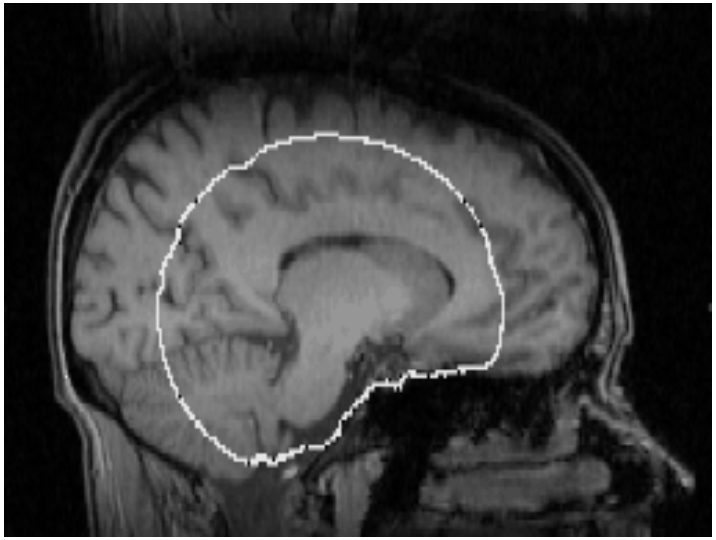
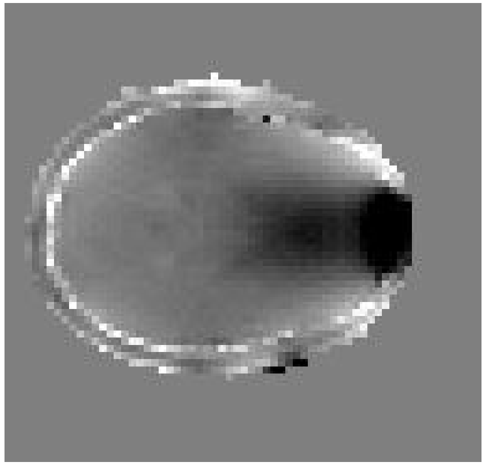
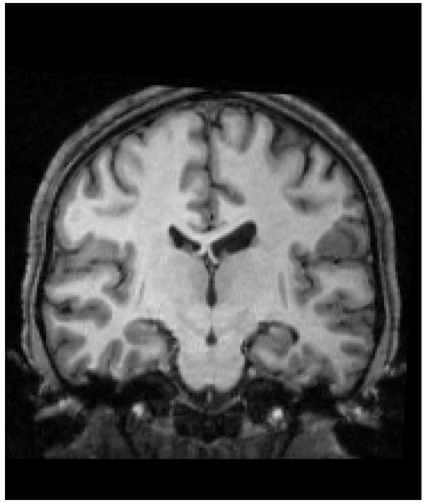
Brain Extraction, Registration & EPI Distortion Correction

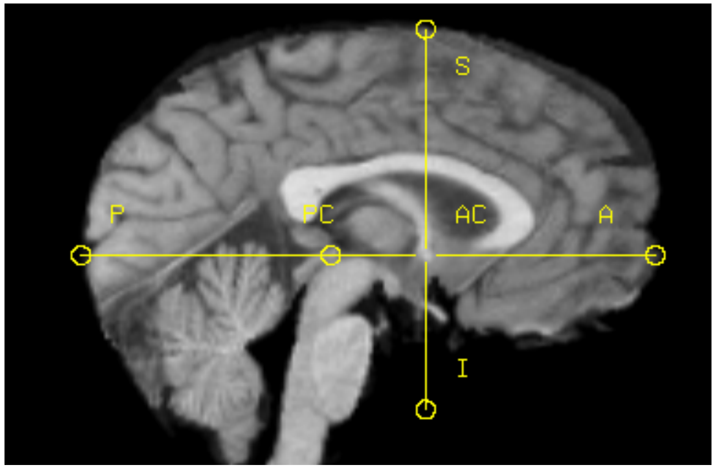
大脑提取，配准&EPI变形矫正

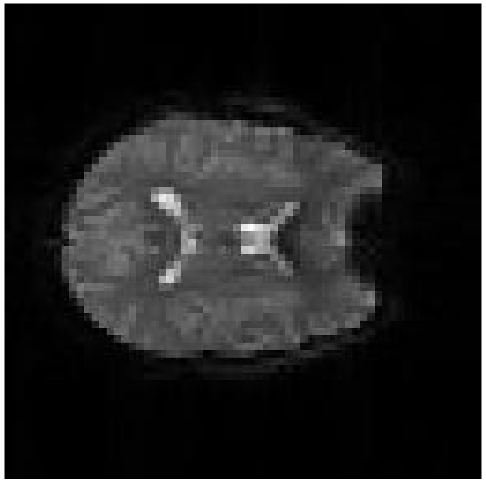
中文翻译：钟嘉慧 孔亚卓

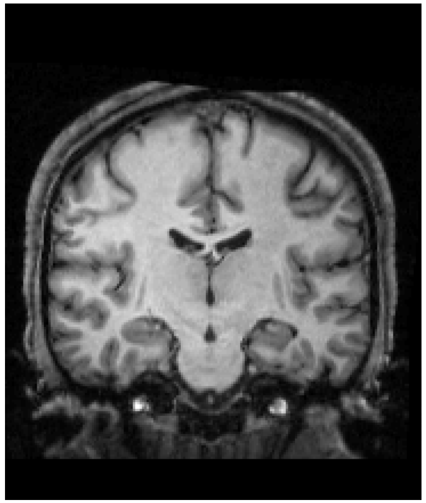












What use is Registration?

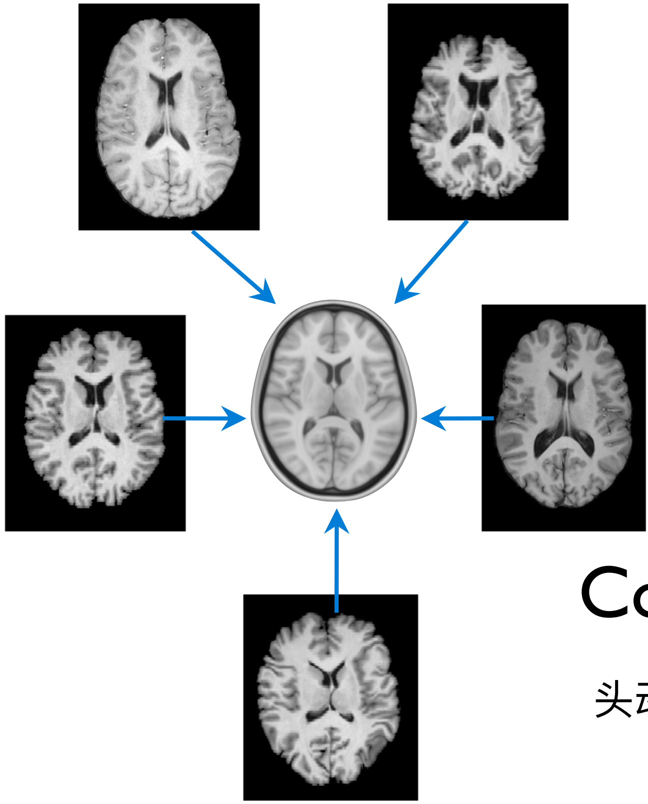
配准的作用

Some common uses of registration:

一些常见的配准用途:

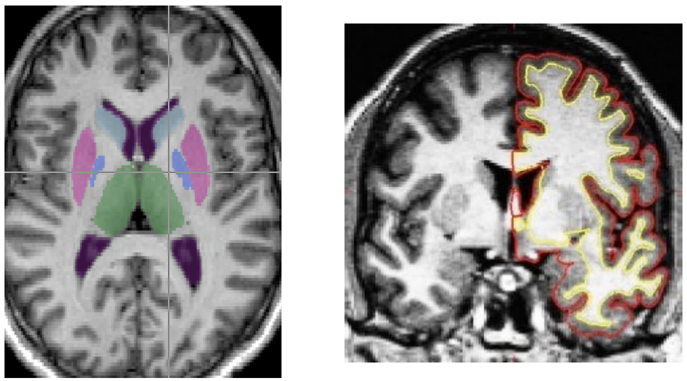
Combining across individuals in group studies: including fMRI & diffusion

在组研究中将个体结合起来：包括fMRI和弥散MRI



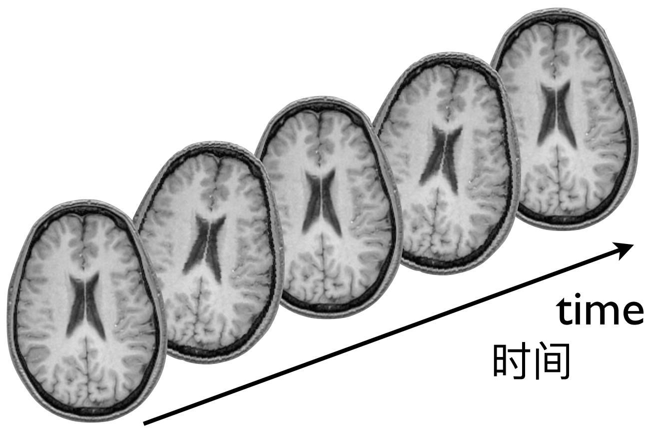
Quantifying structural change

量化结构变化



Correcting for motion

头动矫正



Overview 概述

- Brain Extraction (BET) 大脑提取（BET）
- Registration concepts (FLIRT & FNIRT) 配准概念(FLIRT & FNIRT)
- Practical applications (FLIRT & FNIRT) 实际应用(FLIRT & FNIRT)
  - Single-stage registration 单步配准
  - Multi-stage registrations 多步配准
  - EPI distortion correction EPI变形矫正
  - Pathological image registration 病理异常图像配准

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BET: Brain Extraction Tool

BET:大脑提取工具

Brain / non-brain segmentation

进行大脑/非大脑组织分割

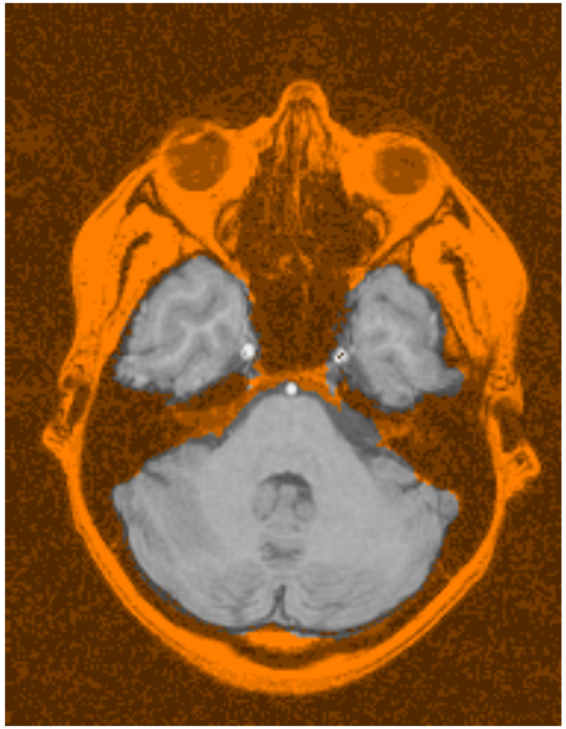
Preparation step for registration and segmentation

配准和分割的预处理步骤

Eliminates non-brain tissues with highly variable contrast and geometry (e.g. scalp, marrow, etc.)

- works best if some fat sat is used

消除对比和几何结构高度变化的非脑组织（如头皮、骨髓等），如果使用一些脂肪饱和带设置，效果会最好



S.M. Smith; Fast robust automated brain extraction; HBM 17(3), 2002.

Robust to bias fields (by using local intensity changes)

不受偏置场的影响（通过使用局部强度变化）

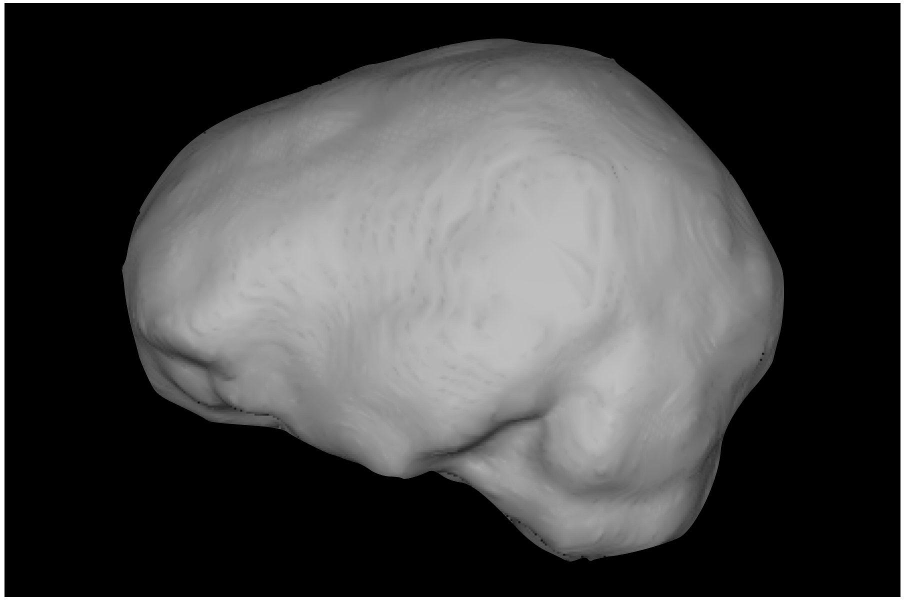
Works with a wide range of MRI sequences (T1, T2, etc.) and resolutions

适用于多种MRI序列（T1、T2等）和分辨率

Example Results 示例结果

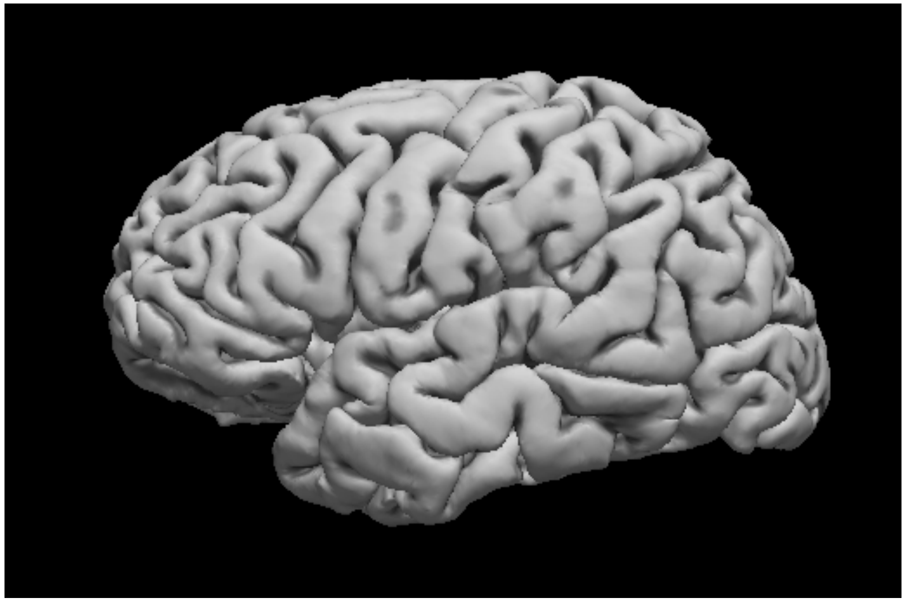
Brain Surface Model

大脑表面模型



Extracted Brain Surface
(not what we aim for here)

