TMBIC

台灣心智科學腦造影中心
資料分析研習營

科技部人文司:

心智科學大型研究設備建置及公同使用服務計畫

TMBIC

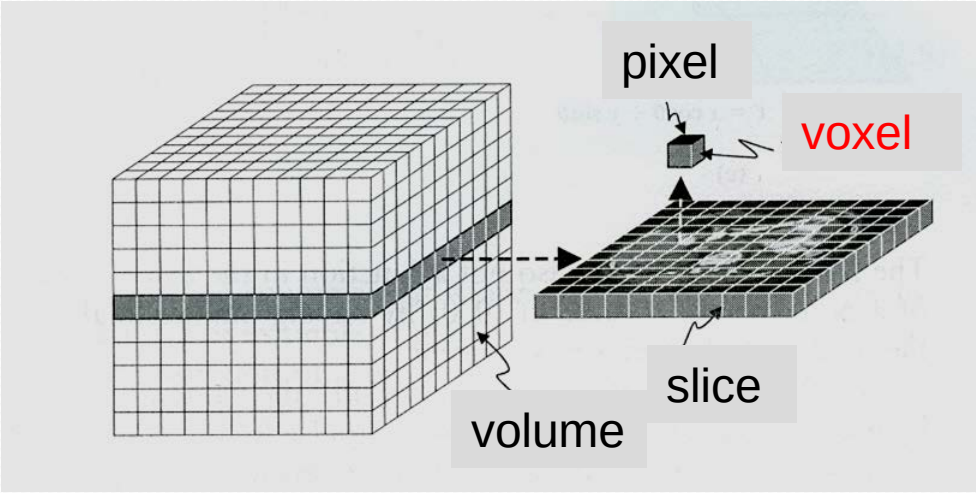
影像資料前處理
Image preprocessing

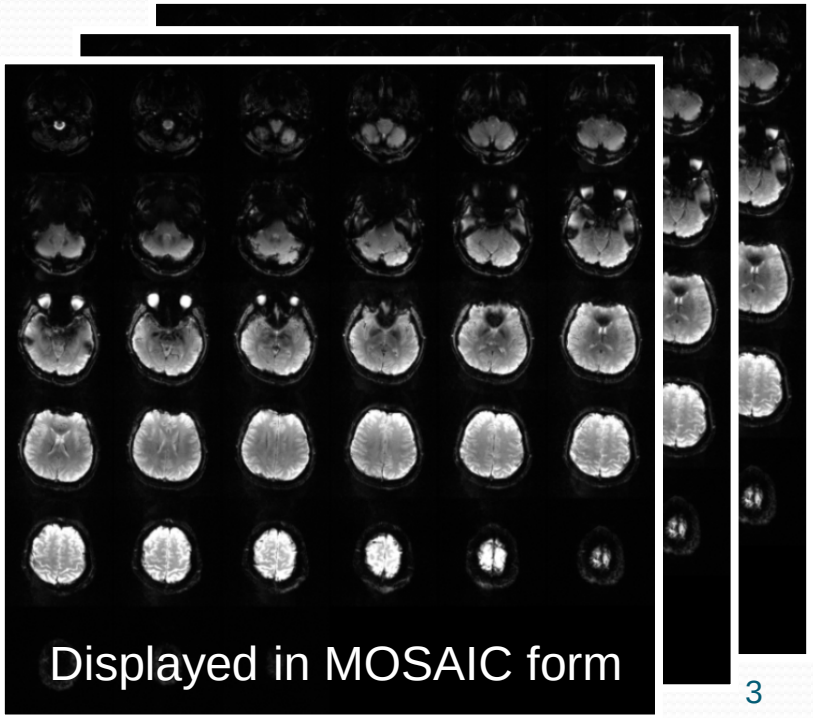
蔡尚岳

政治大學 應用物理研究所

Images as Matrix

- 單張影像為有厚度的二為切面(片) [X, Y]
- 一組頭部影像:多個切面以3d 矩陣儲存 [X, Y, Z]
- 一組fMRI影像：多組於不同時間取得的頭部影像，以4D矩陣儲存 [X, Y, Z, time]





For fMRI, we will have …

- 高解析度結構影像
  - T1 or MPRAGE 以3D矩陣儲存
  - ex: [176 256 256] in [X Y Z]
  - [Left-Right Anterior-Posterior Superior-Inferior]

- fMRI影像資料
  - EPI 影相以4D矩陣儲存
  - ex: [64 64 40 300] for [X Y Z T] if we use 300 measurements and 40 slices

Universal data format

- 影像需要共通的儲存格式
  - Like the “JPG” “BMP” files for digital images
  - These kinds of files can be transferred in internet, computers, digital cameras

- 醫學影像通用格式
  - Dicom 格式， “.ima” or “.dcm”
  - MRI系統自動產生，實驗做完後拿到的影像格式
- Neuroimaging 通用格式
  - NIFTI 格式，“.nii” or “.img”+”.hdr”
  - 各種分析軟體均支援此格式，例如: AFNI、freesurfer、FSL、SPM、Brainvoyager 等等….
  - 基本上就是儲存fMRI影像的四維矩陣

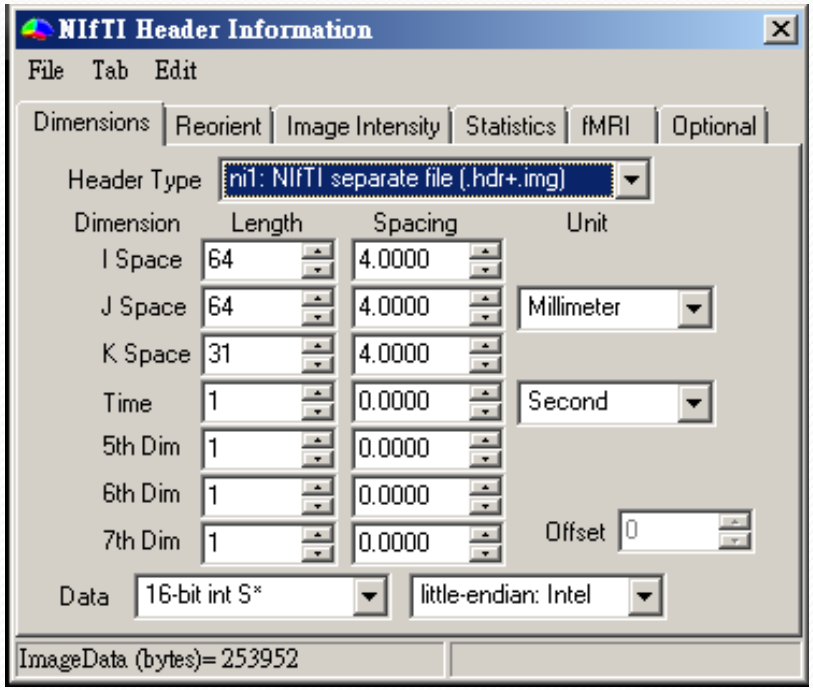
Two NIFTI Data types

- SPM use analyze 7.5 format
  - Two files for one 3D image matrix : image part in ".img" and header in ".hdr"
  - MPRAGE: 1 img file and 1 hdr file
  - fMRI with 300 measurements: 300 img files and 300 hdr files

