Optimization for metabolic rate estimation in hyperpolarized carbon-13 MRI

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Abstract Hyperpolarized carbon-13 magnetic resonance imaging (MRI) is an emerging technology for probing metabolic activity in living subjects, which promises to provide clinicians new insights into diseases such as cancer and congestive heart failure. These experiments involve an injection of a hyperpolarized substrate, often [1-13C]pyruvate, which is imaged over time as it spreads throughout the subjects body and is transformed into various metabolic products. Designing these dynamic experiments and processing the resulting data requires the integration of noisy information across temporal, spatial, and chemical dimensions, and thus provides a wealth of interesting problems from an optimization and control perspective.

In this work we describe three optimization problems that arise in metabolic imaging with hyperpolarized substrates: the design of optimal substrate injection profiles, the design of optimal flip angle sequences, and the constrained estimation metabolism maps from experimental data. We survey computational approaches to optimal control for experiment design and distributed parameter estimation relevant to providing solutions to these problems. We then present a case study that integrates optimal injection design, acquisition design and parameter map reconstruction in a single simulated experiment. This case study is used to illustrate how optimization and control are vital to pushing the abilities of metabolic MRI to its limits.

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