提取的大脑表面（在此处不是我们的目标）



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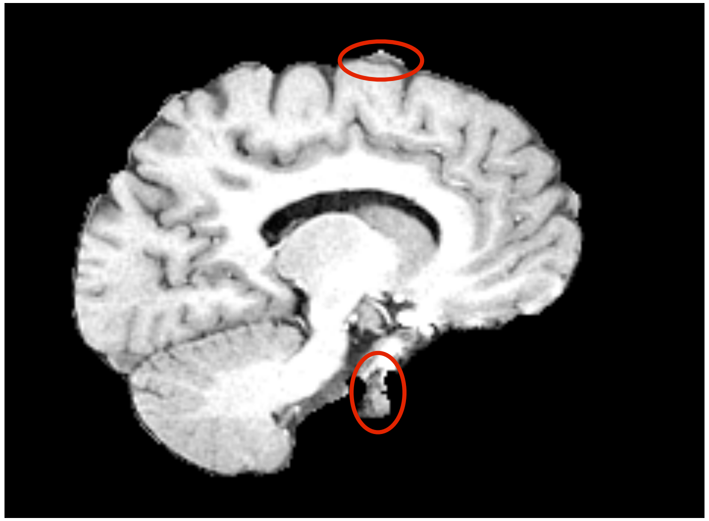
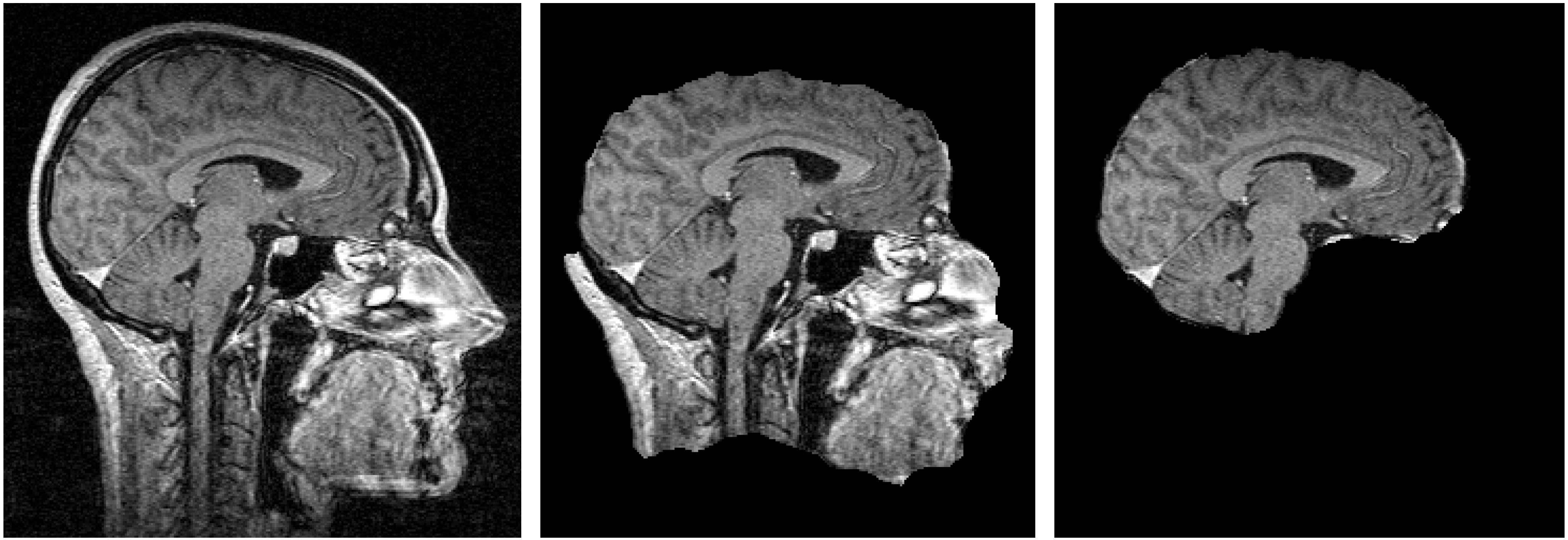


Want to remove the majority of non-brain structures, leaving all the brain intact. Leaving small pieces of non-brain is *unimportant for linear registration*, but it is important for segmentation.

想去掉大部分非大脑结构，让所有的大脑完好无损。
留下小块的非大脑区域对于线性配准并不重要，但对于分割很重要。



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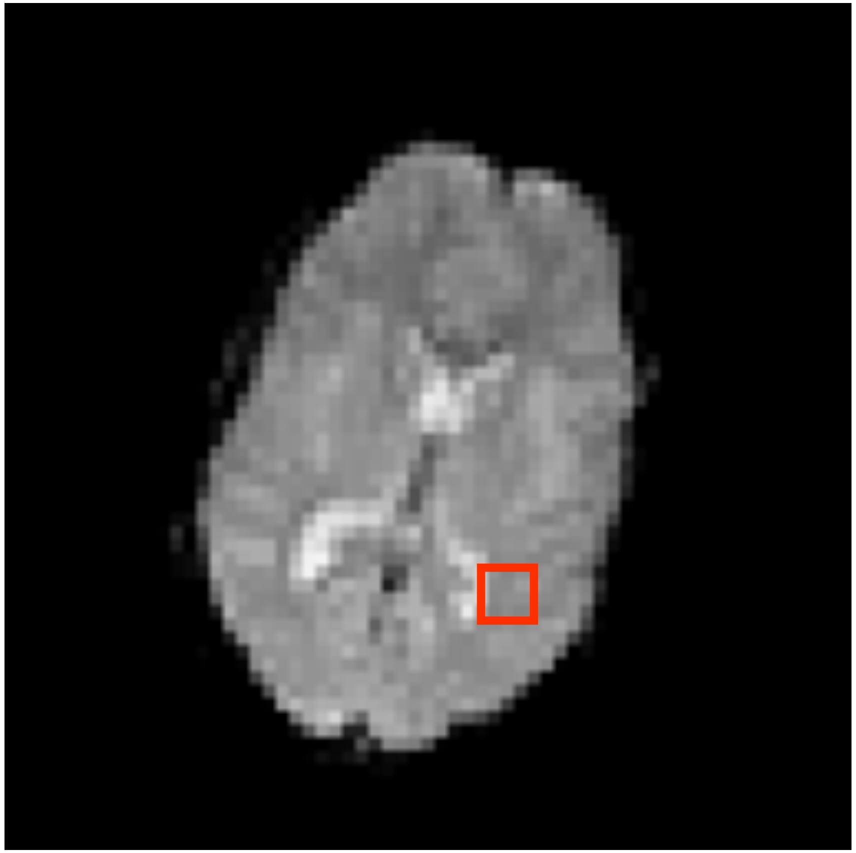
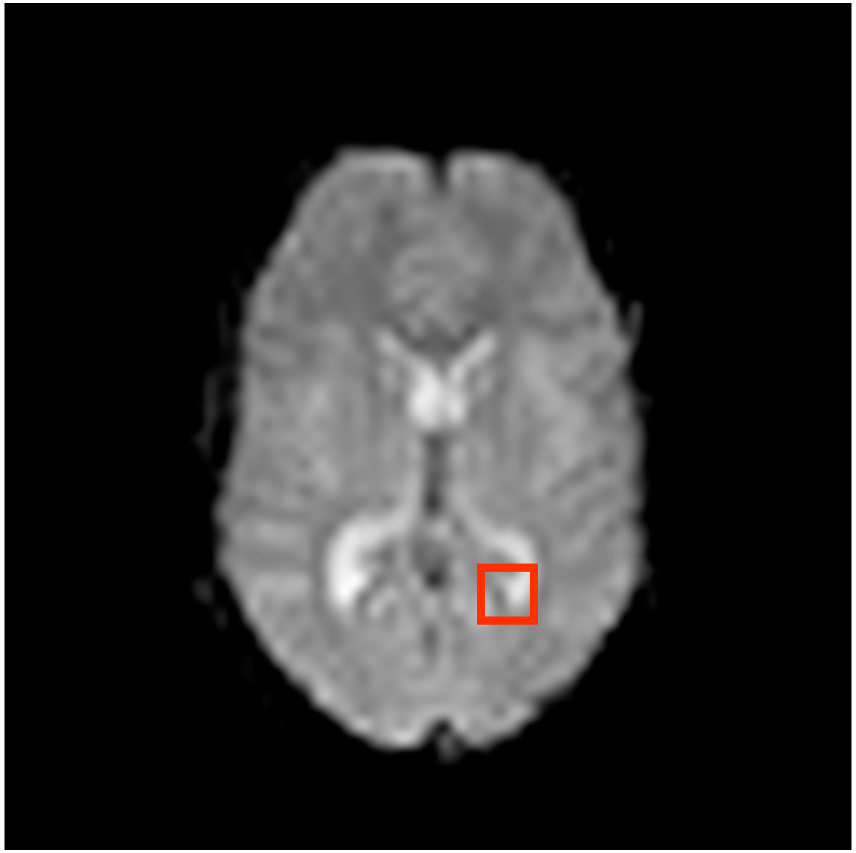
What is Registration?

什么是配准?



What is Registration?
什么是配准?

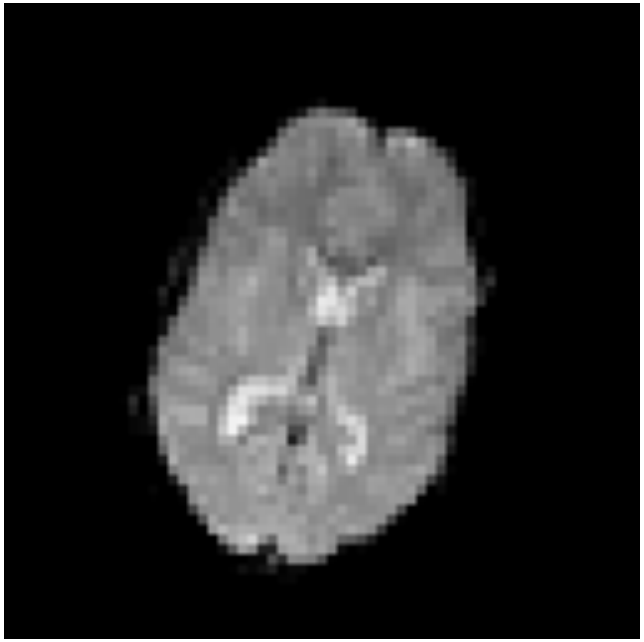


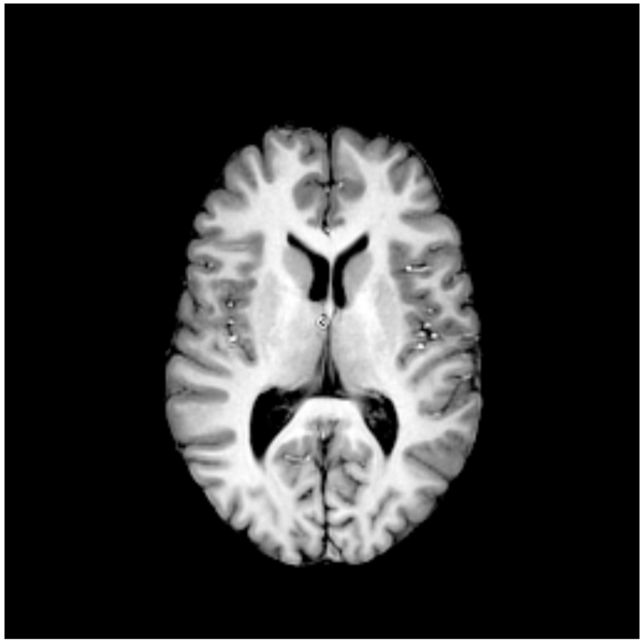
Voxel location = anatomical location
with accurate intensity values

体素位置 = 解剖位置
具有准确的强度值

Basic Registration Concepts

配准的基础概念





Need to understand : 需要明白以下概念:

- Image “spaces” 图像“空间”
- Spatial Transformations 空间变换
- Cost Functions 代价函数
- Interpolation 插值

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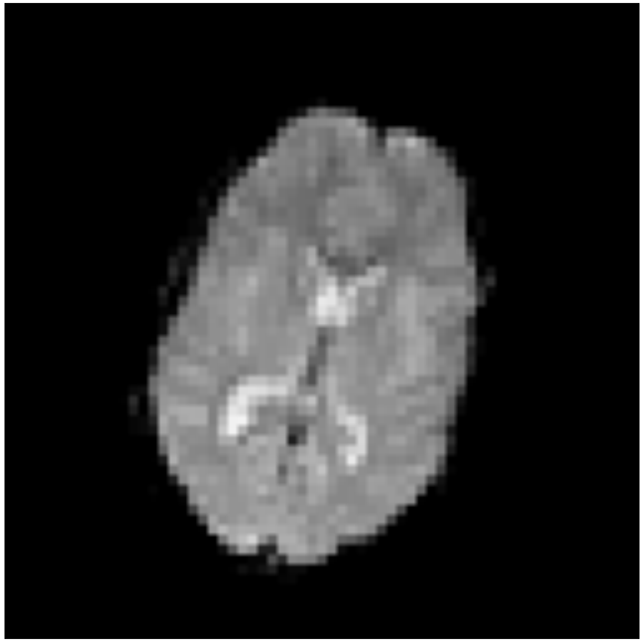