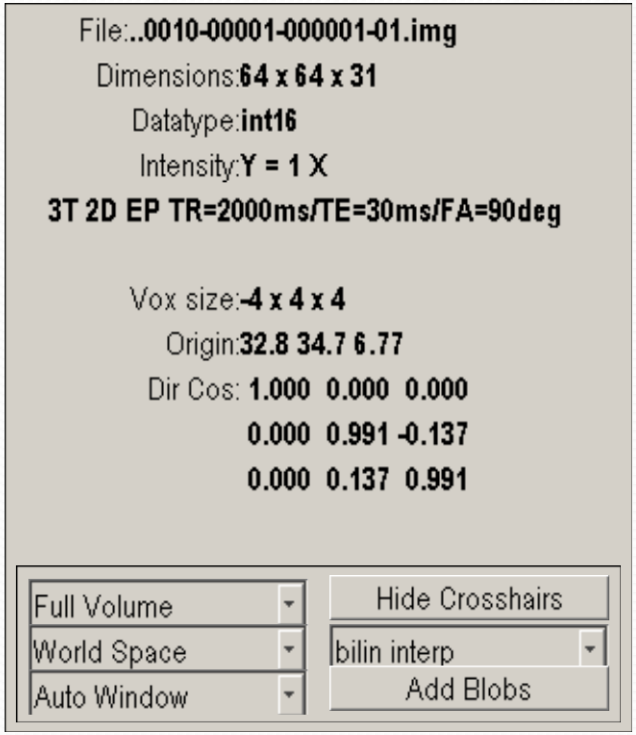
- Nii format is also supported by SPM
  - Image matrix (3D, 4D or more) are directly saved in the "nii" file including header and image
  - MPRAGE: 1 nii file
  - fMRI with 300 measurements: 1 nii file
  - Can be given in compressed form ".nii.gz"

Header is needed

- 紀錄每組影像資料的相關資訊
  - Coordinate information
  - History: all process and the transformation done on the data set



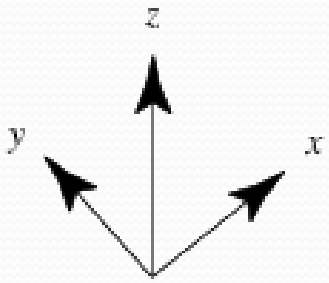
Header information in other tool



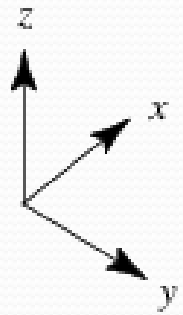
Header information in SPM

Left and Right handed coordinate systems

- Coordinate: NIfTI format files are stored in either a left- or right-handed system Indicated in the header
- Right hand coordinate used in talairach system
  - X increase from left to right
  - Y increase from posterior to anterior
  - Z increase from inferior to superior
- Left hand coordinate used in Analyze format and MNI space
- Mapping between them sometimes requires a flip



right-handed coordinate system



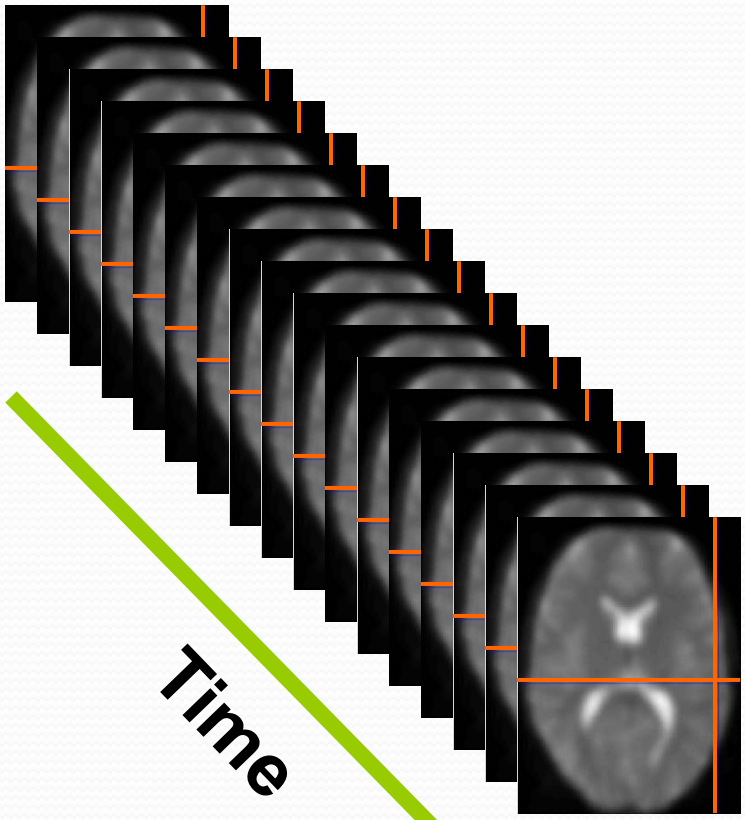
left-handed coordinate system

Image-based spatial process

- fMRI preprocess usually belongs to this type
  - Realignment
  - coregistration
  - Normalization and Segmentation

- Change the intensity or morphology of images
- Apply on images, time point by time point

