# THY COMPUTE

- So is this solved?
- Far from it

$$\mathbf{B}^T\mathbf{B} = \mathbf{B}_z^T\mathbf{B}_z \otimes \mathbf{B}_y^T\mathbf{B}_y \otimes \mathbf{B}_x^T\mathbf{B}_x$$

$$(\mathbf{B}_z \otimes \mathbf{B}_y \otimes \mathbf{B}_x)^T\,\mathbf{DD}(\mathbf{B}_z \otimes \mathbf{B}_y \otimes \mathbf{B}_x)$$

# REGISTRATION TIME

NIH Public Access
Author Manuscript
*Neuroimage*. Author manuscript; available in PMC 2016 February 01.

Published in final edited form as:
*Neuroimage*. 2015 February 1; 106: 284–299. doi:10.1016/j.neuroimage.2014.11.042.

## *DR-BUDDI* (Diffeomorphic Registration for Blip-Up blip-Down Diffusion Imaging) Method for Correcting Echo Planar Imaging Distortions

**M. Okan Irfanoglu**[*,a,b], **Pooja Modi**[a], **Amritha Nayak**[a,b], **Elizabeth B. Hutchinson**[a,b], **Joelle Sarlls**[c], and **Carlo Pierpaoli**[a]

[a]Section on Tissue Biophysics and Biomimetics, National Institute of Child Health and Human Development, National Institutes of Health, Bethesda, 20892, USA

[b]Center for Neuroscience and Regenerative Medicine, Uniformed Services University of the Health Sciences, Bethesda, MD 20814, USA

[c]NIH MRI Research Facility, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, MD 20892, USA

### Abstract

We propose an echo planar imaging (EPI) distortion correction method (*DR-BUDDI*), specialized for diffusion MRI, which uses data acquired twice with reversed phase encoding directions, often referred to as blip-up blip-down acquisitions. *DR-BUDDI* can incorporate information from an undistorted structural MRI and also use diffusion-weighted images (DWI) to guide the registration, improving the quality of the registration in the presence of large deformations and in white matter regions. *DR-BUDDI* does not require the transformations for correcting blip-up and blip-down images to be the exact inverse of each other. Imposing the theoretical “blip-up blip-down distortion symmetry” may not be appropriate in the presence of common clinical scanning artifacts such as motion, ghosting, Gibbs ringing, vibrations, and low signal-to-noise. The performance of *DR-BUDDI* is evaluated with several data sets and compared to other existing

- $$\xi=\int_\Omega CC\left(I_{up}(\phi(\mathbf{x}))\,\mathscr{J}(\phi),\, I_{down}\left(\phi^{-1}(\mathbf{x})\right)\,\mathscr{J}(\phi^{-1})\right)d\Omega$$
- $$\xi_1=\int_\Omega CC(I'_{up}, I'_{down}, \mathbf{x})d\Omega$$
- $$\xi_2=\int_\Omega \left(CC\left(I_{up}(\phi_1(\mathbf{x},0.5)), \mathscr{S}\right)+CC\left(\mathscr{S}, I_{down}(\phi_2(\mathbf{x},0.5))\right)\right)d\Omega$$
- $$\mathscr{K}(\phi_1,\phi_2)=2\frac{I'_{up}\cdot I'_{down}}{I'_{up}+I'_{down}}$$
- $$\xi_3=\int_\Omega CC(\mathscr{K},\mathscr{S},\mathbf{x})d\Omega$$
- $$I''_{up}=I_{up}(\phi_1(\mathbf{x},0.5))\times|\mathscr{J}(\phi_1(\mathbf{x},0.5))|,$$
  $$I''_{down}=I_{down}(\phi_2(\mathbf{x},0.5))\times|\mathscr{J}(\phi_2(\mathbf{x},0.5))|$$
- $$\xi_4=\int_\Omega CC(I''_{up}, I''_{down}, \mathbf{x})d\Omega$$