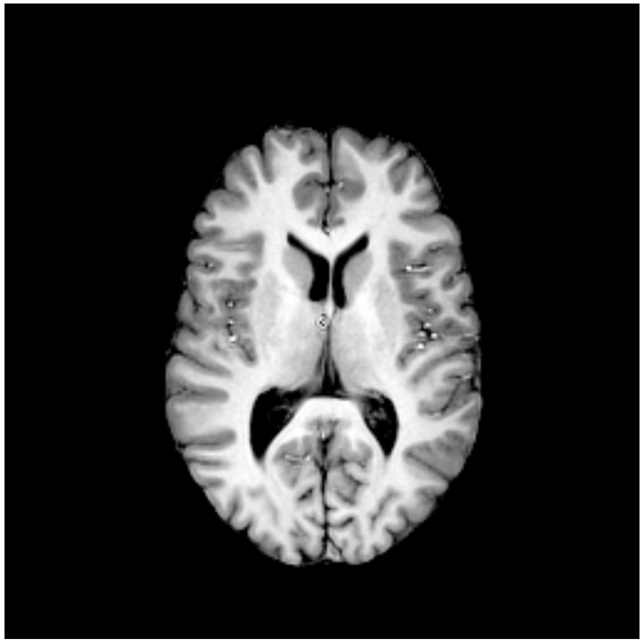

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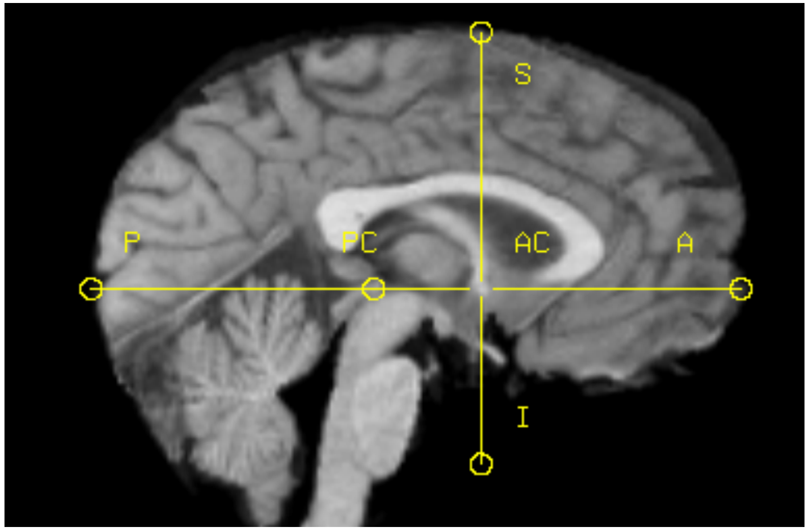
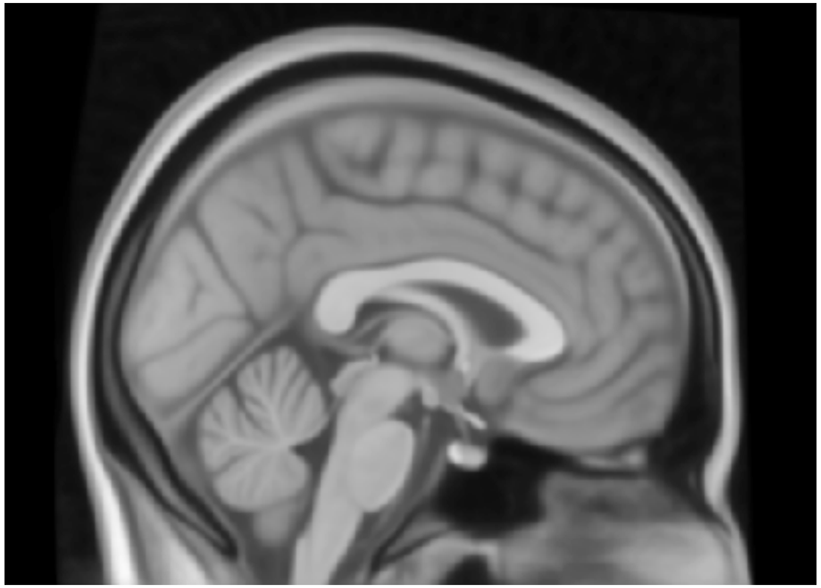
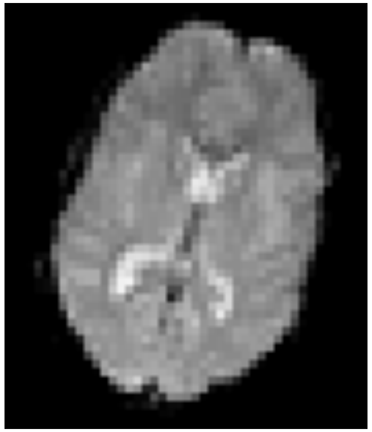
Standard Space 标准空间

- Common reference coordinate system for reporting/describing
  用于报告/描述的公共参考坐标系
- Register all members of a group to this space for group studies
  将所有被试配准到此空间以进行组研究
- Original Talairach & Tournoux coords based on one post-mortem brain
  原始的Talairach和Tournoux坐标基于一个解剖大脑
- Now use standard images based on non-linear group average (MNI152)
  使用基于非线性组平均值的标准图像（MNI152）
- MNI is not quite Talairach
  MNI不是Talairach

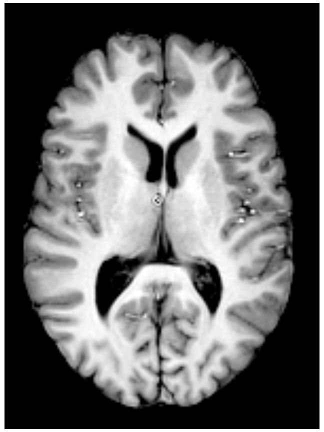




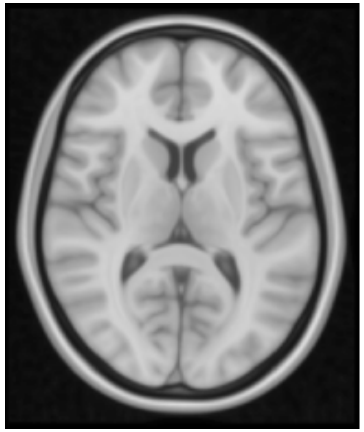
Other “Spaces” 其他“空间”



FMRI
功能MRI



Structural
结构MRI



Standard
标准

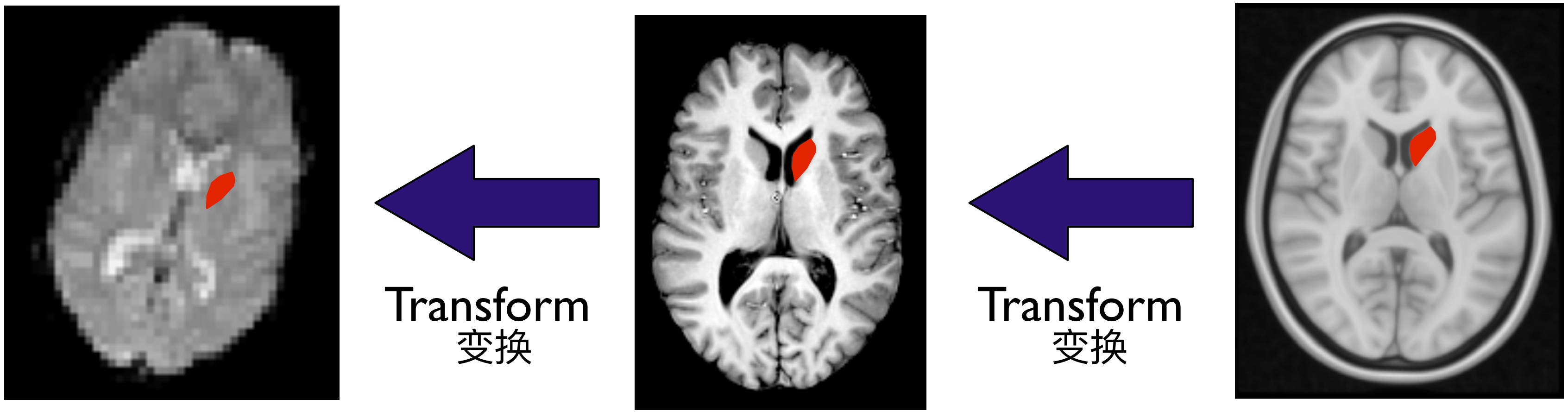
- All images in the same “space” are aligned 所有在同一“空间”内的图像都被对齐

- Different images → different “spaces” 不同图像→不同“空间”
  e.g. standard space, structural space, functional space 如标准空间，结构空间，功能空间

- Can have different resolution images in the same space
  在同一空间内可以有不同像素的图像
  e.g. 1mm and 2mm versions of standard space images 如1mm和2mm版本的标准空间图像

- Want to move image-related info between spaces
  想在不同空间之间移动与图像相关的信息
  e.g. a mask from standard space to structural space 如将掩板从标准空间移动到结构空间

Other “Spaces” 其他“空间”



- Need to *registration between spaces* (via images) and get the transformations before transforming/moving/resampling any image-related info (like masks or atlas ROIs)
  需要(通过图像)在不同空间之间进行配准并在变换/移动/重采样任何图像相关信息(如掩板或感兴趣区图集)之前进行变换
- Can have versions of the same “image” (e.g. a mask) in several different spaces
  可以在几个不同的空间中得到同一“图像”（如掩板）的不同版本
- FSL tools (e.g. FEAT) often move things between spaces
  FSL工具(如FEAT) 经常在不同空间之间移动图像

Other "Spaces" 其他"空间"

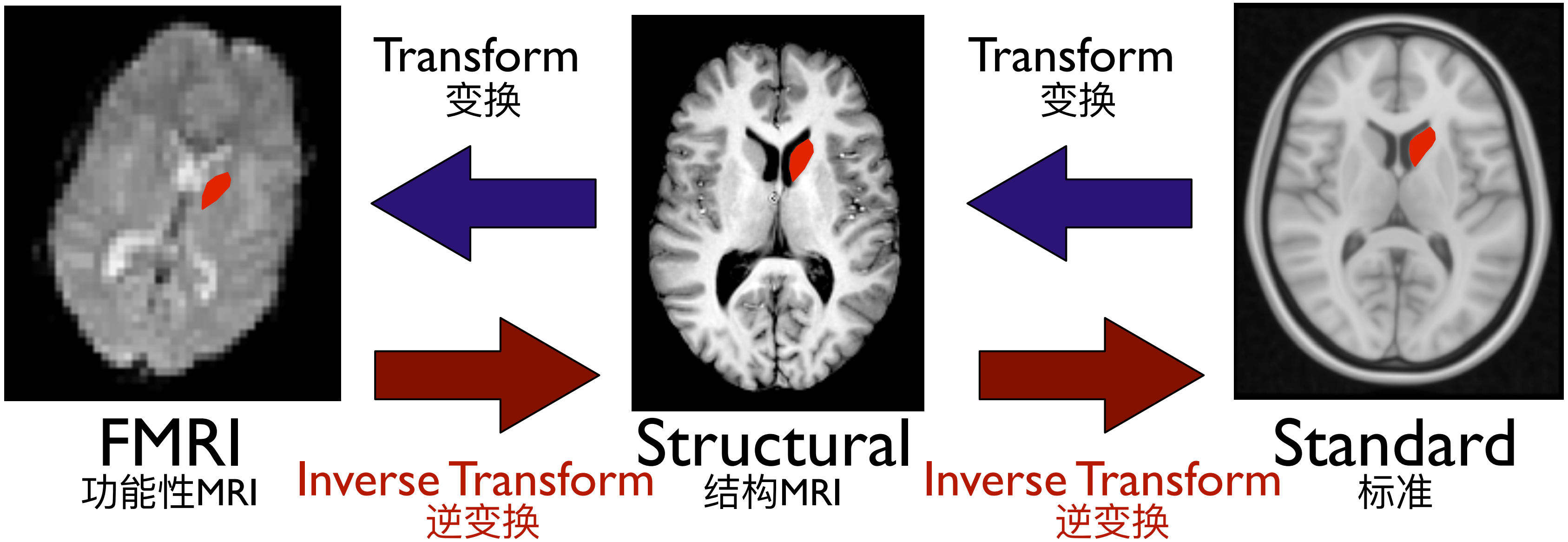


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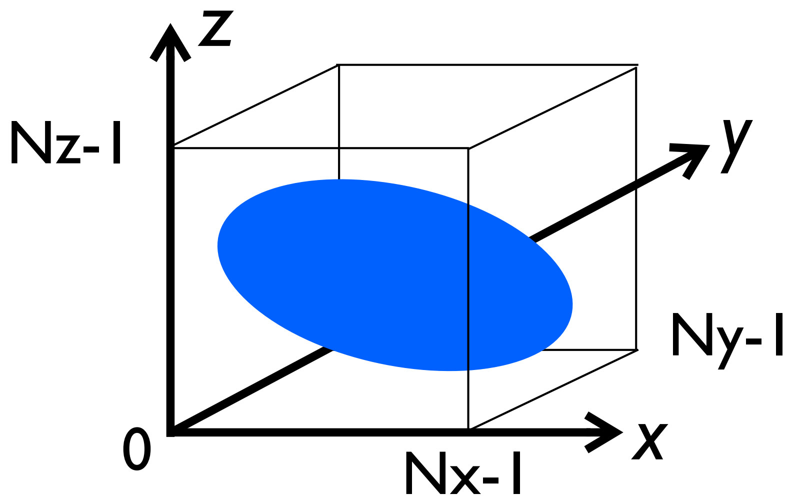
Image (Voxel) Coordinates 图像(体素)坐标

Confusingly, there are many types of coordinates 坐标有很多种，易混淆

Voxel coordinates in FSL:

- Integers between 0 and N-1 inclusive
- Refer to the whole voxel
- Origin in the lower-left corner: (0,0,0)

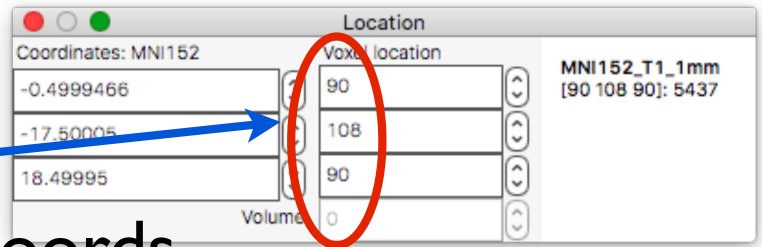
FSL中的体素坐标：包括0到N-1之间的整数，参考整个体素，原点位于左下角(0,0,0)



Axes are not aligned with the anatomy

Cannot distinguish left from right by voxel coordinate values

坐标轴不与解剖结构对齐，无法通过体素坐标值区分左右



FSLeyes reports these

Used by FSL commands & same as NIfTI coords

FSLeyes能够报告这些值，可通过FSL命令使用，与NIfTI坐标值一样

Standard Space Coordinates 标准空间坐标

Standard Space coordinates in FSL: FSL中的标准空间坐标：

Real numbers, in units of *mm* 实数，单位为*mm*

Origin (0,0,0) near centre of image 原点(0,0,0)靠近图像中心

(anatomical landmark; e.g. anterior commisure) (解剖标志，如前连合)

Axes aligned with anatomy (left and right specified)

