongly modulating pulses to implement precise effective Hamiltonians for quantum information processing", J. Chem. Phys. **116**, 7599 (2002)

[3] Khaneja, Navin, Timo Reiss, Cindie Kehlet, Thomas Schulte-Herbrüggen, and Steffen J. Glaser. "Optimal control of coupled spin dynamics: design of NMR pulse sequences by gradient ascent algorithms." J. Mag. Res. **172**, 296-305 (2005).