Voxel-based time series (course) analysis



Time

single voxel time series

Time

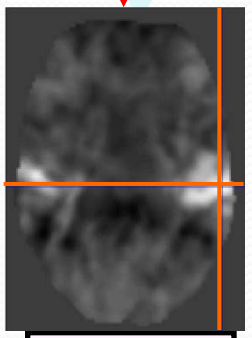
BOLD signal

Model specification

Parameter estimation

Hypothesis

Statistic

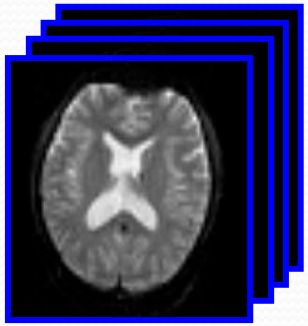


SPM

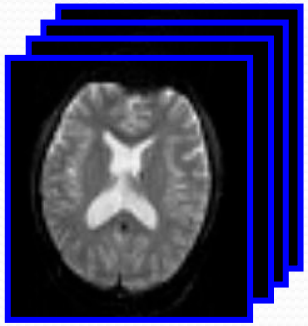
Pre-processing Overview

Statistics or whatever

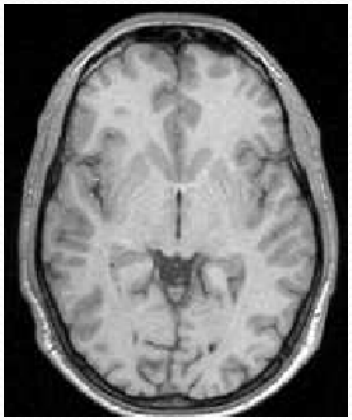
fMRI time-series



Motion Correct & slice timing



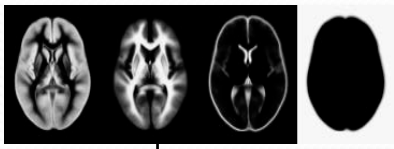
Anatomical MRI



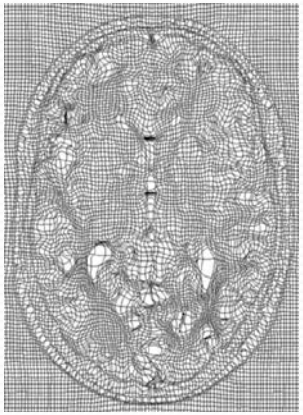
Coregister

$$\begin{pmatrix} m_{11} & m_{12} & m_{13} & m_{14} \\ m_{21} & m_{22} & m_{23} & m_{24} \\ m_{31} & m_{32} & m_{33} & m_{34} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Template