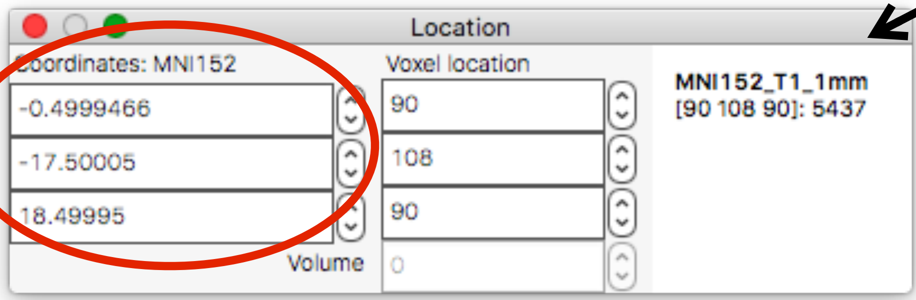
坐标轴与结构学对齐（左右指定）

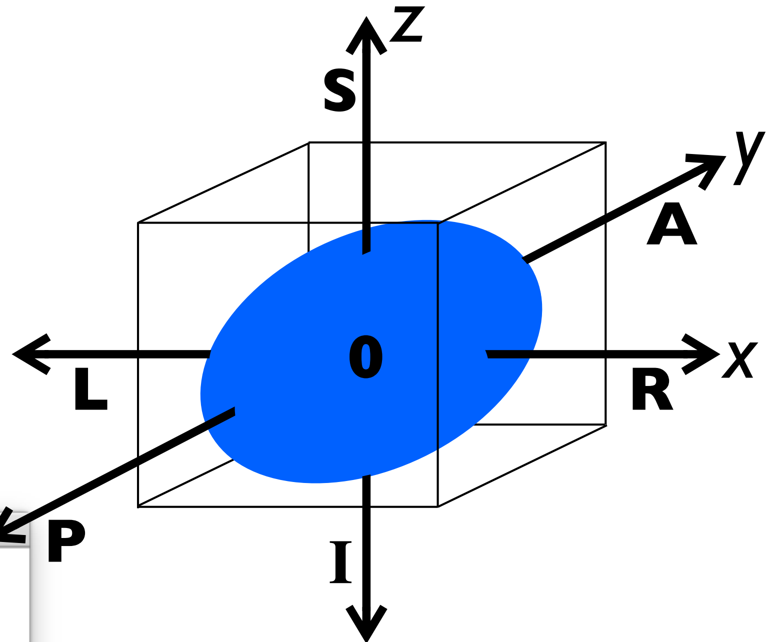
Several standard spaces exist:MNI, Talairach, BrainWeb, etc

有多种标准空间：MNI,Talairach, BrainWeb等

FSLeyes also reports these *when possible*

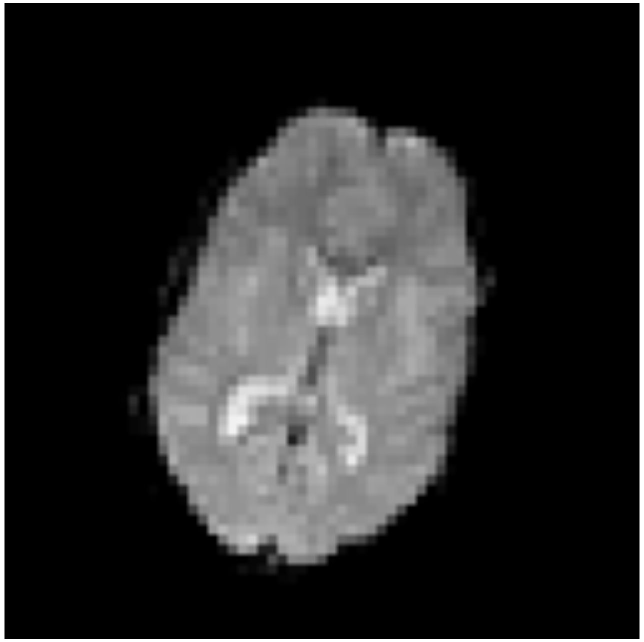
*FSLeyes*还会尽可能报告这些值

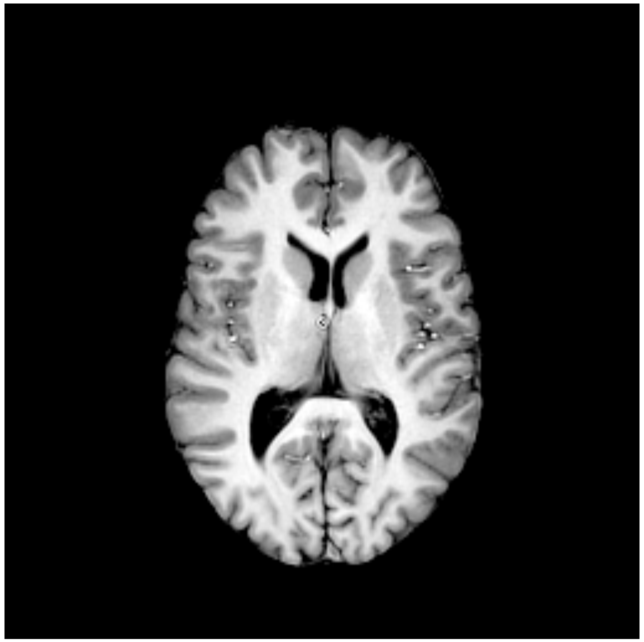




Basic Registration Concepts

配准的基础概念





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Spatial Transformations 空间变换

To align images must transform them

必须先对图像进行变换才能将它们进行对齐

Many types of transformation

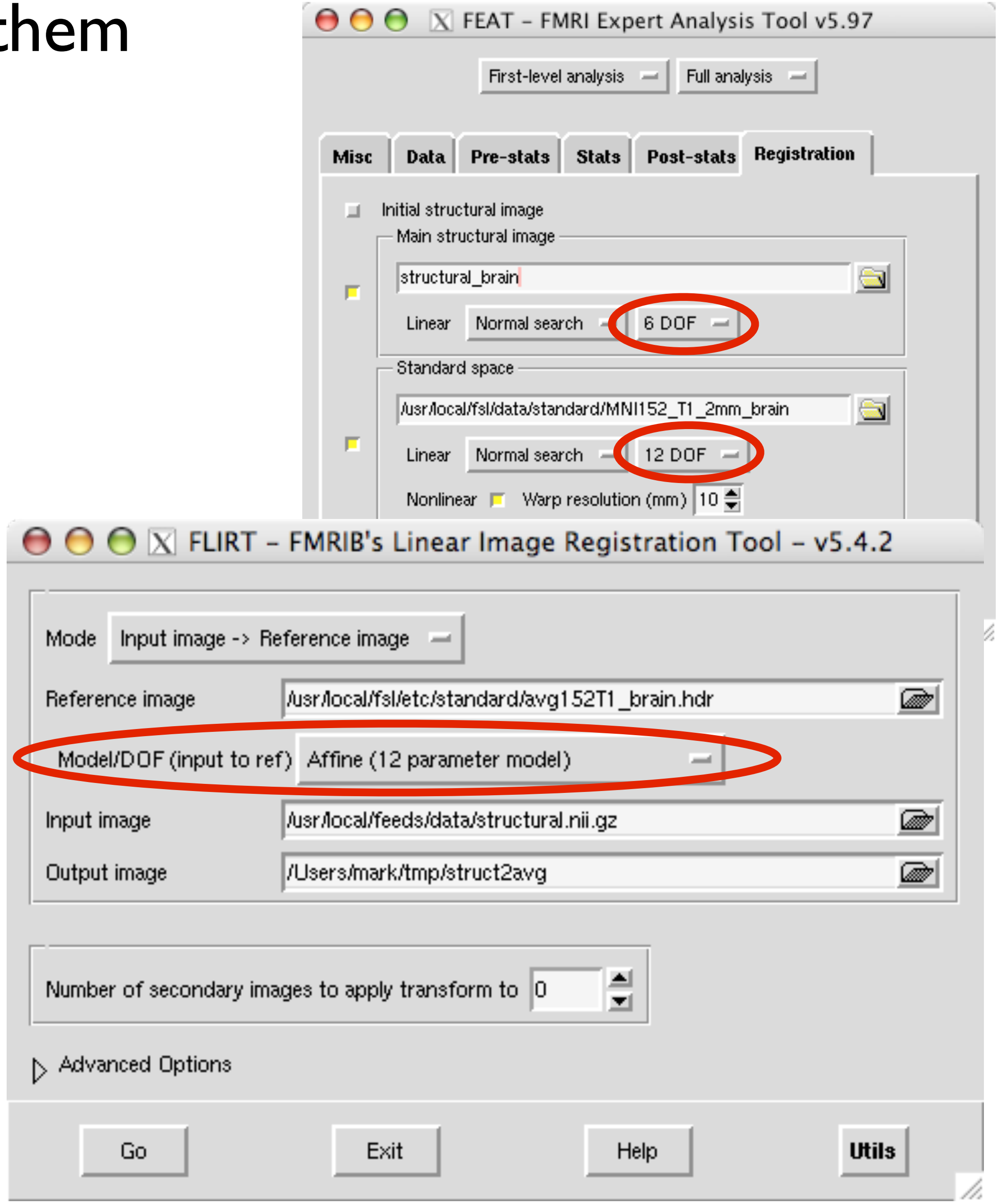
有多种变换的形式

Degrees of Freedom (DOF) partially describe transform

自由度(DOF)可部分描述变换

Examples: 例如：

- Rigid Body (6 DOF) 刚体(6自由度)
- Affine (12 DOF) 仿射(12自由度)
- Non-linear (12 - millions DOF)
  非线性（1200万自由度）

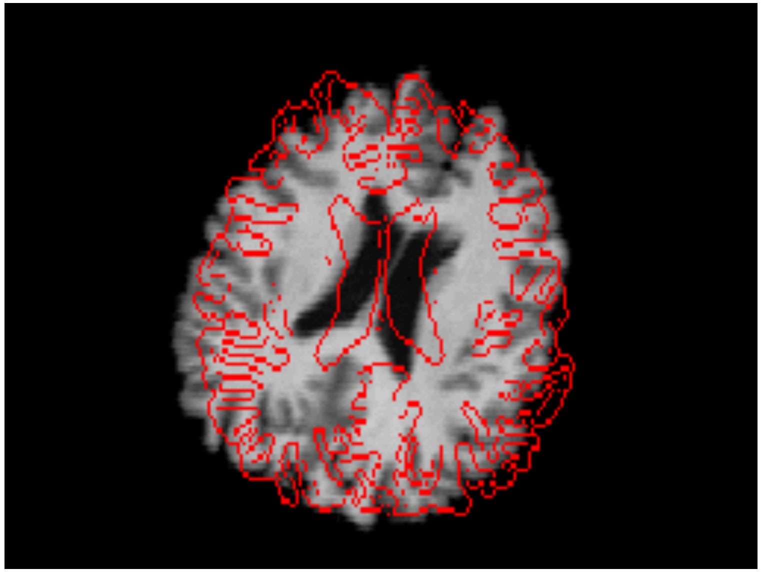


Rigid-Body Transformations 刚体变换

6 DOF in 3D 三维中的6自由度

Includes: 包括:

- 3 Rotations 3个转动



Rigid-Body Transformations 刚体变换

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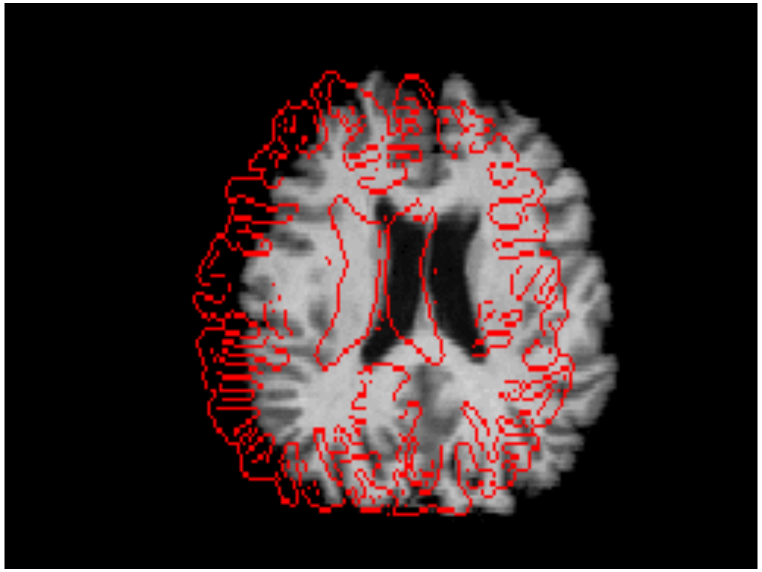
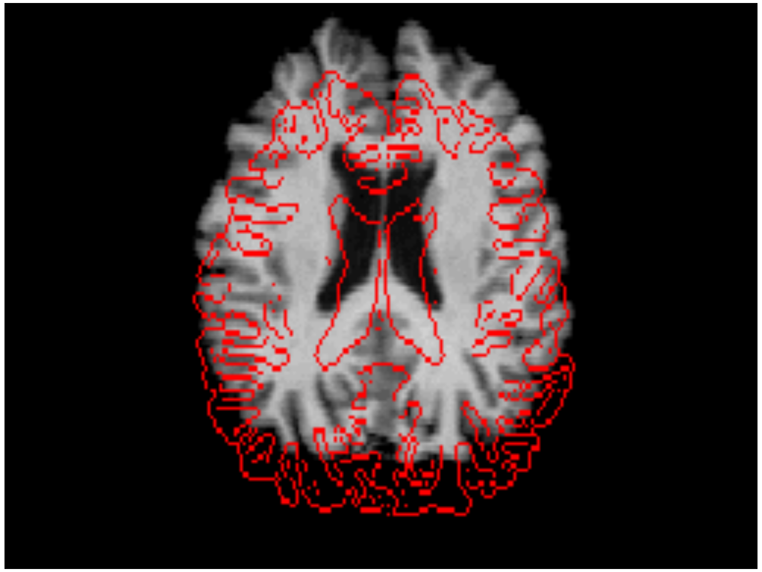


