

# 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<sup>\*,a,b</sup>, Pooja Modi<sup>a</sup>, Amritha Nayak<sup>a,b</sup>, Elizabeth B. Hutchinson<sup>a,b</sup>, Joelle Sarlls<sup>c</sup>, and Carlo Pierpaoli<sup>a</sup>

<sup>a</sup>Section on Tissue Biophysics and Biomimetics, National Institute of Child Health and Human Development, National Institutes of Health, Bethesda, 20892, USA

<sup>b</sup>Center for Neuroscience and Regenerative Medicine, Uniformed Services University of the Health Sciences, Bethesda, MD 20814, USA

<sup>c</sup>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

$$\xi = \int_{\Omega} CC \left( I_{up}(\phi(\mathbf{x})) \mathcal{J}(\phi), I_{down}(\phi^{-1}(\mathbf{x})) \mathcal{J}(\phi^{-1}) \right) d\Omega$$

$$\xi_1 = \int_{\Omega} CC(I'_{up}, I'_{down}, \mathbf{x}) d\Omega$$

$$\xi_2 = \int_{\Omega} (CC(I_{up}(\phi_1(\mathbf{x}, 0.5)), \mathcal{J}) + CC(\mathcal{J}, I_{down}(\phi_2(\mathbf{x}, 0.5)))) d\Omega$$

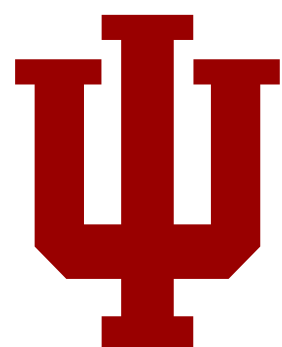
$$\mathcal{K}(\phi_1, \phi_2) = 2 \frac{I'_{up} \cdot I'_{down}}{I'_{up} + I'_{down}}$$

$$\xi_3 = \int_{\Omega} CC(\mathcal{K}, \mathcal{J}, \mathbf{x}) d\Omega$$

$$I''_{up} = I_{up}(\phi_1(\mathbf{x}, 0.5)) \times |\mathcal{J}(\phi_1(\mathbf{x}, 0.5))|,$$

$$I''_{down} = I_{down}(\phi_2(\mathbf{x}, 0.5)) \times |\mathcal{J}(\phi_2(\mathbf{x}, 0.5))|$$

$$\xi_4 = \int_{\Omega} CC(I''_{up}, I''_{down}, \mathbf{x}) d\Omega$$



# REGISTRATION TIME

DIPY

[Home](#) [Workshops](#) [Tutorials](#) [Gallery](#) [CLI](#) [Documentation](#) [Community](#) [Login](#)

Symmetric Diffeomorphic Registration in 3D

## Symmetric Diffeomorphic Registration in 3D

This example explains how to register 3D volumes using the Symmetric Normalization (SyN) algorithm proposed by Avants et al. [\[Avants09\]](#) (also implemented in the ANTs software [\[Avants11\]](#))

We will register two 3D volumes from the same modality using SyN with the Cross Correlation (CC) metric.

```
import numpy as np
from dipy.align.imwarp import SymmetricDiffeomorphicRegistration
from dipy.align.imwarp import DiffeomorphicMap
from dipy.align.metrics import CCMetric
from dipy.core.gradients import gradient_table
from dipy.data import get_fnames
from dipy.io.image import load_nifti, save_nifti
from dipy.io.gradients import read_bvals_bvecs
import os.path
from dipy.viz import regtools
```

Let's fetch two b0 volumes, the first one will be the b0 from the Stanford HARDI dataset

```
hardi_fname, hardi_bval_fname, hardi_bvec_fname = get_fnames('stanford_hardi')

stanford_b0, stanford_b0_affine = load_nifti(hardi_fname)
stanford_b0 = np.squeeze(stanford_b0)[..., 0]
```

The second one will be the same b0 we used for the 2D registration tutorial

- [Symmetric Diffeomorphic Registration in 3D](#)
  - [References](#)