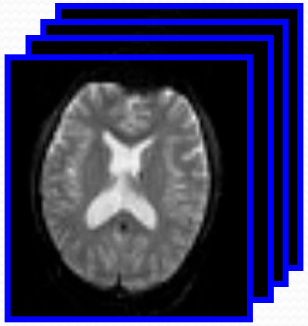


Estimate Spatial Norm

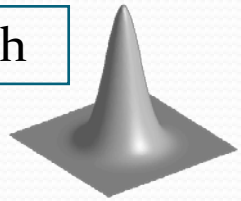


Deformation

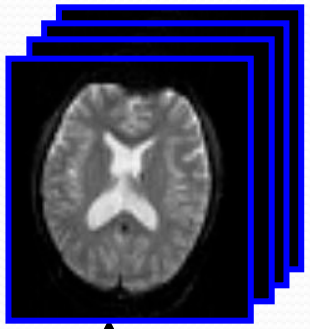
Spatially normalised



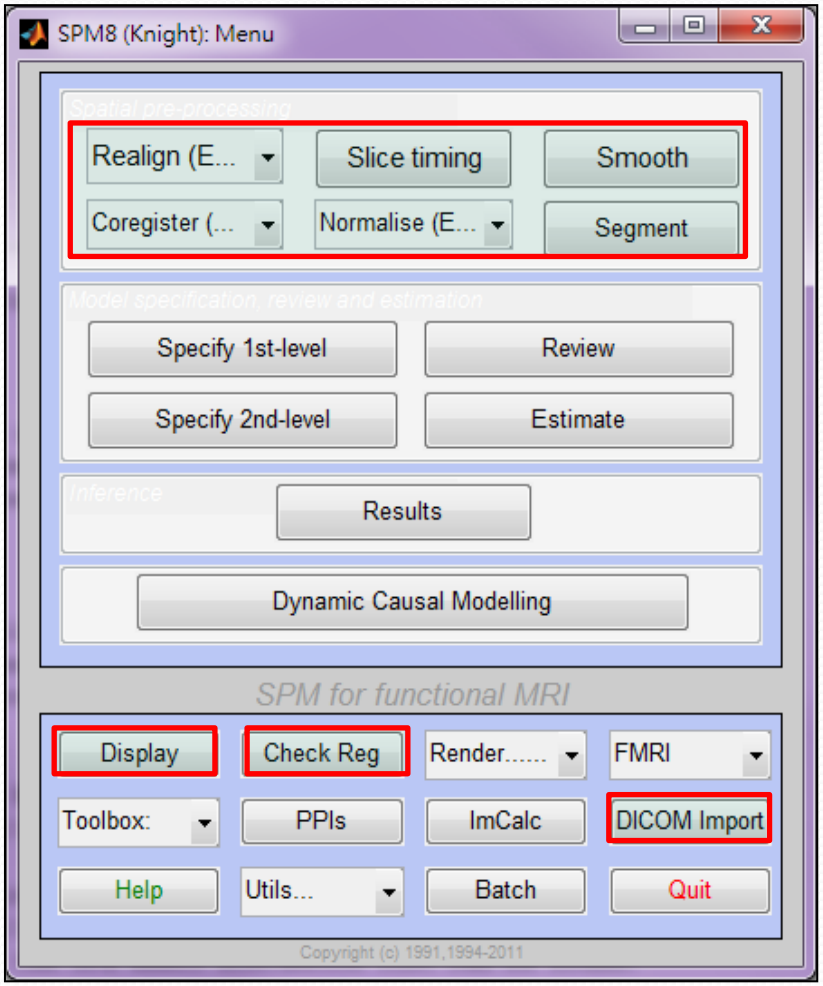
Smooth



Smoothed



SPM functions



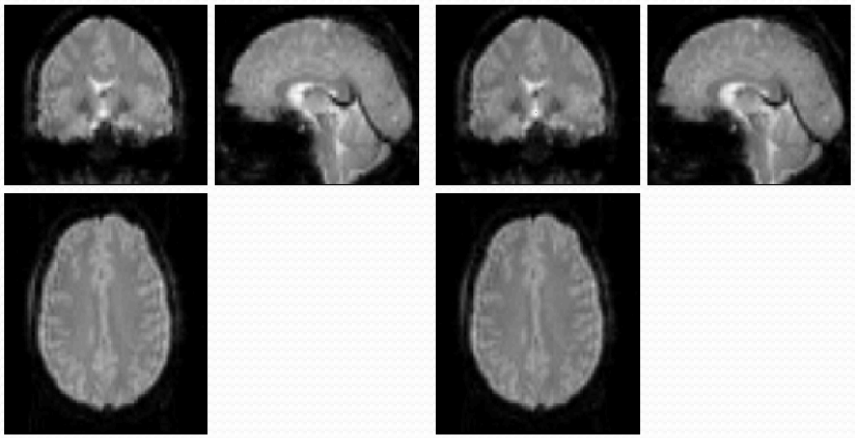
files	• DICOM Import
EPI	• Realign • Slice timing
EPI,T1	• Coregister
EPI,T1 template	• Normalise and Segment
EPI	• Smooth
	• Display and Check Reg

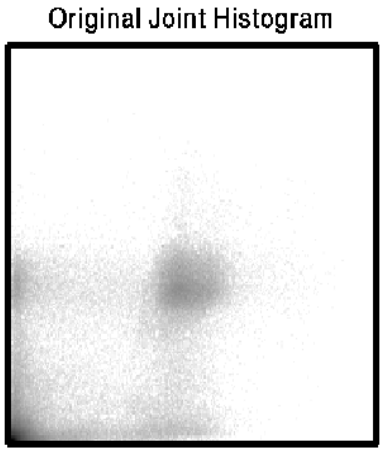
Spatial transformation

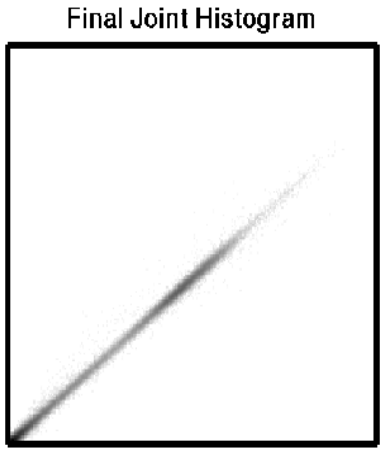
- All voxels in the images can be accessed by [X Y Z] indexes given the origin and orientation (rotational matrix)

- Two procedures to do transformation between A and B
  - Decide the source and reference and choose the proper functions and associate algorithms
    - Register the source (A) to reference (B) image
  - Estimate transformation matrix between A and B, then apply transformation matrix on A
    - SPM will apply transformation matrix on A voxel by voxel and update the coordinate for the header of A
    - You will get a new sets of images after transformation denoted by specified file pre-fix “xx” like r-A

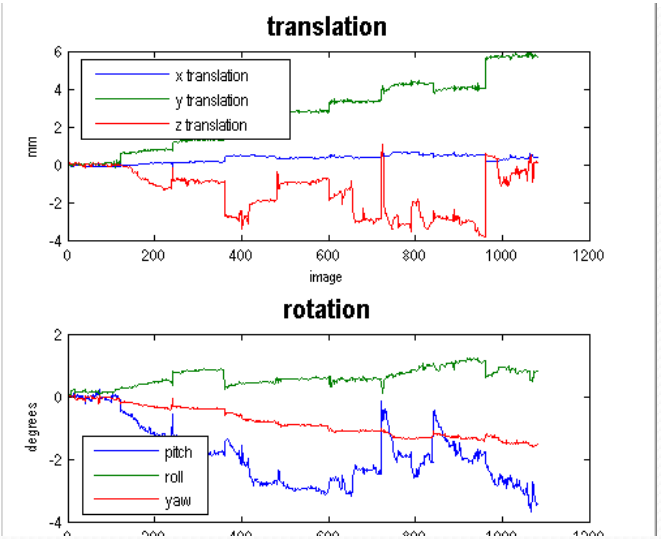
Realignment– motion correction





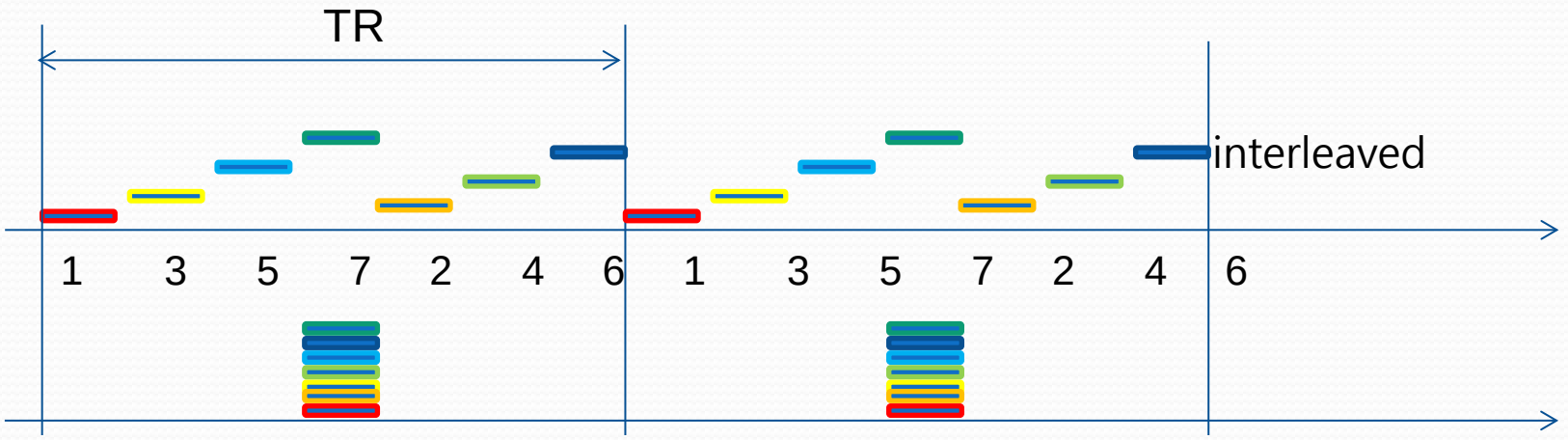


- Correct the motion during EPI scans
  - 6 parameters rigid body transformation
  - Intra-modal registration by minimising mean-squared difference
- All image are aligned to one reference image
  - Can be the first one, middle one or averaged one by doing the process iteratively



