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| |  | | --- | |  | | primer: registration | |  | |
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# ESSENTIAL CONCEPTS

* **Image Spaces (associated with distinct coordinate system)**
  + Native space – coordinates unique to subject’s head placement in MRI scanner
  + Standard space – standard defined coordinates across all images in this space define anatomy location
    - Images in this space can have different resolution
* **Coordinate Systems**
  + Voxel coordinates
    - no units; integers
    - voxel count in each dimension reflecting matrix size
    - Origin: corner of image (e.g., 0,0,0 or 1,1,1)
    - Origin and axes naming conventions differ in programs
  + World coordinates
    - Have units in mm; floating values
    - Denote anatomy
      * Handedness system
        + Right-handed (RAS) system

x+ Left-Right

y+ Posterior-Anterior

z+ Inferior-Superior

Default for: MNI152 space, NifTi

* + - * + LPS system

Default for: Dicom

* + - Origin: can differ in programs, standard space (e.g., MNI152 space origin at anterior commissure)
* **Standard Templates**

RULE: Know demographics of cases used to generate atlas, try match template and study cohort

* + Talairach and Tournoux (TT space)
    - 1 postmortem brain, female, 60 years old
  + MNI152/ICBM 152 (MNI152 space)
    - 152 healthy young adults
  + Study-Specific Templates (Study Specific space)
    - Need substantial representative cases to make
* **Standard Atlas**

RULE: Know demographics of cases used to generate atlas; MAY BE DIFFER from template in same space, try match atlas, template and study cohort

* + Talairach and Tournoux (MNI152 space) - discrete
    - 1 postmortem brain, female, 60 years old
  + AAL (MNI152 space) - discrete
    - Multiple scans from 1 healthy adult
  + Harvard-Oxford (MNI152 space) - probabilistic
    - 37 healthy adults
  + JHU WM (MNI152 space) – probabilistic
    - 28 young healthy adults

# registration decision points

* **Prep - QC input & reference images**
  + Artifacts
  + Sharpness of anatomical features
  + Variability of anatomy
  + Comparable demographics (e.g., atlas, standard template, study cohort)
  + FOV sampling of body similar (e.g., amount of neck included)
* **Prep - Reorient (optional)**
  + Initialization
* **Prep - Crop (optional)**
  + Remove non brain areas in FOV in both images so sampling similar (e.g., neck)
* **Prep - Brain extraction of input & reference image (optional)**

RULE: input & reference image MUST match in skull sampling (BAD: 1 w/skull, 1 w/out)

* + Quality needs to be good, if not – better to not do
* **Registration - Spatial transformations**

DEFINITION: *Calculate* the best alignment of the images by determining parameters of the spatial transformation

* + Linear Transformation (within-subject, same anatomy)
    - Rigid-Body (6-DOF: 3 rotations, 3 translations)
      * Within-subject registration
      * Initializing other methods
    - Affine (12-DOF: 3 rotations, 3 translations, 3 scaling, 3 sheers/skews)
      * Eddy-current distortion correction
      * Initializing nonlinear transformations
  + Non-linear Transformation/Warp (between-subject, differ anatomy)
    - 12+ DOF
    - REQUIRE: Initialize with affine registration
    - DEFINE: Regularization (depend on SNR, CNR, artifacts, image type)
      * High: low quality images (smoother distortion)
      * Low: high quality images (allow more distortion)
* **Registration - Cost functions (more restrictive usually more robust)**

RULE: more restrictive usually more robust, listed first

* + Sum of squared differences (same modality, same session)
  + Normalized correlation (same modality, different session)
  + Correlation ratio (any MRI images)
  + Mutual information/Normalized mutual information (any images)
  + Boundary-Based Registration (images with contrast around boundaries)

Alternative methods for images with pathology, bad-quality/artifacts

* + Cost function weighting/masking: manually define mask to exclude weighting
  + Cost functions based on robust statistics: automatically define mask
* **Resample/Transform –** *Apply* the spatial transformation & creating image in new space

RULE: Avoid degradation of images; resample/interpolate only 1x

* + Create and check quality of separate registrations before concatenating and applying to image 1x

REQUIRE:

* + **Interpolations (Lower resolution to higher resolution)**
    - Nearest Neighbor (discrete ROI/atlas)
      * PRO: Retains original values
      * CON: blocky edges
    - Linear interpolation (parametric maps, probabilistic/statistical maps)
      * Allows floating integers
      * PRO: Retains original range of values
      * PRO: Better represent spatial boundaries/stats values
      * CON: involve small amount of smoothing/blurring
      * ROIs when thresholding with binarization (acct for PVE at boundaries)
        + ROI to include: high threshold ~ 0.9
        + ROI to exclude: low threshold ~0.1
        + ROI closest anatomical representation: ~0.5
    - Nonlinear Spline interpolation (structural T1s)
      * Allows floating integers
      * PRO: Preserve sharp boundaries
      * CON: Creates small amount of ringing artifact
      * CON: Changes original range of values, can be higher
  + **Downsampling (higher resolution to lower resolution)**
    - Explicit averaging: include values from all the overlapping voxels in a suitable average
    - Presmoothing: spatially smoothing high resolution input image BEFORE interpolation