3 Translations 3平动



Used for **within-subject** registrations

用于被试内配准

Affine Transformations 仿射变换

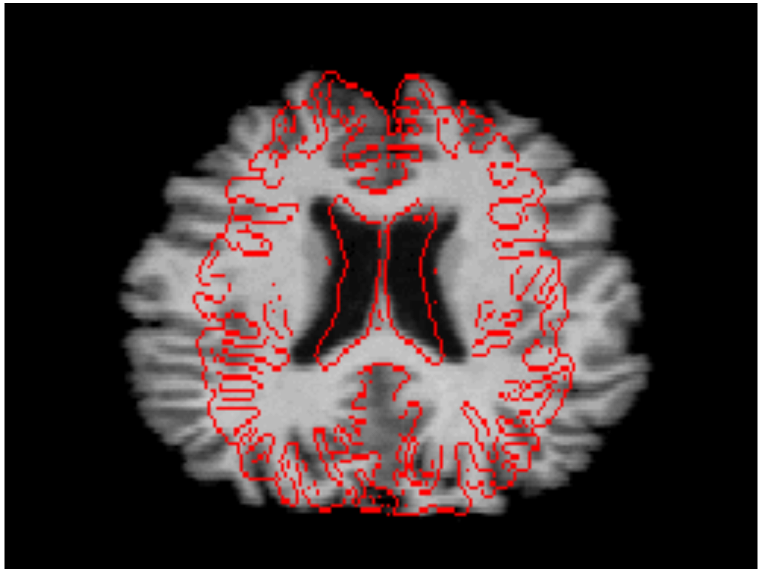
12 DOF in 3D

三维中的12自由度

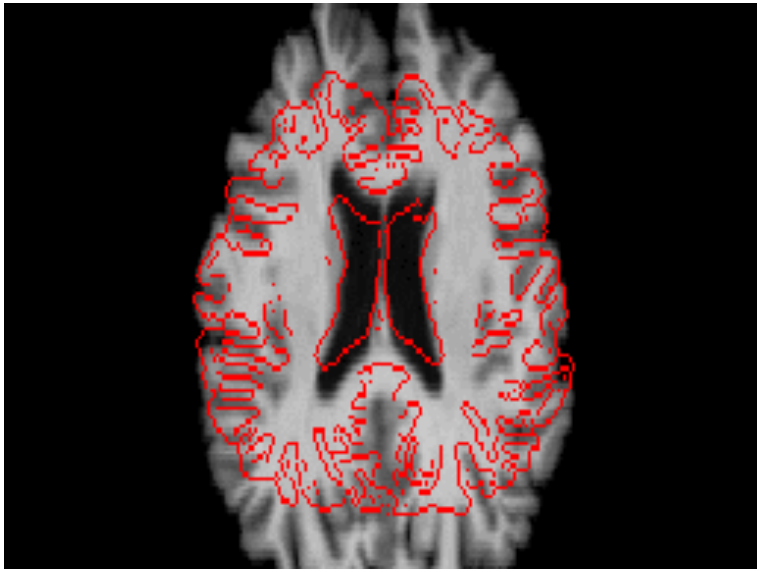
Linear Transf. 线性变换

Includes: 包括

- 3 Rotations 3转动
- 3 Translations 3平动



3 Scalings 3缩放



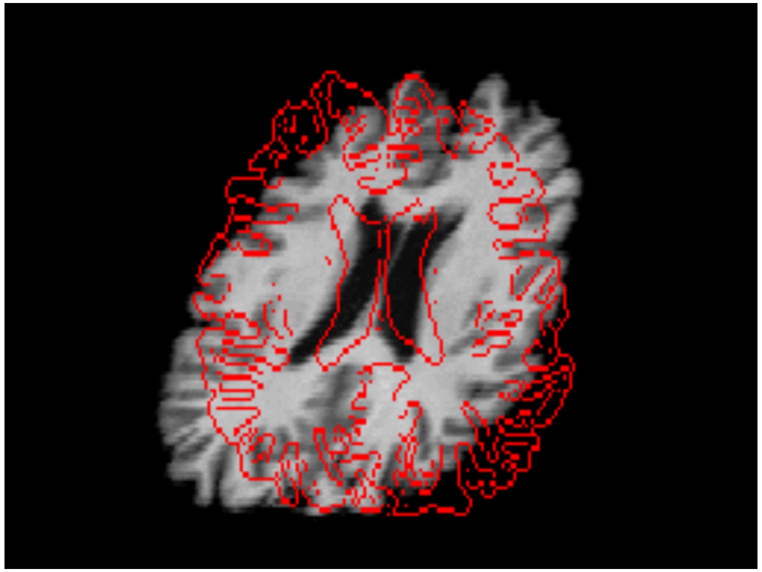
Affine Transformations 仿射变换

12 DOF in 3D 三维中的12自由度

Linear Transf. 线性变换

Includes: 包括

– 3 Rotations 3转动
– 3 Translations 3平动



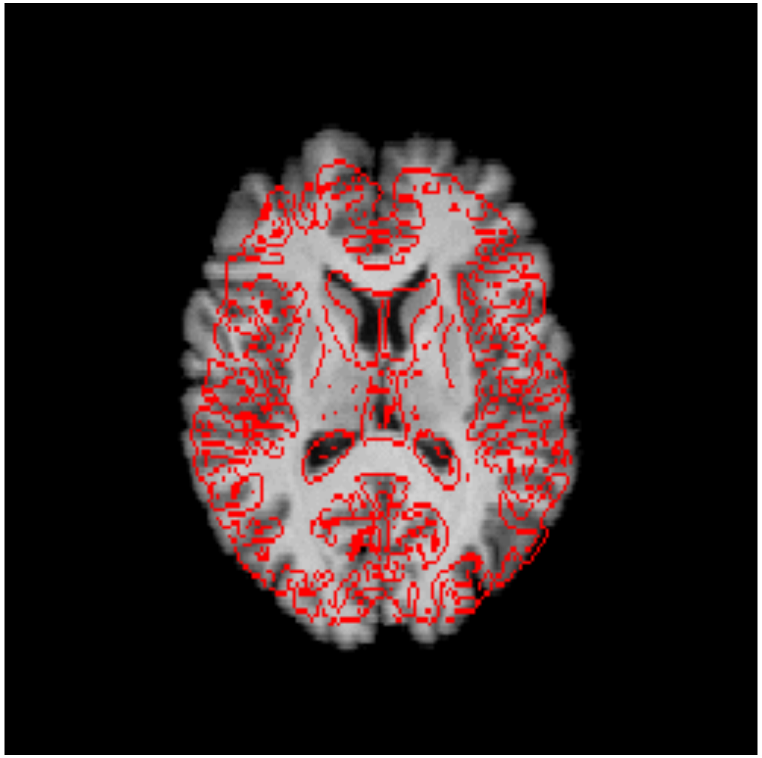
– 3 Scalings 3缩放

3 Skews/Shears 3偏斜/剪切

Used for eddy current correction
and initialising non-linear registration
用于涡流校正以及初始化非线性配准

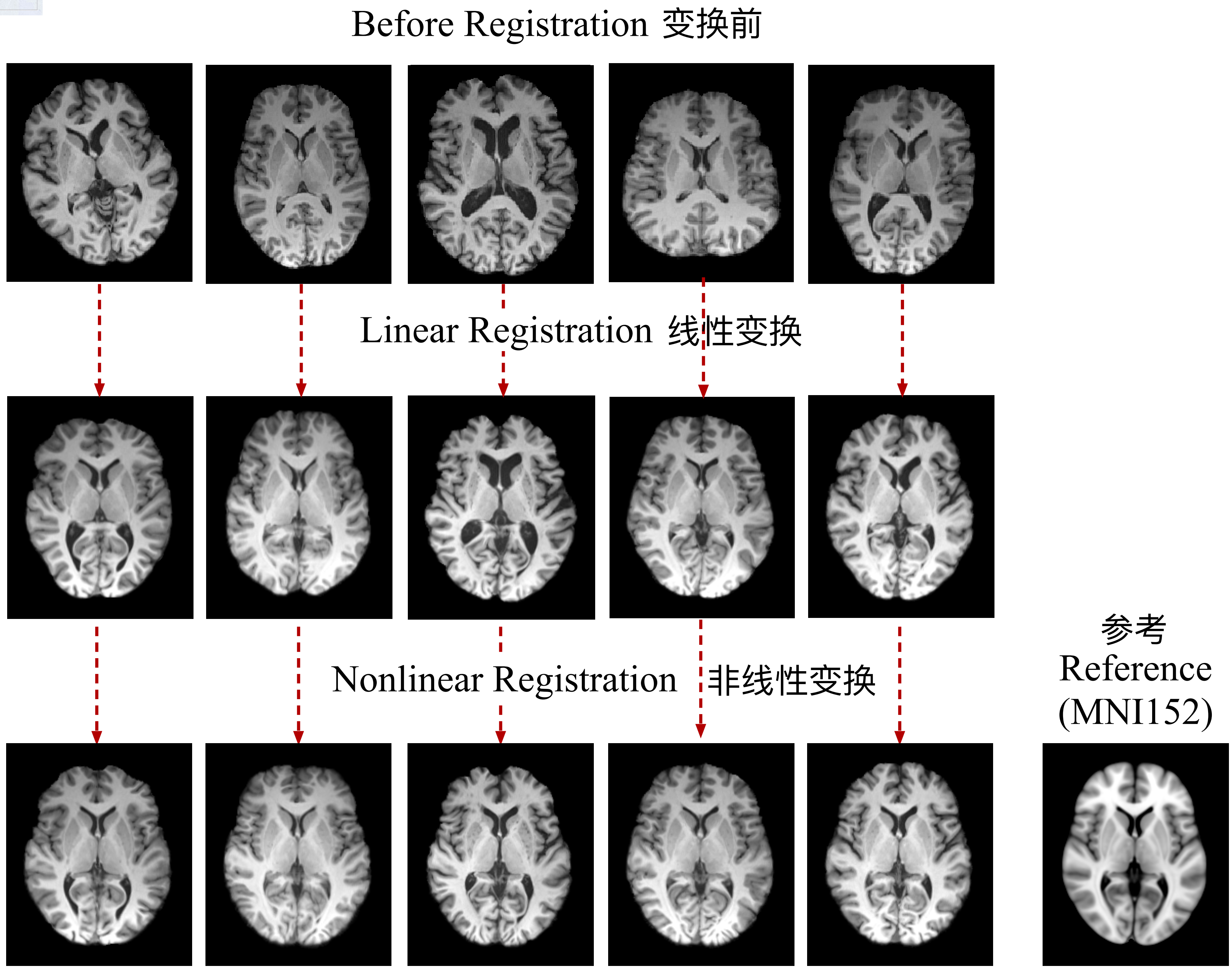
Non-Linear Transformations 非线性变换

More than 12 DOF 多于12自由度
Can be purely local 可以是纯局部的
Subject to constraints: 受以下限制：
- Basis Functions 基函数
  - e.g. B-Splines 如B样条函数
- Regularisation 正则化
- Topology-preservation 拓扑保持特性



Used for good quality **between-subject** registrations
用于高质量的被试间配准

Non-Linear Transformations 非线性变换



What transform/DOF do I use?

如何选择变换/自由度

Rigid body (6 DOF) 刚体(6自由度)

- within-subject motion 被试内运动

Non-linear (lots of DOF!) 非线性(多自由度)

- high-quality image (resolution, contrast) & same modality of reference/ template 高质量图像(分辨率,对比)&相同的参考/模板形式
- better with a non-linear template (e.g. MNI152_T1_2mm) 最好使用非线性模板(如MNI152_T1_2mm)

Affine (12 DOF) 仿射(12自由度)

- needed as a starting point for non-linear 非线性变换中需要它作为起点
- align to affine template, or using lower quality images, or eddy current correction 对齐仿射模板，图像质量较差，或用作涡流校正

Global scaling (7 DOF) 全局缩放(7自由度)

- within-subject but with global scaling (equal in x,y,z) 被试内变换，但在x,y,z上进行了相同的全局缩放
- corrects for scanner scaling drift in *longitudinal studies* 纵向研究中用于校正扫描仪的缩放漂移

More DOF is ***NOT*** always better (e.g. within-subject) 多的自由度不总是意味着更好(如被试内配准)

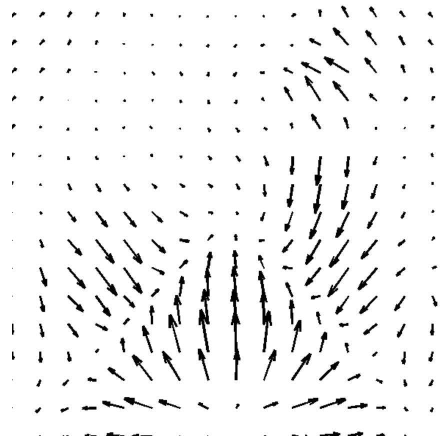
What do the transformations look like?

转换是什么样的

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

An affine transformation is represented by these 12 numbers.
This matrix multiplies coordinate vectors to define the transformed coordinates.

仿射变换由这12个数字来代表。
该矩阵将坐标向量相乘以定义转换后的坐标。



A non-linear transformation can be represented by a ***deformation field***.

非线性变换可用变形场来表示

Non-linear deformation 非线性变换

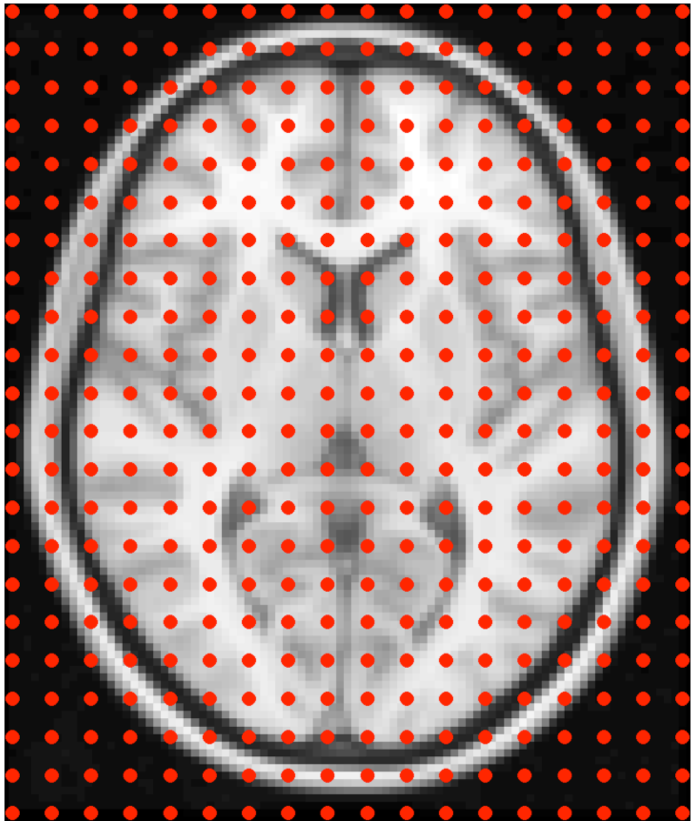
Regularisation, Warp Resolution and DOF

正则化，变形分辨率与自由度

Spacing of points =
warp resolution =
regularisation = DOF

点的间距=变形分辨率=正则化= DOF

- Various ways of controlling warp *smoothness*
  有多种控制变形平滑度的方法
- Less DOF = smoother
  较少的自由度=更平滑
- Lower warp resolution = smoother
  较低的变形分辨率=更平滑
- Higher regularisation = smoother
  更高的正则化=更平滑