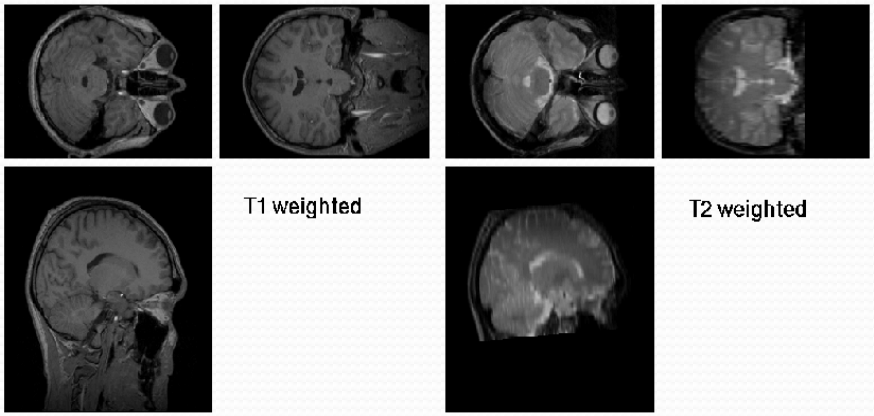
Slice timing correction

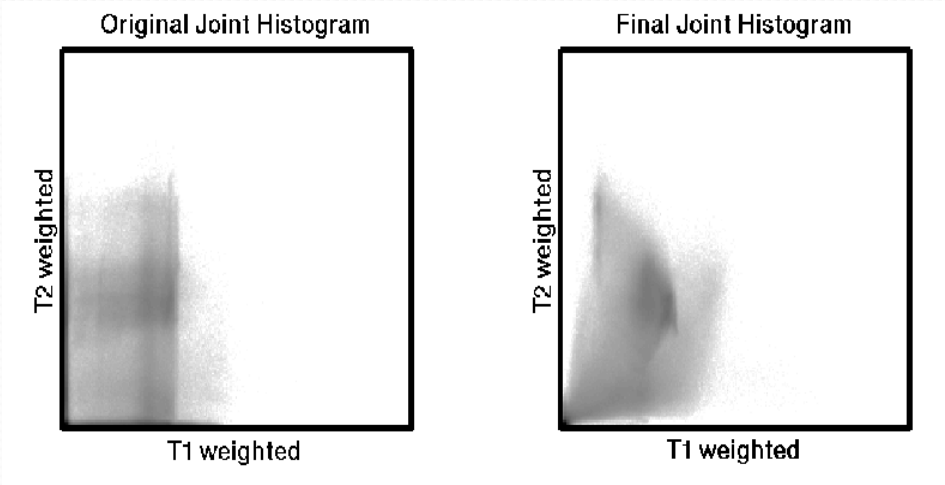
- Slices are not acquired simultaneously
- Align the timing of all slices to a referenced time by interpolation
  - Number of slice (ex:33)
  - TR (ex:2 seconds)
  - TA = TR-(TR/number of slices) (ex:2-2/33)
  - Slice order: mostly interleaved (ex:[1:2:33 2:2:33] for odd or [2:2:40 1:2:40] for even)
  - Reference slice (ex 33 which is the middle one)



Coregistration – T1 and EPI

- Match images from same subject but different types
  - 12 parameters affine transformation
  - Inter model registration by maximizing mutual information
  - Achieve more precise spatial normalization of fMRI images using anatomical image
- Estimation: Averaged EPI after realignment to T1 MPRAGE
- Reslice: apply to EPI after slice timing correction





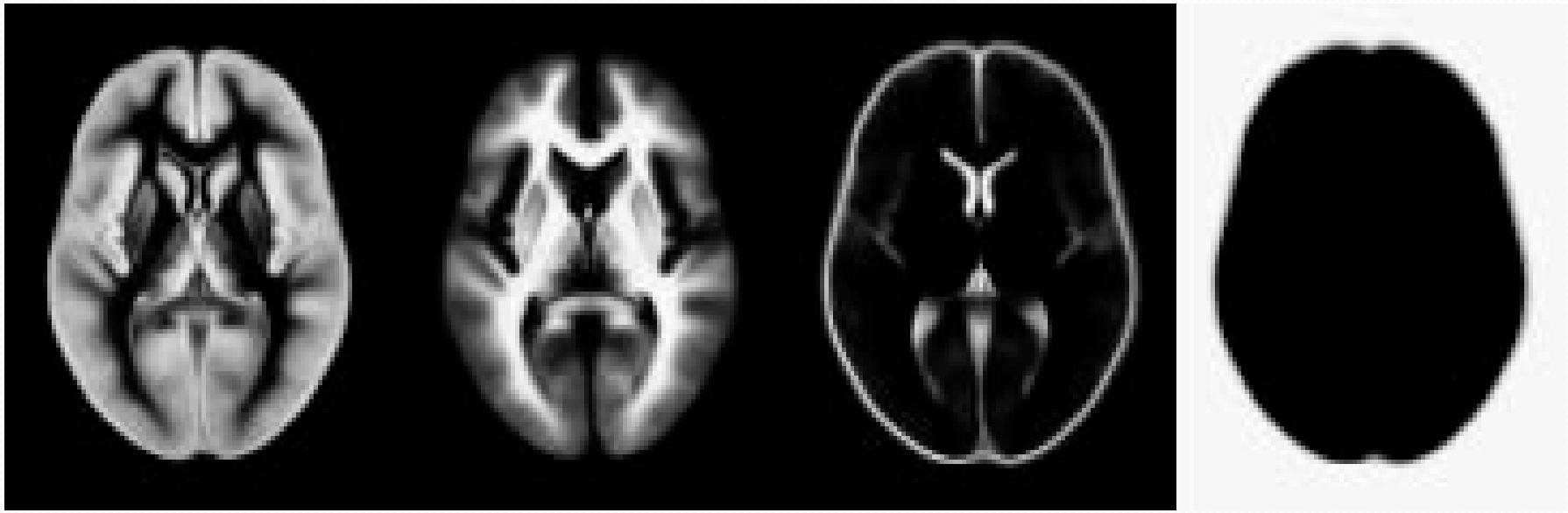
Spatial Normalisation

- Brains of different subjects vary in shape and size
- All into a common anatomical space (Template)
  - Examine activation regions across subjects in group analysis
  - Report findings in a common anatomical space

