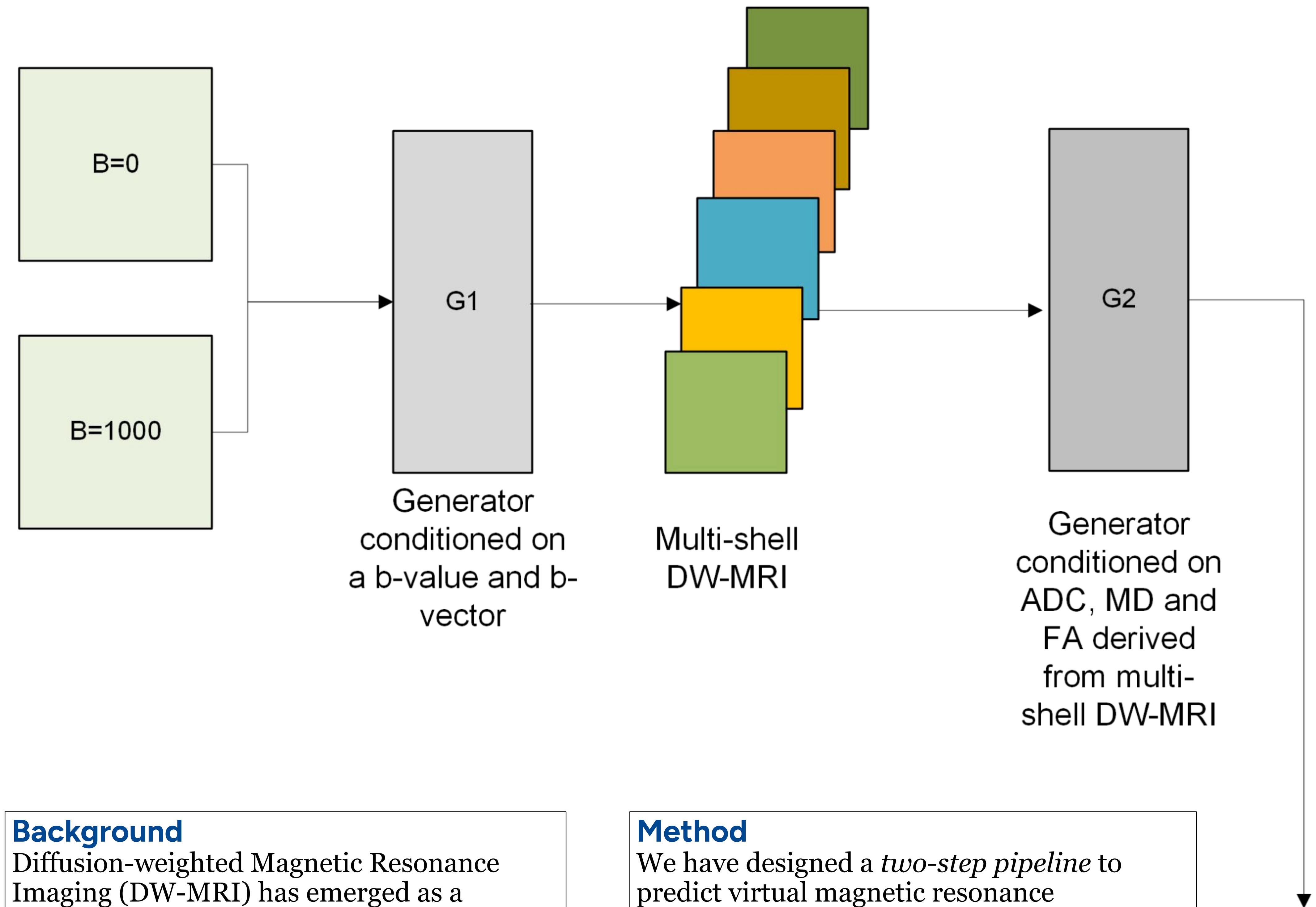
Generating virtual Magnetic Resonance Elastography

Sanna Persson, Christoffer Olsson, Rodrigo Moreno – KTH Royal Institute of Technology

Magnetic resonance elastography (MRE) is a technique that is able to estimate the mechanical properties of tissues with MRI, such as stiffness and viscosity. It has shown great potential for neuroimaging applications. Virtual MRE (vMRE) has been proposed an alternative to MRE. The main assumption of vMRE is that multi-shell diffusion MRI (dMRI) is correlated to MRE. We propose to ***develop deep learning-based pipeline to predict MRE from single-shell dMRI***.



Background

Diffusion-weighted Magnetic Resonance Imaging (DW-MRI) has emerged as a powerful tool for non-invasively probing the complex architecture of white matter tracts in the living brain. The technique captures the diffusion of water molecules, which preferentially occurs along the length of axonal fibers. The parameters b-value and b-vector represent the strength and direction of the diffusion.

Magnetic Resonance Elastography (MRE) is a different MRI technique that measures the mechanical properties of tissues such as stiffness by visualizing the propagation of waves which is indicative of various pathological conditions. However, the equipment required for MRE is *not widely available*. In Sweden, KTH is currently the only site equipped to perform brain-MRE, highlighting the need for alternative methods to assess brain tissue properties.