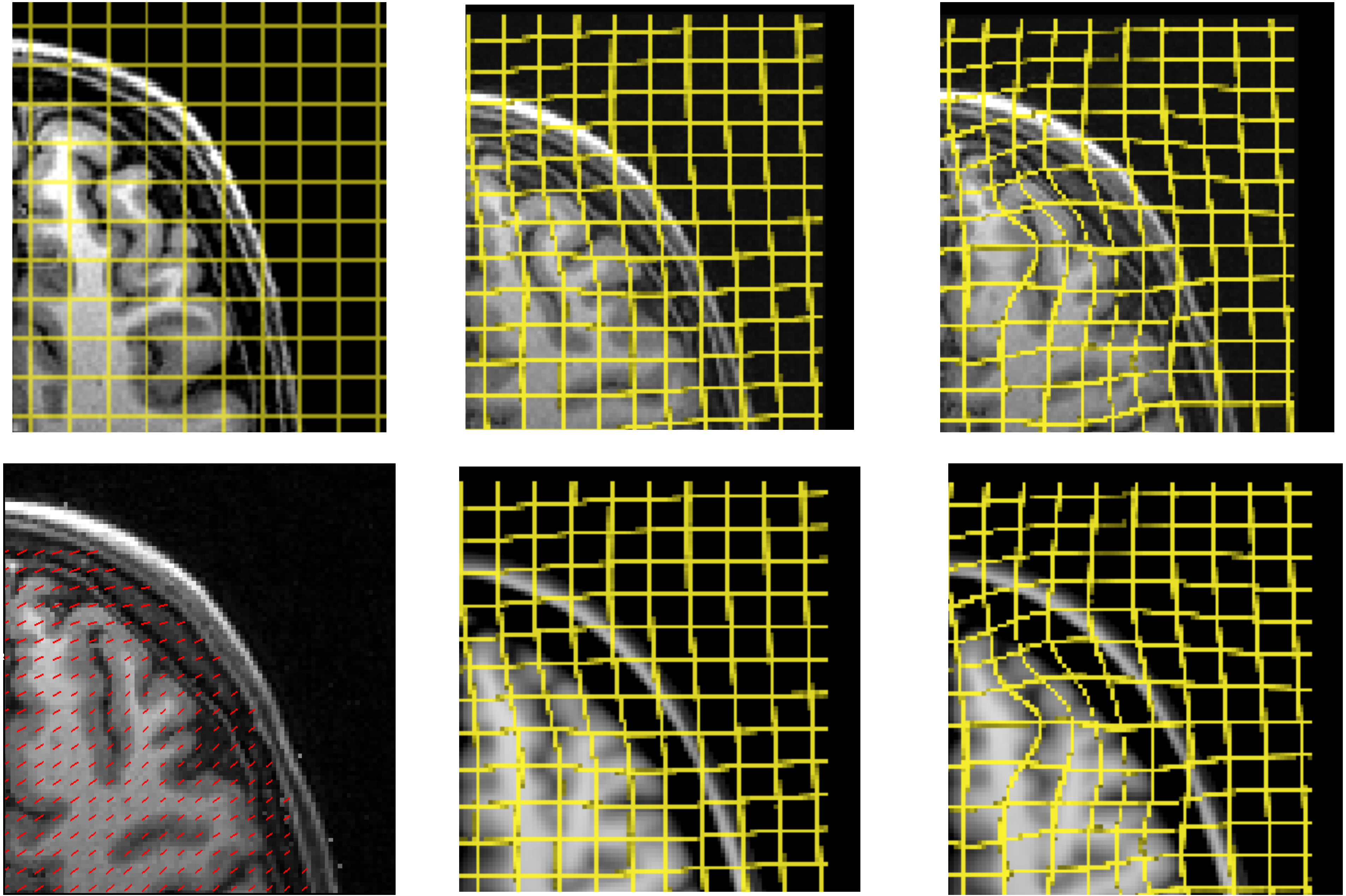
Non-linear deformation 非线性变换

High Regularisation
高正则化

Lower Regularisation
低正则化

Input
输入

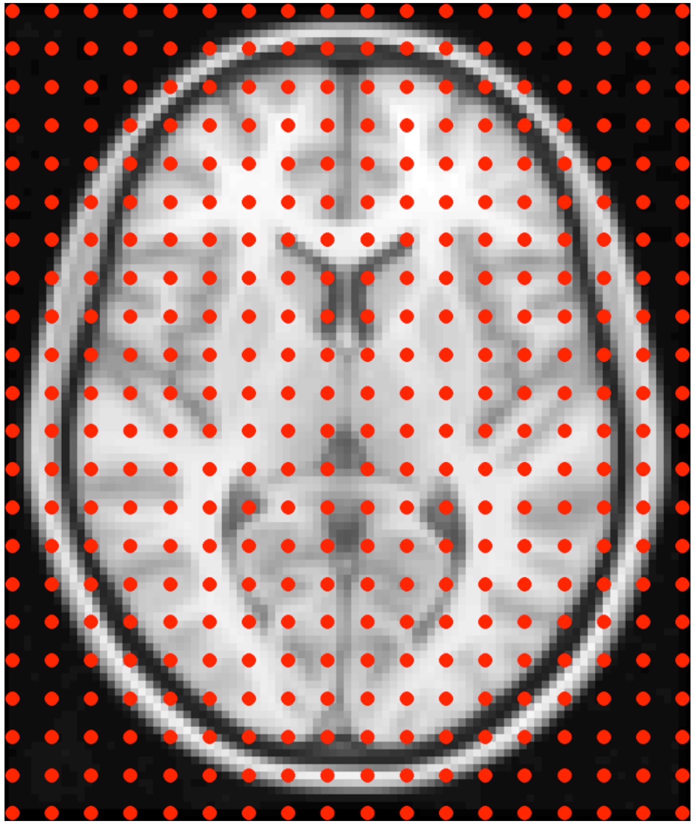
MNI



Non-linear deformation 非线性变换
Regularisation, Warp Resolution and DOF
正则化，变形分辨率与自由度

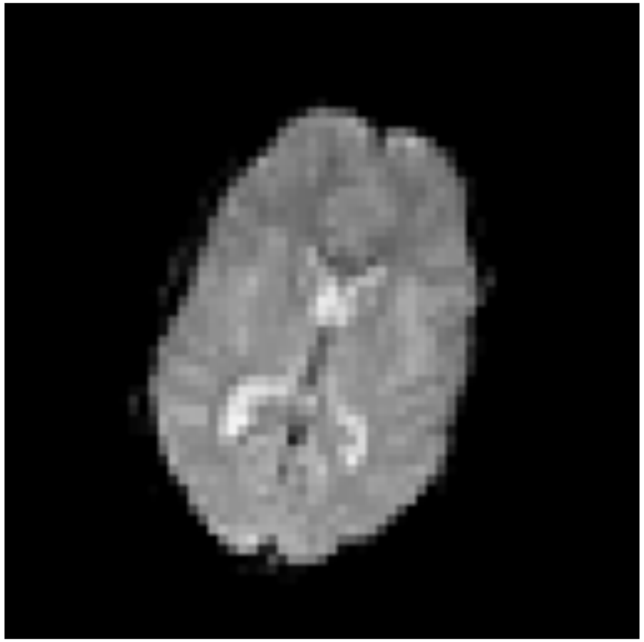
- Various ways of controlling warp *smoothness*
  有多种控制变形平滑度的方法
- Less DOF = smoother
  较少的自由度=更平滑
- Lower warp resolution = smoother
  较低的变形分辨率=更平滑
- Higher regularisation = smoother
  更高的正则化=更平滑
- Default warp resolution of 10mm is a good compromise for MNI152
  默认控制点间距（在配置文件中）为10mm，作为MNI152的良好折衷
- Between two subjects can use less smooth warps (less regularisation, higher warp resolution, more DOF)
  在两个被试之间可以使用不太平滑的变形（较少的正则化，较高的变形分辨率，更多的自由度）

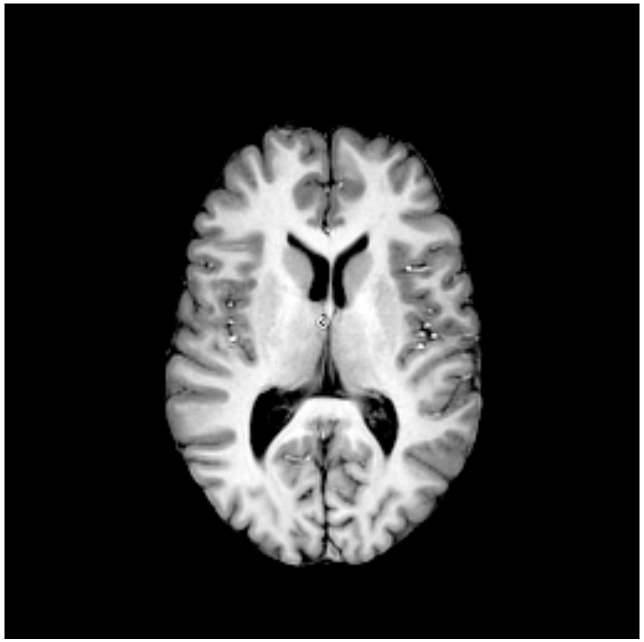
Spacing of points = warp resolution = regularisation = DOF
点的间距=变形分辨率=正则化= DOF



Basic Registration Concepts

配准的基础概念





Need to understand : 需要明白以下概念:

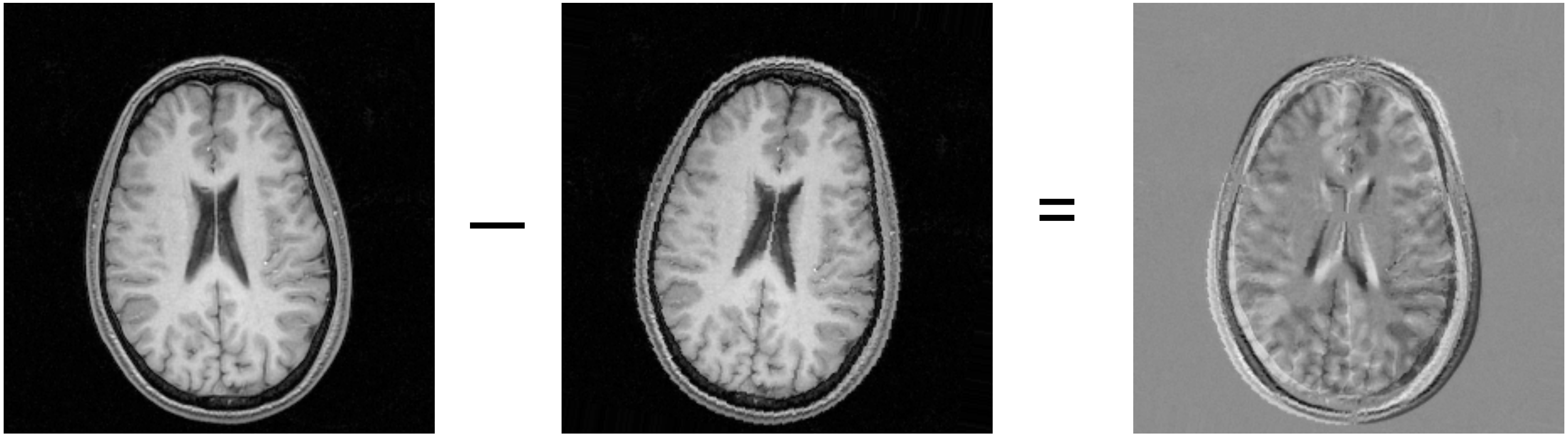
- Image “spaces” 图像“空间”
- Spatial Transformations 空间变换
- Cost Functions 代价函数
- Interpolation 插值

Cost Function 代价函数

Measures “goodness” of alignment 衡量对齐的“好坏”

Seek the minimum value 寻求最小值

Several main varieties 有几个主要变量



Similarity function is opposite (maximum sought)

相似函数与之相反（寻求最大值）

FLIRT: Cost Functions

FLIRT: 代价函数

FMRIB's	FMRIB的
Linear	线性
Image	图像
Registration	配准
Tool	工具

FLIRT: Cost Functions 代价函数

Important: Allowable image modalities 重要：允许的图像模式

Less important: Details 不太重要：细节

Least Squares 最小二乘	*Same modality* 相同模式 (exact sequence parameters 确切的序列参数)
Normalised Correlation 正态相关	*Same modality* 相同模式 (can change brightness & contrast) (可以改变亮度和对比)
Correlation Ratio 相关比	*Any MR modalities* 任何MR模式
Mutual Information 共同信息	*Any modalities* 任何模式 (including CT, PET, etc. 包括CE,PET等)
Least Squares 最小二乘	*Same modality* 相同模式 (exact sequence parameters) (确切的序列参数)
BBR 基于边界的配准	*Within-subject EPI to structural* (see later) 被试内EPI到结构

FNIRT: Cost Functions

FNIRT: 代价函数

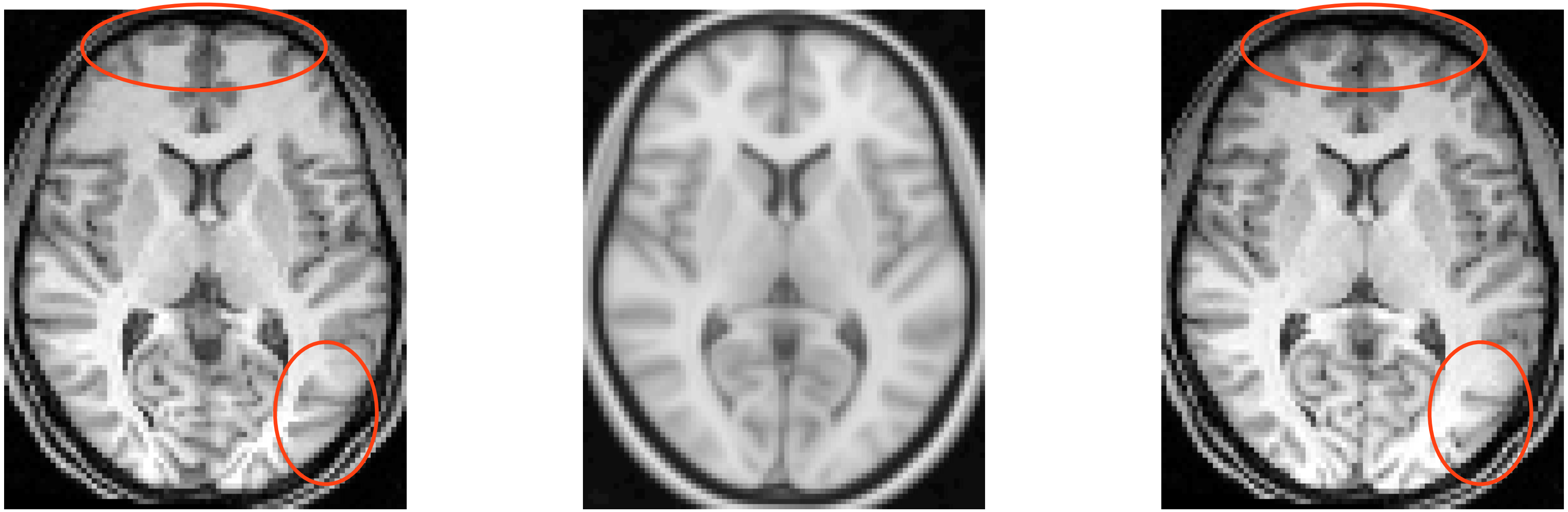
FMRIB's	FMRIB的
Non-Linear	非线性
Image	图像
Registration	配准
Tool	工具