- In SPM, alignment is achieved by matching grey matter with grey matter and white matter with white matter
  - Segmentation is needed
  - Images with good GM/WM contrast gives better results

Segmentation

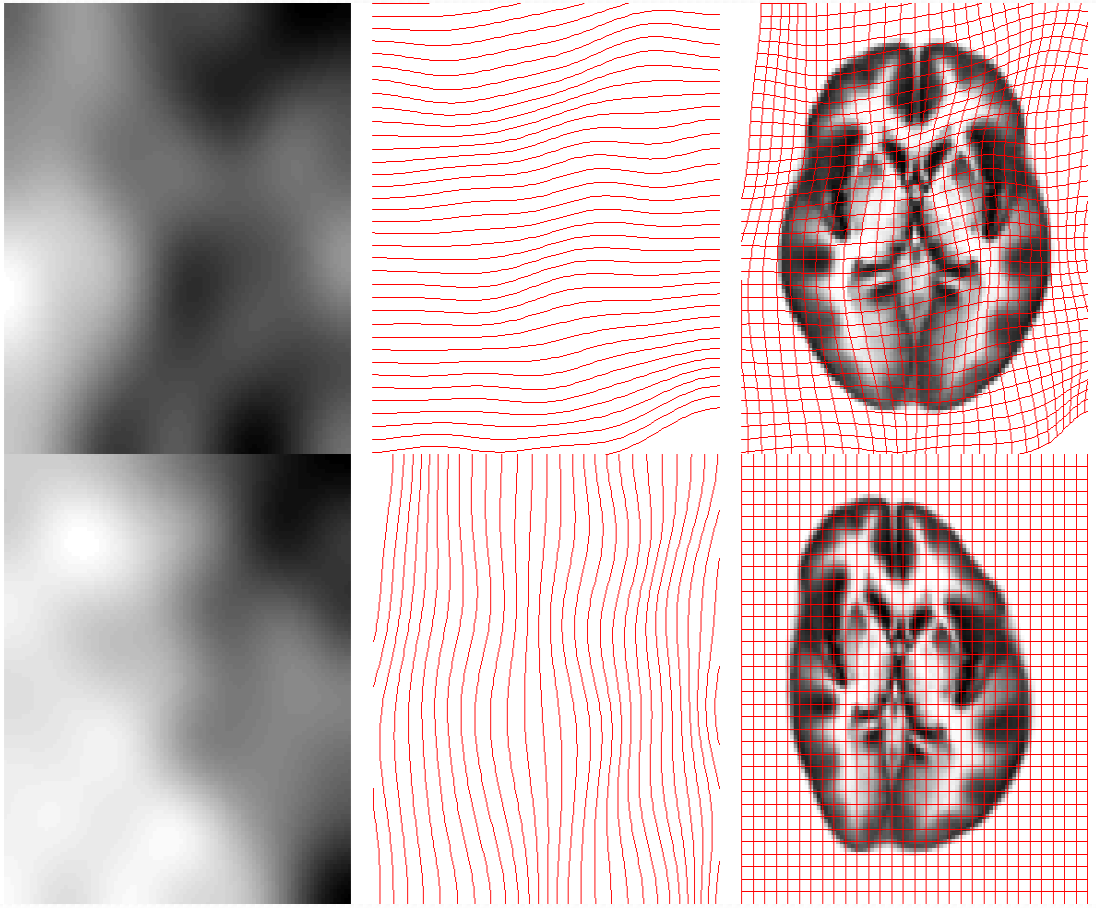
- Tissue probability maps (TPMs)
- SPM8 estimates a spatial transformation that can be used for spatially normalising images



ICBM Tissue Probabilistic Atlases. These tissue probability maps are kindly provided by the **International Consortium for Brain Mapping**, John C. Mazziotta and Arthur W. Toga.

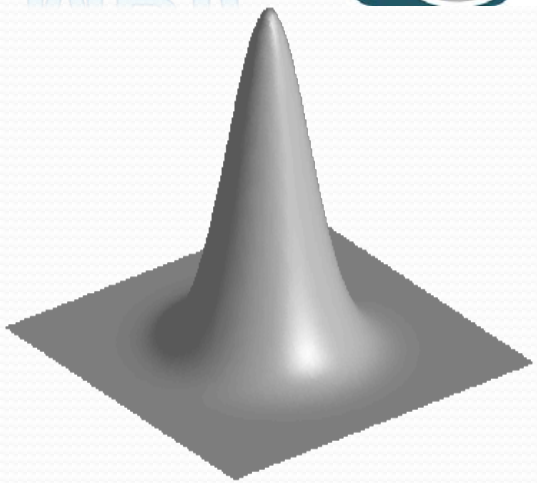
Deforming the Tissue Probability Maps

- Tissue probability images are deformed so that they can be overlaid on top of the image to segment
- Transformation function will be generated denoted by “SN”
- Normalization can be done reversely using the transformation function denoted by “invSN”