Previous research has shown that for the liver, there is a correlation between DW-MRI and MRE, suggesting that diffusion properties may be linked to tissue mechanical properties. This approach could leverage the diffusion information from DW-MRI to estimate mechanical properties.

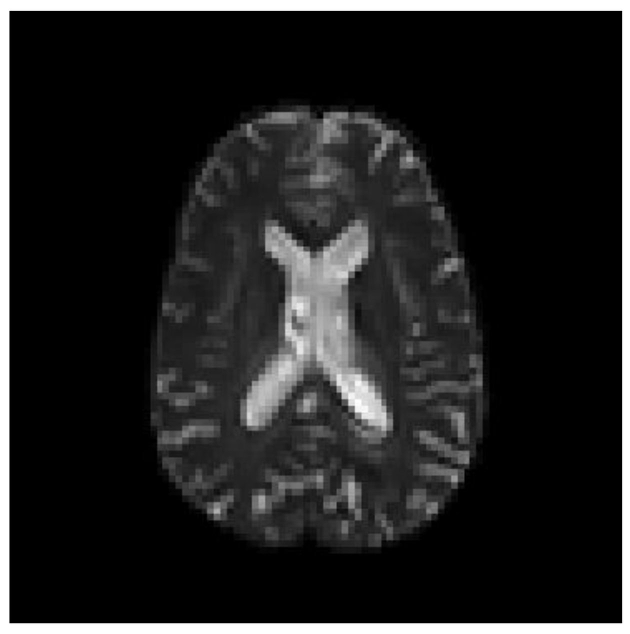
Method

We have designed a *two-step pipeline* to predict virtual magnetic resonance elastography from single-shell DW-MRI. The pipeline is designed to promote *explainability* separating the prediction of multi-shell DW-MRI and the brain stiffness. The two different conditional generative models have similar architectures and our experiments include 3D-UNETs and latent diffusion model.

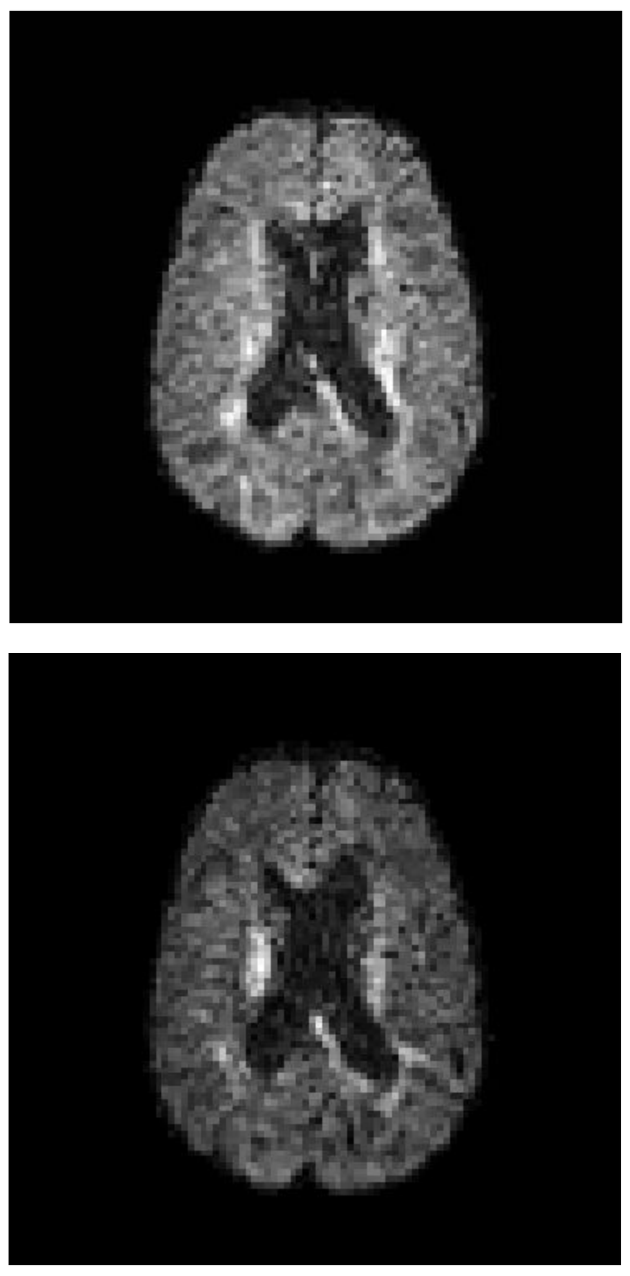
The first step involves a deep learning model that predicts multi-shell DW-MRI data from single-shell inputs. This model is pretrained on the Human Connectome Project data with b-values of 1000, 2000, and 3000 s/mm², and is fine-tuned on our custom dataset, which includes healthy controls, Parkinson's patients, and young individuals with a greater range of b-values.

The second model is trained to predict brain stiffness from our own MRE data, using inputs derived from the enriched diffusion data, specifically the Apparent Diffusion Coefficient (ADC), Mean Diffusivity (MD), and Fractional Anisotropy (FA).The project is still ongoing, and current results are preliminary.

Single-shell diffusion MRI



Multi-shell diffusion MRI



Magnetic Resonance Elastography Stiffness map