FNIRT: Cost Functions

FNIRT: 代价函数

FNIRT: Cost Functions 代价函数

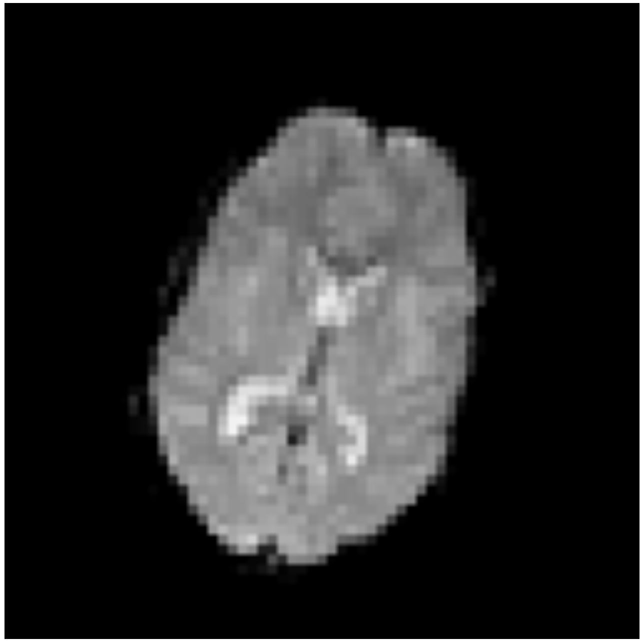
- *Only uses Least Squares* as cost function 仅使用最小二乘法作为代价函数
  so *images must be of the same modality/sequence* 图像必须具有相同模式/序列
- Also includes an explicit model for bias field (RF inhomog.)
  也引入了偏置场场（射频不均匀）的显式模型
- Estimate displacement field *and* RF bias field together 联合估计位移场和偏置场
- Options exist to control bias field (turn off/on, smoothness)
  存在用于控制“偏置场”的选项（关闭/打开、平滑度）

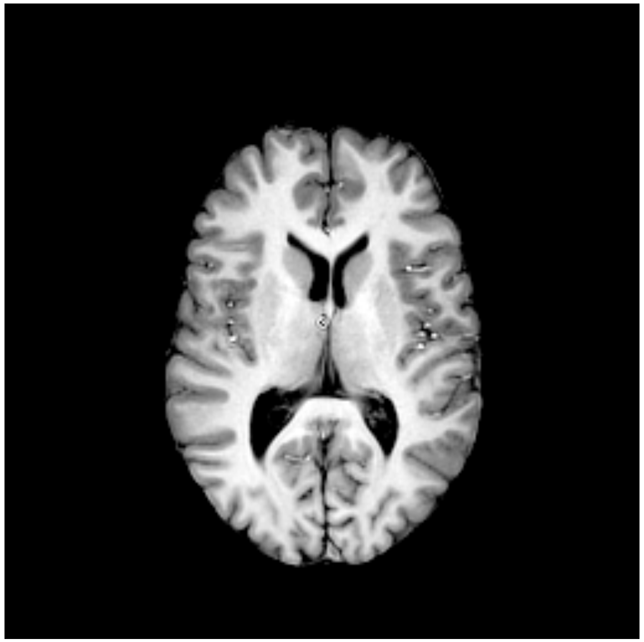


Without RF modelling 无射频建模 | Template 模板 | With RF modelling 有射频建模

Basic Registration Concepts

配准的基础概念





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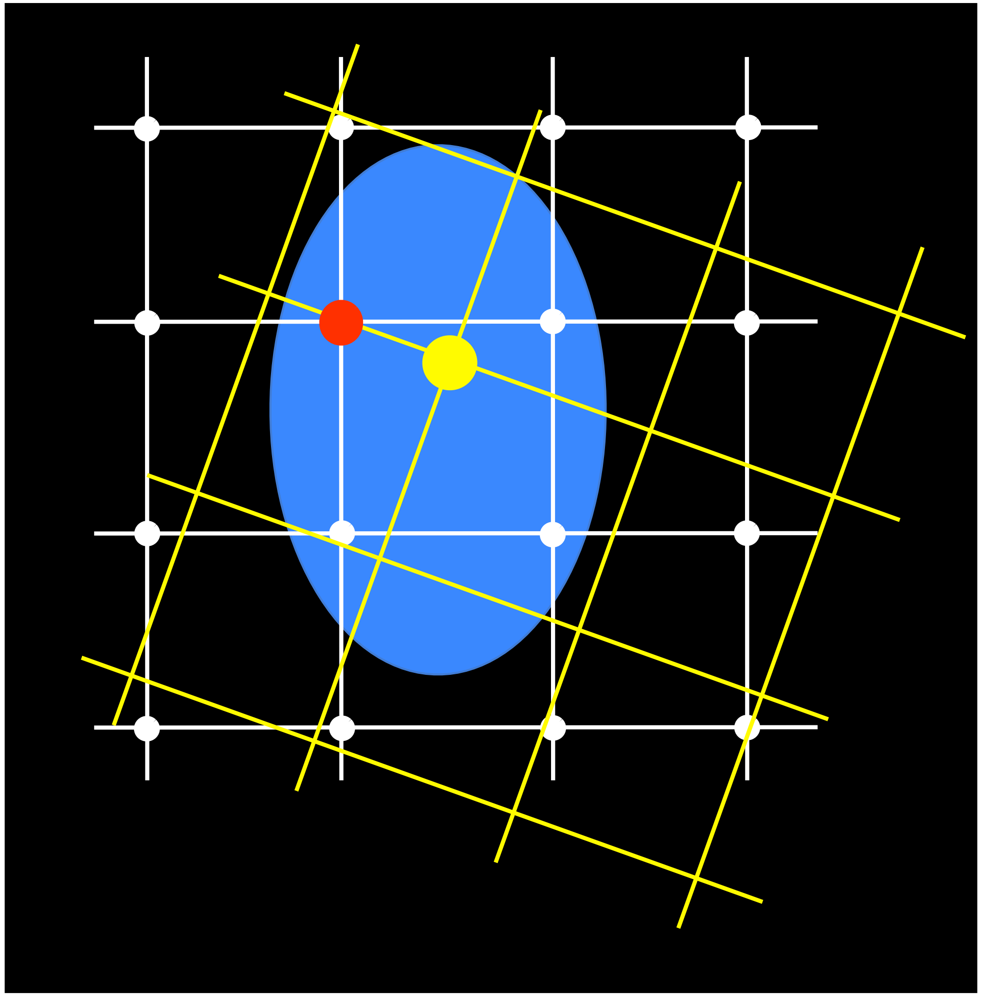
Interpolation 插值

Finds intensity values between grid points

在网格点之间查找强度值



Various types include 多种形式

- Nearest Neighbour 最近邻法
- Trilinear 三线性
- Spline 样条曲线
- Sinc 正弦
- k-Space methods k空间法

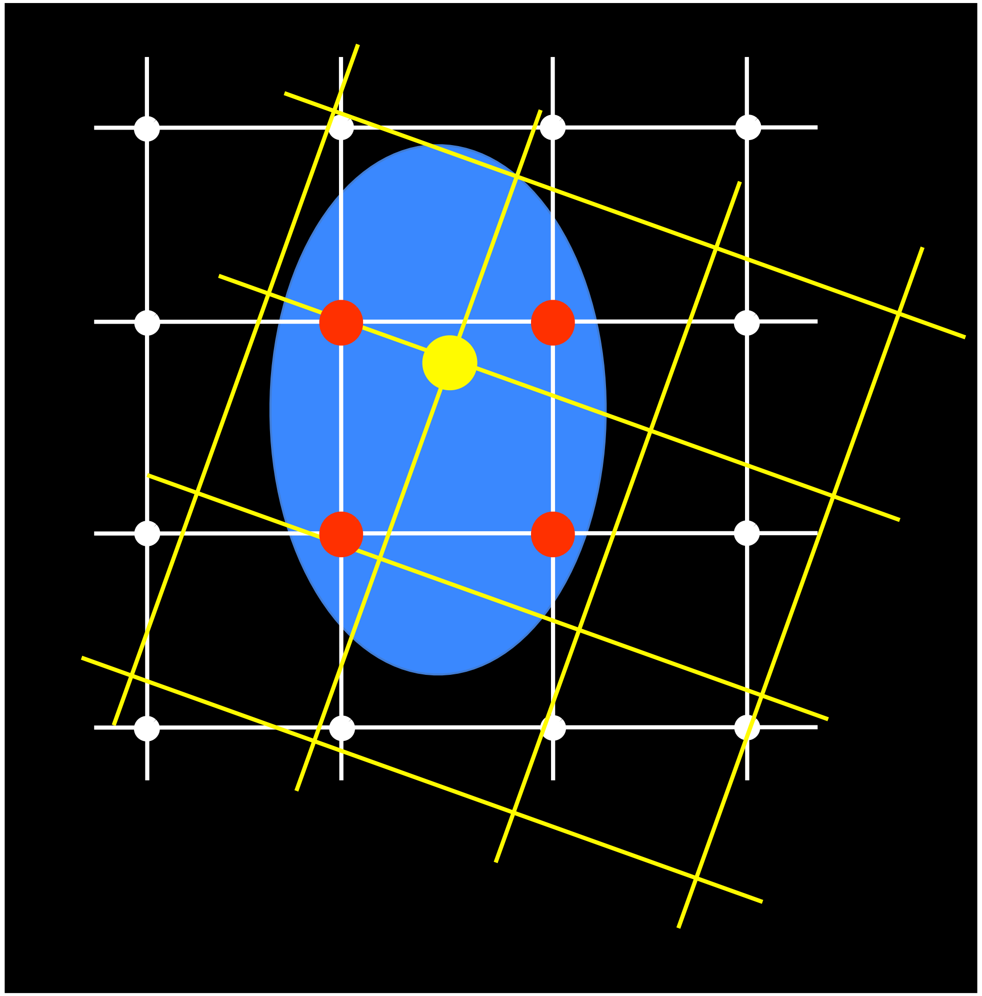
Fast, but blocky - can be used for discrete labels

快速，但块状 - 可用于离散标签

Interpolation 插值

Finds intensity values between grid points

在网格点之间查找强度值



Various types include 多种形式

- Nearest Neighbour 近邻法
- Trilinear 三线性
- Spline 样条曲线
- Sinc 正弦
- k-Space methods k空间法

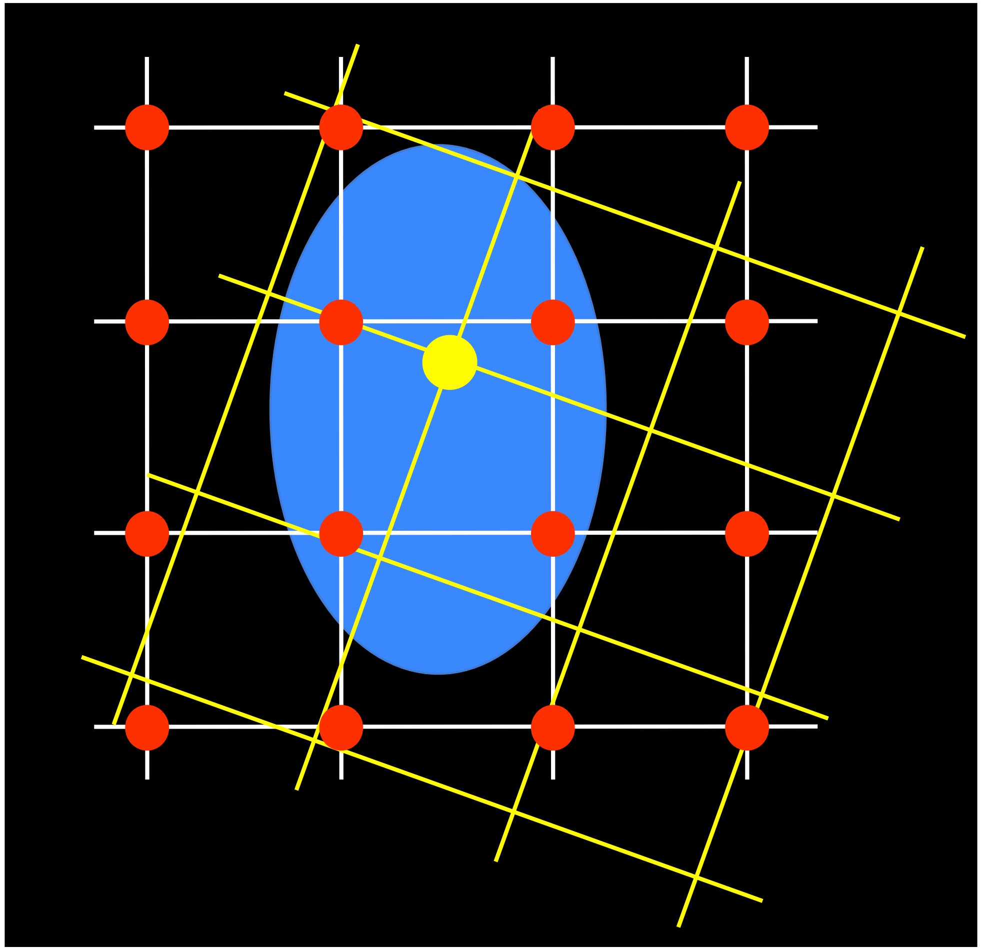
Fast, with some blurring - most common option

