Brain Biomechanics Data

(updated 07/18/2023)

Site: University of Delaware (**UDEL**)

Data Type: Magnetic Resonance Elastography (**MRE**)

Datasets Available: 61

Overview

Each dataset corresponds to a structural imaging acquisition (T1-w, T2-w, DWI, SWI, and ToF), and a 3D MRE multiband, multishot spiral sequence acquisition at 30, 50, and 70 Hz with 1.5 mm isotropic voxels. Skull vibration was induced by an occipital actuator. All images were acquired on a Siemens Prisma 3T scanner using a 64 channel coil. Material properties are estimated from the acquired MRE data using non-linear inversion (McGarry 2012.). Detailed description of the data and acquisition of raw data can be found in Bayly et al. (2021).

Information about each subject within the datasets are documented in a csv file in the data repository: U01_NITRC_subject_info_v04.csv

Description of Data Folders

The name of each folder consists of the subject ID (e.g. U01_UDEL_0001), followed by the visit number. Four types of processed data are included for each subject.

A. Anatomy: "*_SLANT" (0.8 mm isotropic voxels, registered rigidly to MNI-152)

- *_ MPRAGEPre_norm_deface.nii.gz: the processed, defaced T1-weighted MPRAGE in MNI space.
- *_ 3DT2_norm.nii.gz: processed T2-weighted image in MNI space.
- *_ MPRAGEPre_norm_slant.nii.gz: segmented brain regions using SLANT-CRUISE.
- *_ brainmask.nii.gz: binary brain mask
- *_ falx.nii.gz: segmented falx
- *_ tentorium.nii.gz: segmented tentorium

B. Diffusion: "*_DWI" (0.8 mm isotropic voxels, registered rigidly to MNI-152)

- *_ DT.nii.gz: the processed diffusion tensor
- *_ DT_EV.nii.gz: the eigenvectors of the diffusion tensor.
- *_ DT_FA.nii.gz: the fractional anisotropy

C. MRE data (folder for each frequency, generally 30, 50, 70 Hz).

- All data is defined using the LPS (or RAI) scanner coordinate system. The first coordinate is –R/+L, second coordinate is –A/+P, and the third coordinate is –I/+S. Spatial coordinates are provided in mm.
- * _disp_re.nii and *_disp_im.nii: contain the complex lagrangian displacement components over time along the x-, y-, and z-axis, respectively. Values are in microns and represent the total displacement (see Badachhape 2017) determined from MRE phase after spatial and temporal unwrapping.
- * _curl_re.nii and *_curl_im.nii: contain the complex curl fields over time, as calculated from the displacement fields.

- *_strain_re.nii and *_ strain_im.nii: contain the real and imaginary parts of the Cartesian components of the complex lagrangian strain tensor in order exx, eyy, ezz, exy, eyz, ezx
- *_strain_OSS.nii: contains the octahedral shear strain as calculated in McGarry 2011.
- *_anat.nii: contains a T2-like anatomical image in the MRE data space.
- *_ props_shear_real.nii.gz and *_ props_shear_imag.nii.gz: the computed storage modulus ('real') and loss modulus ('imag') from NLI.
- *_ props_shear_stiff.nii.gz and *_ props_shear_dr.nii.gz: the computed shear stiffness ('stiff') and damping ratio ('dr') from NLI.

D. **Anatomical Data in MRE Space**: "*_register_to_MRE" (1.5 mm isotropic voxels, registered rigidly to MRE data space)

- This folder contains the same files in folders (A) and (B), but rigidly registered and downsampled to the MRE data space. These images allow for a one-to-one correspondence between the voxels in the MRE data and the anatomical segmentations. The 'moving image' is defined as the "*_3DT2_norm.nii.gz" image from the data in (A). The 'fixed image' is defined as the 50 Hz "*_anat.nii" from the MRE data in (C). The rigid transformation from the fixed image to the moving image is provided in the "*_RigidTransform.mat" file, which is generated from ANTs. The anatomical images in (A) and (B) are then transformed to the MRE space using ANTs. The T1w and T2w images are transformed using 5th order B-spline interpolation. Binary images use nearest neighbor interpolation, while the SLANT segmentation used the 'multilabel' interpolation. The diffusion data uses a 4D tensor transformation within ANTs. Example registration and transformation code is given in the appendix below.

Notes and Updates

- (July, 2022) Subject U01_UDEL_0011 only has 30 Hz and 50 Hz MRE data.
- (July, 2022) Subject U01_UDEL_0028 only contains material property estimates for MRE data.
- (July, 2022) Note that for subjects scanned at multiple sites, a column has been added to identify "cross-site IDs."
- (July, 2023) Displacement files for subjects U01_UDEL_0007 - U01_UDEL_0036 have been updated to reflect a correction in data processing.
- (July, 2023) Subjects U01_UDEL_0025, U01_UDEL_0027, U01_UDEL_0031, and U01_UDEL_0047 do not contain displacement data due to poor rigid body motion unwrapping.
- (July, 2023) Subjects U01_UDEL_0042 and U01_UDEL_0059 only contain displacement data for 30 Hz and 50 Hz.
- (July, 2023) Subject U01_UDEL_0043 only contains 30 Hz and 50 Hz MRE data.
- (July, 2023) Subject U01_UDEL_0061 only contains 50 Hz and 70 Hz MRE data.

References:

Bayly, P. V., et al. (2021). MR imaging of human brain mechanics in vivo: new measurements to facilitate the development of computational models of brain injury. Annals of Biomedical Engineering, 49, 2677–2692.

McGarry, M. D. J., Van Houten, E. E. W., Johnson, C. L., Georgiadis, J. G., Sutton, B. P., Weaver, J. B., & Paulsen, K. D. (2012). Multiresolution MR elastography using nonlinear inversion. Medical physics, 39(10), 6388-6396.

Badachhape AA, Okamoto RJ, Durham RS, Efron BD, Nadell SJ, Johnson CL, Bayly PV. The Relationship of Three-Dimensional Human Skull Motion to Brain Tissue Deformation in Magnetic Resonance Elastography Studies. J Biomech Eng. 2017 May 1;139(5):0510021–05100212. doi: 10.1115/1.4036146. PMCID: PMC5444212.

McGarry MD, Van Houten EE, Perriñez PR, Pattison AJ, Weaver JB, Paulsen KD. An octahedral shear strain-based measure of SNR for 3D MR elastography. Phys Med Biol. 2011 Jul 7;56(13):N153-64. doi: 10.1088/0031-9155/56/13/N02. PMCID: PMC3172714.

Appendix 1: ANTs registration and transformation

<u>Rigid Registration</u>

- antsRegistration -d 3 -o [$outputName, $outputName_Warped.nii.gz, $outputName_InverseWarped.nii.gz] -a 1 -z 1 -r [${FixedImage}, ${MovingImage}, 1] -t Rigid[0.1] -m MI[${FixedImage}, ${MovingImage}, 1, 32, Regular, 0.25] -c [1000x500x250x100,1e-6,10] -f 8x4x2x1 -s 3x2x1x0vox --float 1 –verbose

<u>Rigid Transformation</u>

(change the -n option for interpolation method)

- antsApplyTransforms -d 3 -i $*_MPRAGEPre_norm_slant_macruise.nii.gz -o $outputName_macruise.nii.gz -r ${FixedImage} -n MultiLabel -t [$outputName_Composite.h5] --verbose