Brain Biomechanics Data

Site: Henry Jackson Foundation (**HJF**)

Data Type: Tagged MRI

Datasets Available: 10

Overview

Each dataset corresponds to a structural imaging acquisition (T1-w, T2-w, DWI, SWI, and ToF), and a tagged MRI acquisition with 1.5 mm isotropic voxels using either a neck extension (NE) or neck rotation (NR) head motion. All images were acquired on a Siemens 3T Biograph scanner using flexible array and spine receive coils. Raw data were processed using the harmonic phase finite element method (HARP-FE) to produce displacement and strain fields (Gomez et al. 2018).

More information about data acquisition and processing can be found in Knutsen et al. (2020) and 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_2021_Oct_14.csv

Description of Data Folders

The name of each folder consists of the subject ID (e.g. U01_HJF_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. Tagged MRI data (folder is named with either "NR" or "NE" for each subject)

- The images are all oriented in RAI => +x is right to left, +y is anterior to posterior, +z is inferior to superior. All of the data is in the same space. The T1 and segmentation are 3D volumes (x,y,z); the displacement and strain data are 4D volumes (x,y,z,time); the vectors associated with the principal strains are 5D volumes (x,y,z,time,[e_x e_y e_z]).
- *_u/v/w.nii.gz: the displacement (mm) time-history with respect to the skull along the x-, y-, and z-axes, respectively.
- *_Exx/Eyy/Ezz/Exy/Exz/Eyz.nii.gz: the Cartesian strain components versus time.
- *_Eoct.nii.gz: the octahedral shear strain.

- *_E1/E2/E3.nii.gz: the principal strain components along vectors V1/V2/V3, respectively.
- *_V1/V2/V3.nii.gz: the principal strain vectors for each magnitude E1/E2/E3, respectively.
- *_Q1/Q2/Q3.nii.gz: the anatomical coordinate system, relative to the scanner coordinate system, for the data. Each file corresponds to the coordinates (mm) in x (Q1), y (Q2), and z (Q3).
- *_PVA.mat: contains information on the applied head cradle motion in the direction of loading (z rotation for NR and x rotation for NE), and the correspondence between the head motion and strain data.
    a. The time (ms), angular position (degrees), angular velocity (rad/s), and angular acceleration (rad/s^2) correspond to the measured device motion.
    b. peakAlpha: peak angular acceleration (rad/s^2)
    c. linearAcc: peak linear acceleration at the center of mass (g)
    d. frameNumber: the number of each tagged MRI data frame.
    e. frameCenter_ms: the time in ms of each tagged MRI data frame, aligned with the timing of the kinematics.
    f. centerOfRotation: the spatial coordinates of the experiment center of rotation (mm), with the coordinates of the whole brain in the Q1/Q2/Q3.nii.gz files.
    g. centerOMass: the spatial coordinates of the brain center of mass (mm), with the coordinates of the whole brain in the Q1/Q2/Q3.nii.gz files.

D. Anatomical Data in Tagged MRI Space: "*_register_to_tMRI" (1.5 mm isotropic voxels, registered rigidly to the tagged MRI data space)

- This folder contains the same files in folders A and B, but rigidly registered and downsampled to the tagged MRI data space. These images allow for a one-to-one correspondence between the voxels in the tagged MRI data and the anatomical segmentations. The rigid transformation from the data in A (anatomical) to the data in B (MRE) is provided in the "*_RigidTransform.mat" file, which is generated from ANTs.

Instruction on Data Extraction

Included is a toolbox to load NIFTI files (.nii) into Matlab (niftimatlib-1.2). An example of how to use the toolbox is given below:

First, unzip the *gz files using gunzip in Matlab or similar:
*gunzip('*_T1.nii.gz');*

*N = nifti('*_T1.nii');*
T1 = N.dat(:,:,:); % 3D matrix with signal intensity of the image at each voxel
mat = N.mat; % qform matrix
res = N.hdr.pixdim(2:4); % image resolution
clear N % always clear N once you've pulled the necessary information. Otherwise, possible to overwrite data

*N = nifti('*_u.nii');*
u = N.dat(:,:,:,:); % number of colons should equal the dimension of the data. If unsure, N.dat.dim provides the data dimension
clear N

When the data is loaded in, dimension 1 is x, dimension 2 is y, and dimension 3 is z. I often permute the first and second dimensions when visualizing the images so that the x-dimension is along the x-axis in Matlab.

References:

Gomez, A. D., Knutsen, A. K., Xing, F., Lu, Y. C., Chan, D., Pham, D. L., ... & Prince, J. L. (2018). 3-D measurements of acceleration-induced brain deformation via harmonic phase analysis and finite-element models. IEEE Transactions on Biomedical Engineering, 66(5), 1456-1467.

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.

Knutsen, A. K., Gomez, A. D., Gangolli, M., Wang, W. T., Chan, D., Lu, Y. C., ... & Pham, D. L. (2020). In vivo estimates of axonal stretch and 3D brain deformation during mild head impact. Brain multiphysics, 1, 100015.