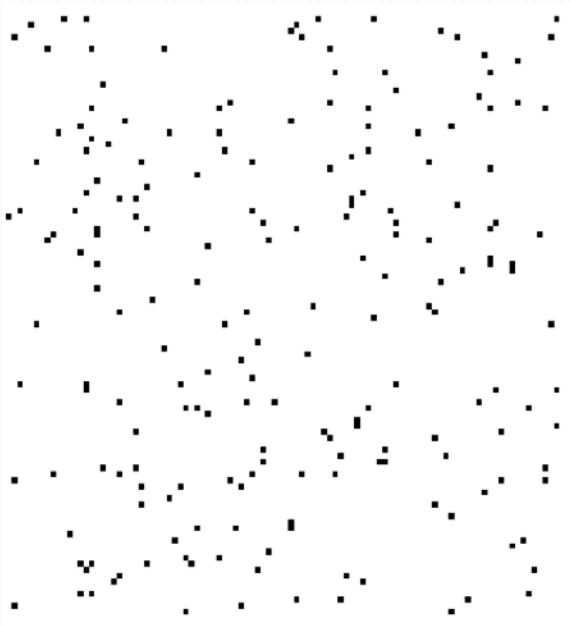


Smooth

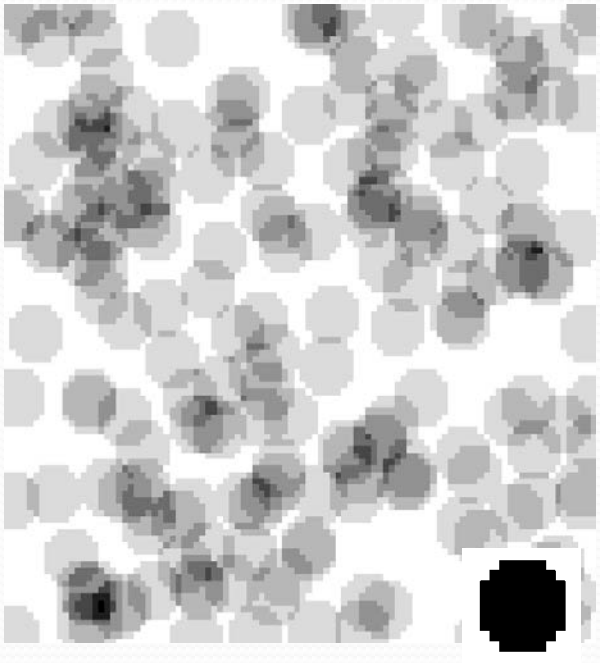
- Blurring the images by a kernel
- Increase SNR but spatial resolution
- Effective voxel size



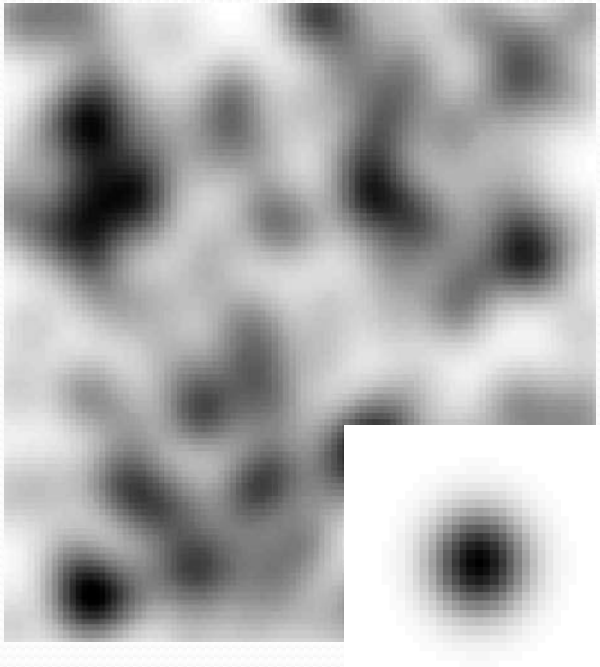
Before convolution



Convolved with a circle



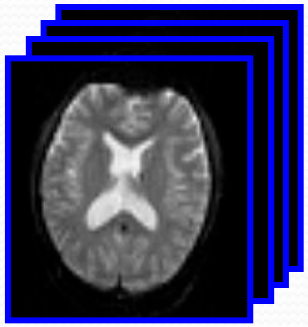
Convolved with a Gaussian



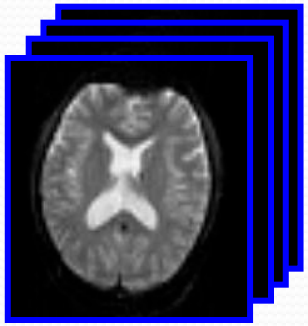
Pre-processing Overview

Statistics or whatever

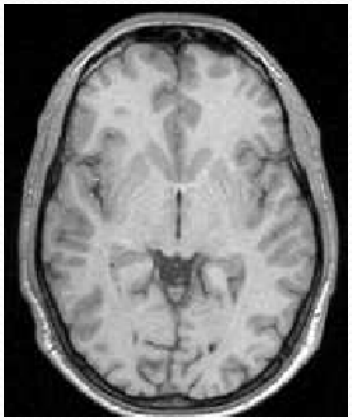
fMRI time-series



Motion Correct



Anatomical MRI



Coregister

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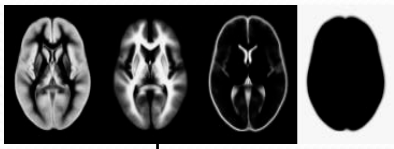
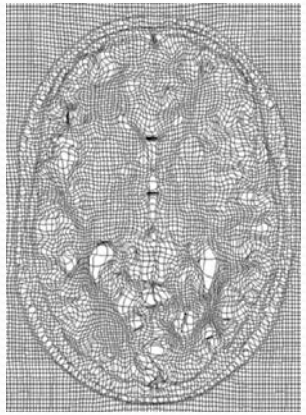
Template

