ABSTRACT

IMPROVED SIMULATION, BAYESIAN ESTIMATION, PHASE ACTIVATION, AND NON-CARTESIAN RECONSTRUCTION IN FMRI

John C. Bodenschatz, M.S.

Marquette University,

March 10, 2026

In fMRI it is desirable to obtain bright images with high contrast and low noise at an increased temporal resolution. Doing so allows for a more reliable assessment of capturing cognitive temporal dynamics. Many techniques have been employed and tested to collect more images per unit of time, while maintaining a high quality image. This has been done both in-plane (SENSE, GRAPPA), and through-plane (CAIPIRINHA, CAIPIVAT) with promising results. Following a description of work done towards a unified fMRI simulation software package, this dissertation will present work towards three methods to enhance fMRI time series images. The simulation software package presented is entitled *Simulation and Harmonic Analysis of k-Space Readout* (SHAKER) and is designed to simulate fMRI time series for statisticians. At present, most statistical researchers involved in fMRI simulate their own data in-house and may not necessarily do so in a way that is representative of the machine. SHAKER aims to provide a software package that allows for fast simulations to be done without the need for a high understanding of how an MRI machine works. The time series simulated by SHAKER will be used to demonstrate the efficacy of the three techniques presented that will improve fMRI images. The first method makes use of the first three k-space arrays in fMRI time series that are often discarded due to having a higher signal than the remaining images. These brighter images will be used to assess hyperparameters for prior distributions that will be combined with distributionally accurate likelihood images from the steady-state time series to form posterior images that have higher signal and contrast, with lower noise. The second method focus on phase-only activation in complex-valued fMRI time series. The phase half of the data is often discarded, and only the magnitude is studied. We will show that the phase part of the data contains biological information, in particular task-related signal change, that has exciting physiological implications. The third method introduced in this dissertation will operate in a radial k-space where instead of sampling on a Cartesian grid, points are collected on spokes that each pass through the center of k-space. This method of sampling k-space has many proven benefits, but is not without it's challenges- in particular, reconstructing the k-space arrays back into images. A few, fully-sampled radial k-space arrays can be used to assess hyperparameters for prior distributions that can be combined with subsampled likelihood images from the fMRI time series to form posterior images. It is expected that these images will have higher signal and contrast, lower noise, and measured at significantly higher temporal resolutions than conventional subsampling techniques offer.