Complex-valued Neural Networks for the Reconstruction of MR Fingerprinting

Background Magnetic resonance fingerprinting (MRF) provides a unique concept for simultaneous and fast acquisition of multiple quantitative MR parameters. Despite acquisition efficiency, adoption of MRF into the clinics is hindered by its dictionary-based reconstruction, which is computationally demanding and lacks scalability. Alternative reconstruction approaches relying on deep learning, i.e. convolutional neural networks, have recently been proposed with promising results [1]. However, further improvements in reconstruction accuracy, precision, and speed are desirable. Two promising lines of research are modelling the underlying physical processes involved in the MRF sequences (Figure 1) and modelling the complex-valued imaging data.

Aim The student will investigate the use of complex-valued deep learning, especially invertible neural networks [2], for the reconstruction of MRF data of the thigh and leg.

Materials and Methods The method will be developed and evaluated on images acquired with the MRF T1-FF sequence for T1 water relaxation time and fat fraction mapping of the skeletal muscle. A dataset of the human thighs and legs of patients with neuromuscular diseases (n=164) is available. First, experiments with complex-valued deep learning will be performed, and second, the physical processes will be modelled using complex-valued invertible neural networks. The student will evaluate the method on the provided data and compare the performance to existing methods [1].

Environment The student will actively collaborate with members of the Support Center of Advanced Neuroimaging (SCAN) and the Department of Neurology at the Inselspital, broadening his/her experience on different areas of basic and applied research. Further, as this project is a collaboration with the NMR laboratory at the Institute of Myology in Paris, the student will also engage with an external team of MR physicists during the thesis.

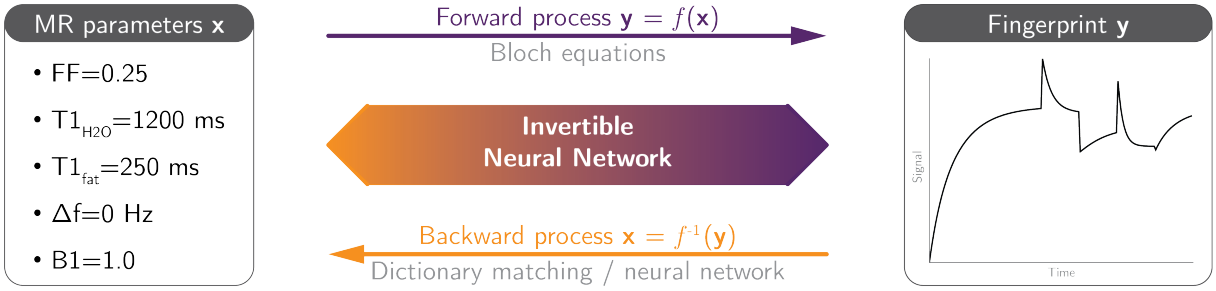

Fig. 1: Overview of an invertible neural network (INN) in the context of MRF. The forward process simulates fingerprints **y** *from MR parameters* **x***, usually by Bloch simulations. The backward process estimates MR parameters* **x** *of a fingerprint* **y***, usually by dictionary matching or recently neural networks. The INN is capable of doing both the forward and backward process, i.e., it learns the MR physics. Modelling the complex-valued nature of MR data in the INN, might further boost the learning of the MR physics.*

Nature of the Thesis
Image analysis & Machine learning: 60 %
Experiments & Evaluation: 40 %

Requirements
Interest in machine learning, especially deep learning
Programming knowledge in Python (or equivalent)
Interest in MR physics

Supervisors
Fabian Balsiger[1], Ph.D.
Olivier Scheidegger[2], PD Dr. med.

Institutes
[1]Support Center for Advanced Neuroimaging (SCAN), Institute of Diagnostic and Interventional Neuroradiology, Inselspital
[2]Department of Neurology, Inselspital

References
[1] Balsiger et al (2020) Spatially Regularized Parametric Map Reconstruction for Fast Magnetic Resonance Fingerprinting. Med Image Anal 64:101741. doi: 10.1016/j.media.2020.101741
[2] Moran et al (2018) Deep, complex, invertible networks for inversion of transmission effects in multimode optical fibres. Adv. Neural Inf. Process. Syst. 31:3280–3291

Contact
Fabian Balsiger, fabian.balsiger@insel.ch