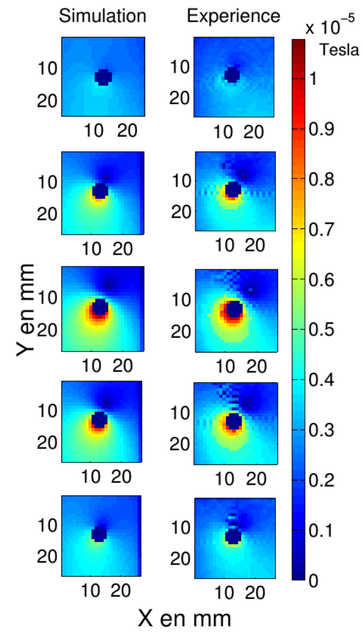
Using learning techniques to solve high-dimensional inverse problems – application to MRI safety of active brain implants (Research)

Context: Active medical implants are a frequent contra-indication to magnetic resonance imaging (MRI) exams. In this context, there is a risk of heating of the tissues due to the radio-frequency (RF) currents induced in electrically conducting parts of the implant.

We aim to develop a method to directly measure RF currents in implant wires based on MRI data sensitive to the RF magnetic field B_1, acquired with with low RF exposure. Such a method would help in quantifying RF currents rapidly in tests under standardized conditions. If proven reliable and safe, it could ultimately be applied in patients, thereby potentially extending the range of conditions under which MRI exams are known to be safe for an individual.

We have recently developed a novel B_1-mapping MR acquisition method to measure RF magnetic fields with high dynamic range. Currently, the analysis is based on simple dictionary matching methods applied to MR signals from individual voxels.



Simulation and measurement of the RF magnetic field around an implant wire in a test object.

Project: Instead of a dictionary search for signals to reconstruct B_1, followed by a separate estimation of the current, we aim to learn the functional relationship between MR signals from multiple voxels or k-space locations and RF currents from simulations. In comparison to a standard grid search, the proposed regression approach should limit the required dictionary size and reduce computation time. While the problem of regression has been extensively studied, the case where the dimension of the input variable (MR signals) is far greater than that of the response (RF current) remains a challenge. We propose to apply the GLLiM regression [1] that bypasses the problems associated with high-to-low regression. The project comprises several steps:

- (i) Modeling of the B_1 surrounding a wire implant
- (ii) Numerical simulation of the MRI acquisition of B_1 maps in the presence of RF currents
- (iii) Deriving RF current in the wire from the B_1 data using GLLiM
- (iv) Validation of the explored methods on experimental data obtained in test objects.

The project comprises an experimental part performed on the 3-T MRI of the Grenoble MRI platform (IRMaGe). The main part however will consist in the use of simulation and data analysis tools in a Matlab or Python environment. Existing Matlab and C-CUDA tools will need to be adapted or extended. The balance between the different aspects developed in the project is flexible and may be adapted to the interests of the applicant. This project may lead to a subsequent PhD thesis project.

[1] Deleforge, A., Forbes, F., and Horaud, R. (2015). High-dimensional regression with Gaussian mixtures and partially-latent response variables. Statistics and Computing, 25(5), 893-911.

Experience/Background: Project for final year engineering or science students (M2R/PFE) from applied maths, statistics, computer science, biomedical engineering, physics or related fields. Knowledge of Matlab and/or Python is required. Knowledge in elecromagnetism, RF transmission and/or MRI is a plus.

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Dates: 2019/2020 academic year.