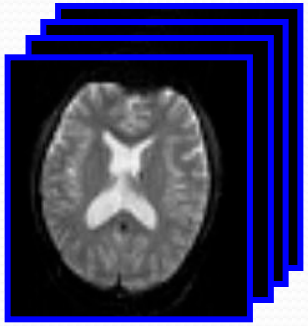


Estimate Spatial Norm

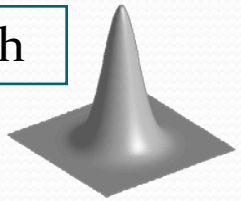


Deformation

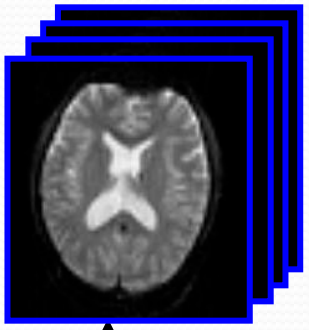
Spatially normalised



Smooth



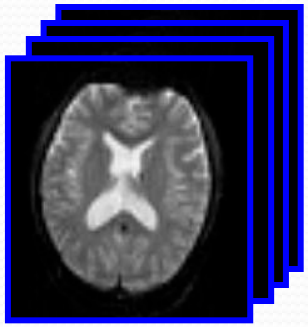
Smoothed



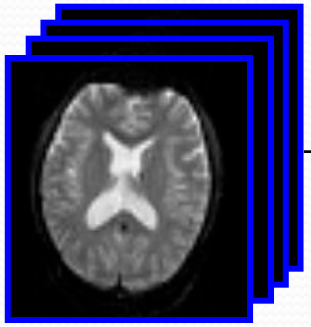
Alternative pipeline

Statistics or whatever

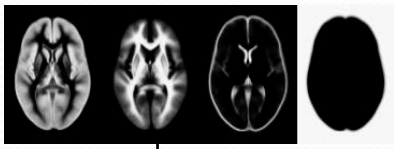
fMRI time-series



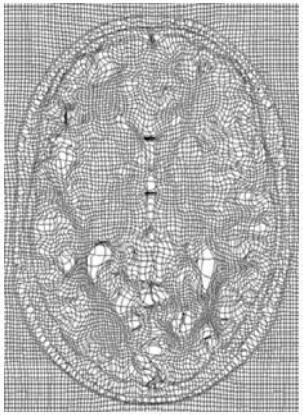
Motion Correct



Template

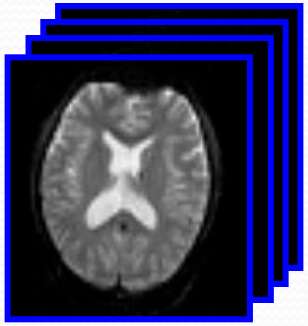


Estimate Spatial Norm

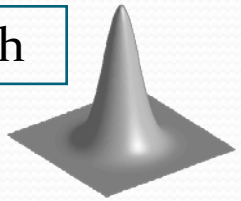


Deformation

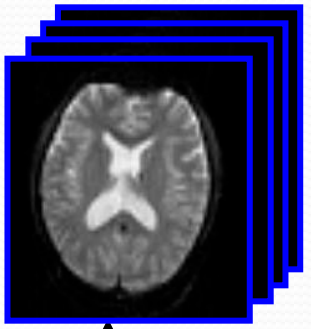
Spatially normalised



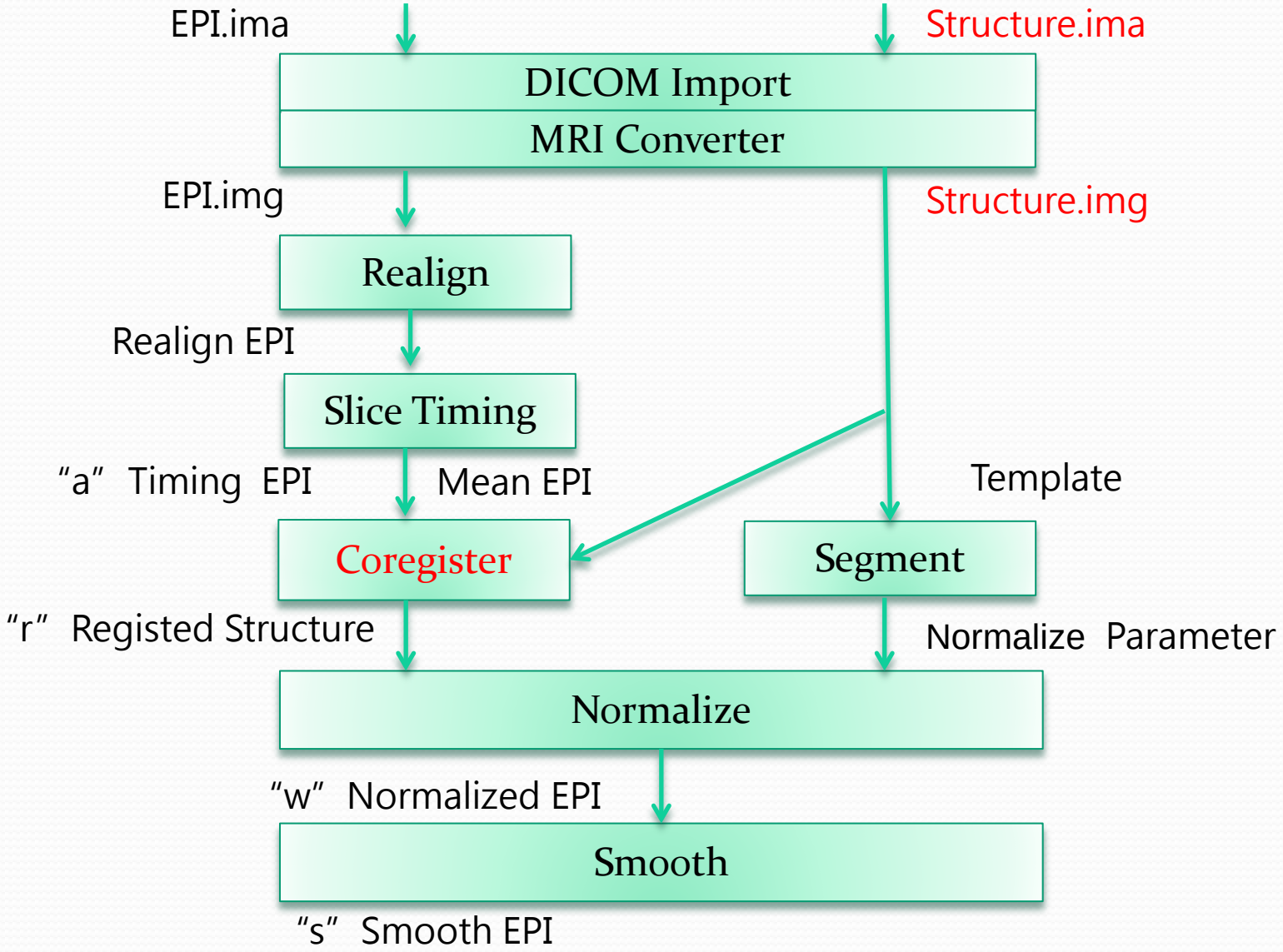
Smooth



Smoothed



Flowchart


EPI.ima
Structure.ima
DICOM Import
MRI Converter
EPI.img
Structure.img
Realign
Realign EPI
Slice Timing
"a" Timing EPI
Mean EPI
Template
Coregister
Segment
"r" Registed Structure
Normalize Parameter
Normalize
"w" Normalized EPI
Smooth
"s" Smooth EPI