Optimizing the contrast-to-noise ratio per unit of time of clinical MR sequences: an optimal control approach

Industrial Ph.D. (CIFRE) – CREATIS/SIEMENS

Overview

In clinical practice, MRI is a modality of choice for both visualization and diagnosis, because of the wide range of achievable contrast it allows. Although MR images are not directly quantitative (unlike tomography for instance), the acquired signal can be modelled using for instance the Bloch equation, which rules the magnetization evolution in presence of a static (B_0), and a time-varying radio-frequency (B_1) magnetic fields.
Tailored B_1 fields can be designed in order to control the magnetization evolution and obtain images with specific characteristics. In this context, optimal control theory has been applied on the Bloch equation for various MRI applications such as excitation, refocusing and more recently contrast optimization in a pre-clinical context [1, 2, 3].
Following the work on contrast optimization, the proposed Ph.D. will have three main objectives:

1. Transfer and apply the optimal control contrast optimization framework on clinical sequences in collaboration with the industrial partner (SIEMENS)

2. Develop strategies to make the resulting contrast robust to excitation (B_1) variations

3. Improve the optimal control framework to consider steady-state optimization, which should improve the contrast-to-noise ratio per unit of time

The first phase of the project will be devoted to pulse and sequence implementation on a SIEMENS MR scanner, with tests on phantoms and comparison with standard weighting sequences (DIR, T2FLAIR, T1VIBE). Subsequently, and in parallel with further pulse developments, application of the proposed contrast strategies will be conducted on volunteers, and will help to target a specific contrast useful for the diagnostic. The third phase

will aim at showing the clinical benefit of the approach, on applications defined in collaboration with the radiology department of the *Centre Léon Bérard* (CLB).
Several advances are expected in particular in the context of pelvis and/or neuro imaging. More precisely, it is expected that: i) the contrast improvement will reduce the need for contrast agents, and ii) the differentiation between tumoural versus inflammatory tissues will be improved.

Conditions

This work is a collaboration between CREATIS, SIEMENS Healthineers, and the CLB. The candidate will join the CREATIS research laboratory situated in Lyon (France), in a team focusing on innovative MR acquisition methodologies. At CREATIS, the candidate will work under the supervision of E. Van Reeth and O. Beuf/H. Ratiney. MR acquisitions will be performed at CLB, under the supervision of F. Pilleul.
The position is expected to start in autumn 2018. The net salary is of the order of 1700€ per month.

Candidate

The candidate is expected to have a solid background on MR physics and numerical optimization. Good communication and coordination skills are also required to successfully interact with the research laboratory (CREATIS), the industrial partner (SIEMENS), and the medical team (CLB).

Contacts

Please send a CV and an application letter, in which relevant previous experiences will be detailed, to:
E. Van Reeth, Asst. Pr. at CPE/CREATIS: vanreeth@creatis.insa-lyon.fr
H. Ratiney, Researcher at CREATIS: helene.ratiney@creatis.insa-lyon.fr
O. Beuf, Researcher Director at CREATIS olivier.beuf@creatis.insa-lyon.fr
F. Pilleul, Medical Doctor at CLB: frank.pilleul@creatis.insa-lyon.fr

References

[1] Marc Lapert, Y Zhang, et al. Exploring the physical limits of saturation contrast in magnetic resonance imaging. *Scientific Reports*, 2(589), 2012.

[2] Eric Van Reeth, Hélène Ratiney, et al. Optimal control design of preparation pulses for contrast optimization in MRI. *Journal of Magnetic Resonance*, 279:39 – 50, 2017.

[3] Eric Van Reeth, Helene Ratiney, et al. A simplified framework to optimize mri contrast preparation. *Magnetic Resonance in Medicine*, 2018.