快速，不太精确- 最常见的选择

Interpolation 插值

Finds intensity values between grid points

在网格点之间查找强度值



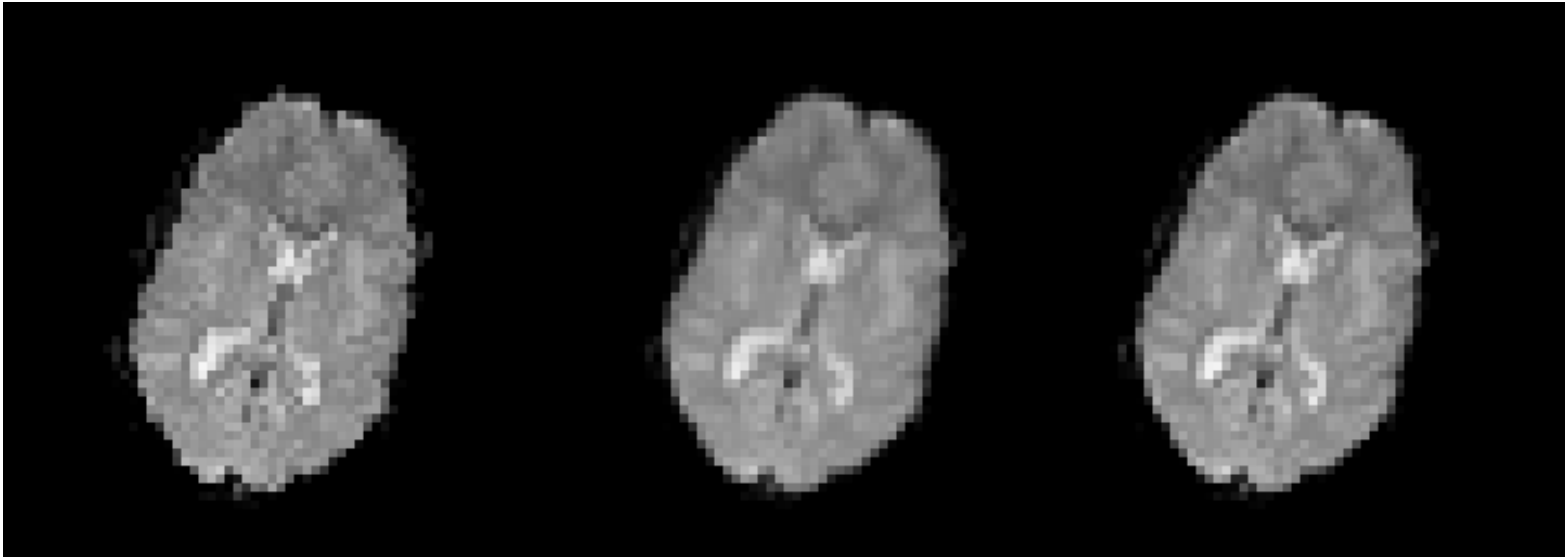
Various types include 多种形式

- Nearest Neighbour 近邻法
- Trilinear 三线性
- Spline 样条曲线
- Sinc 正弦
- k-Space methods k空间法

Slower (spline is fairly fast) - creates sharp images but can create values outside the original range

较慢(样条曲线法会快一些) - 创建清晰的图像，但会创建原始范围之外的值

Interpolation 插值



Nearest Neighbour
近邻法

Trilinear
三线性

Spline
样条曲线

Affects accuracy of subsequent analysis 影响后续分析的准确性

Important for *quantitative imaging* 对于定量成像很重要

Can affect size of artefacts 会影响伪影的大小

Applying Transformations 应用变换

- Step 1: Estimating a transformation

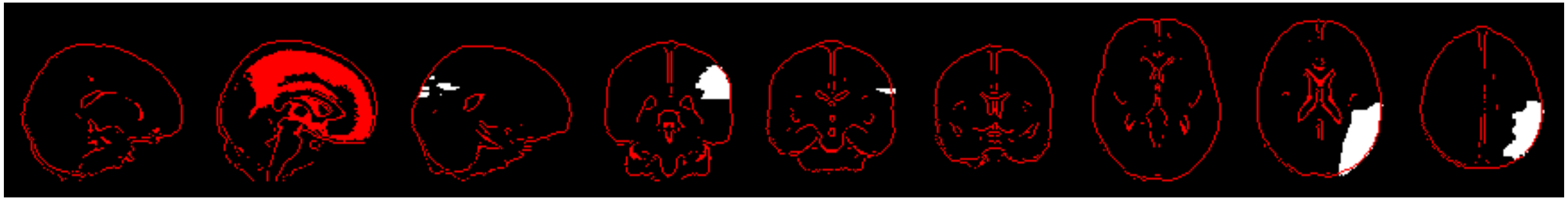
  第一步: 评估变换

  - finding the transformation 找到变换
  - no resampling 不要重采样

Applying Transformations 应用变换

- Step 1: Estimating a transformatio 评估变换
  - finding the transformation 找到变换
  - no resampling 不要重采样
- Step 2: Resampling 重采样
  - *applying* a transformation 应用变换
  - thus creating a new, modified image
    从而创建一个新的修改过的图像
- Registration can mean either 配准也可能意味着
- Usually delay *resampling* 通常会延迟重采样
  as it *reduces image quality* 因为它降低了图像质量
- Other terms: coregistration & spatial normalisation
  其他术语：配准&空间标准化

Transforming Masks 变换掩板



Mask values are normally 0 and 1 (integer format) 掩板的值通常为0和1(整数格式)

Interpolation gives values in between 插值会给出0和1之间的值

if rounded to integer → mask "shrinks"

如果舍入为整数 → 掩板会"缩小"

Ensure output datatype = float *(apply warp & flirt default)*

确保输出数据格式=float (采用*warp & flirt*的默认值)

Re-threshold (binarize) the transformed mask

重新设置变换掩板的阈值（二值化）

"Correct" thresholding depends on the particular case "正确"阈值取决于具体情况

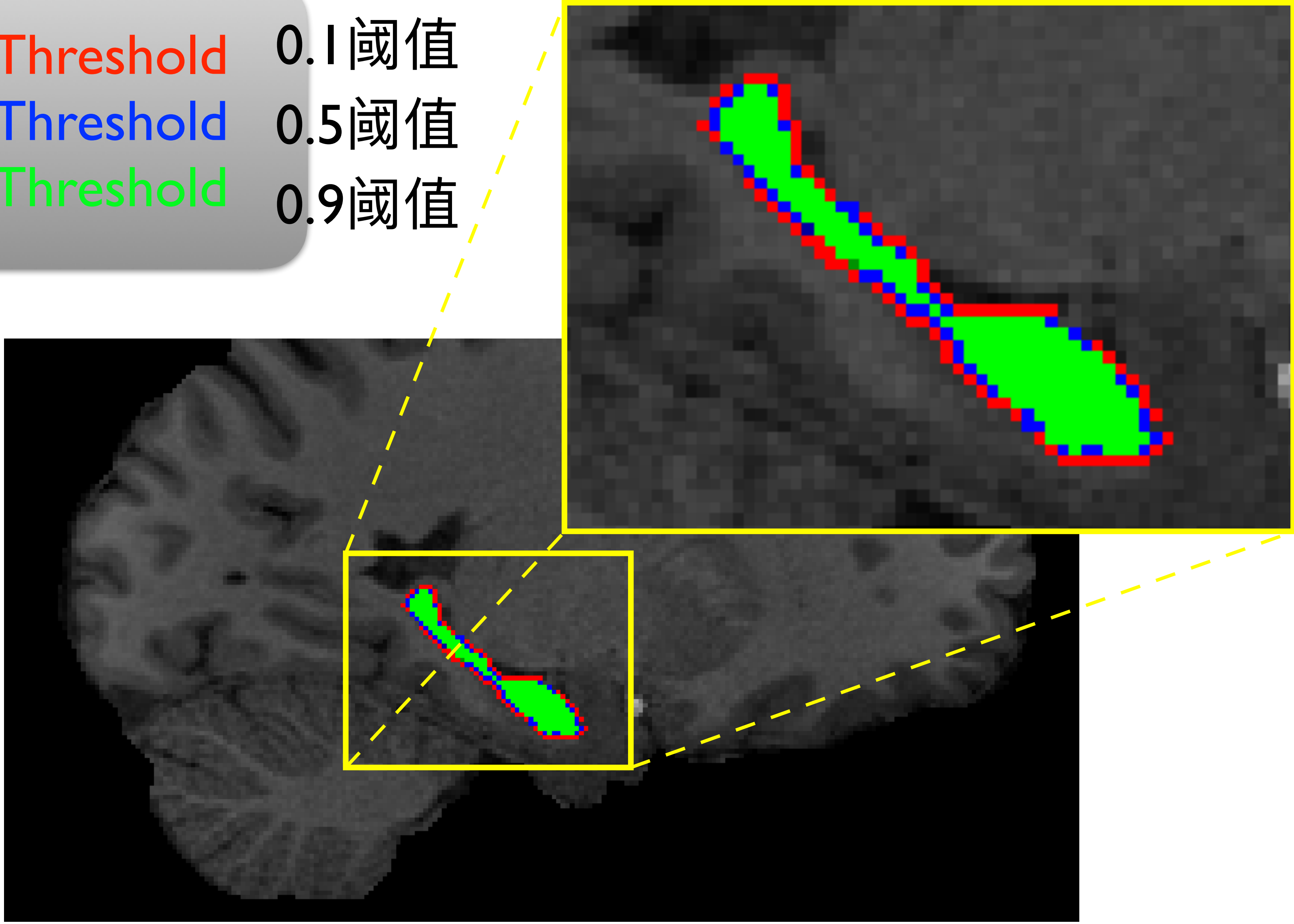
- Threshold near 0.0 to include partial-volume edges 阈值接近0.0以包括部分体积边缘
- Threshold near 1.0 to exclude partial-volume edges 阈值接近1.0以排除部分体积边缘
- Threshold at 0.5 to keep the same size (approx) 阈值为0.5以保持(大致)相同的大小

Transforming Masks 变换掩板

0.1 Threshold 0.1阈值

0.5 Threshold 0.5阈值

0.9 Threshold 0.9阈值



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  - Pathological image registration 病理异常图像配准

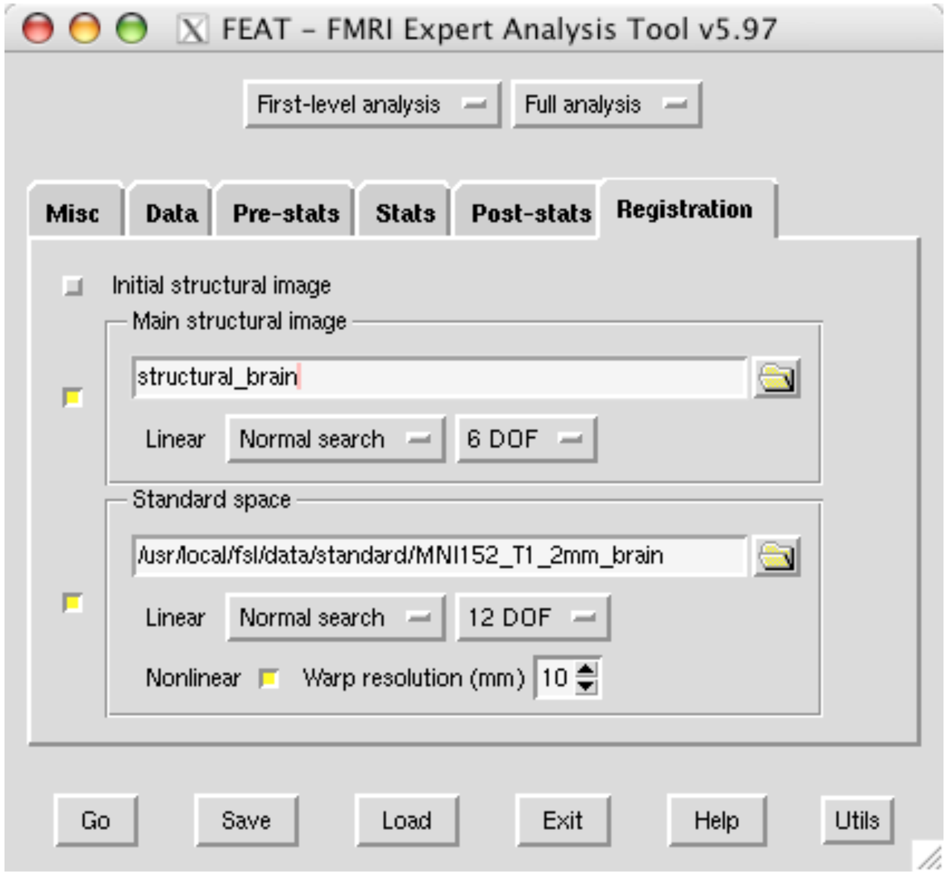
Registration with FSL 使用FSL进行配准

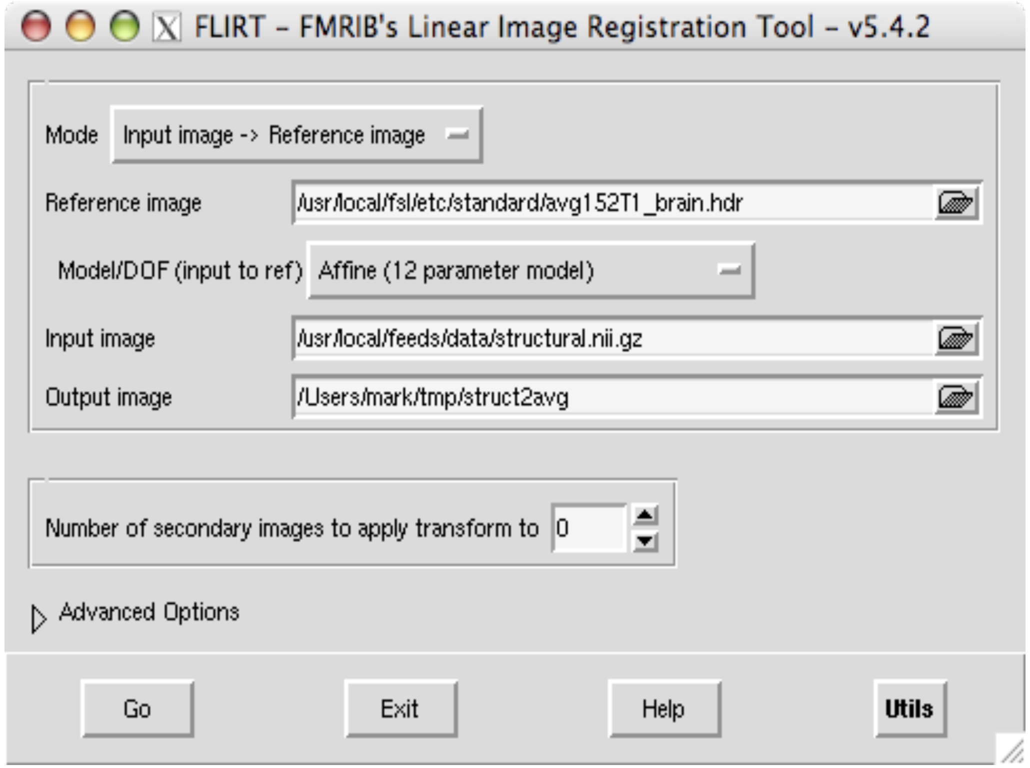
Two main tools: 两个主要的工具：

FNIRT & *FLIRT*

(FMRIB's Non-Linear/Linear Image Registration Tool)

(FMRIB的线性/非线性图像配准工具)





Both tools used by FMRI and Diffusion tools

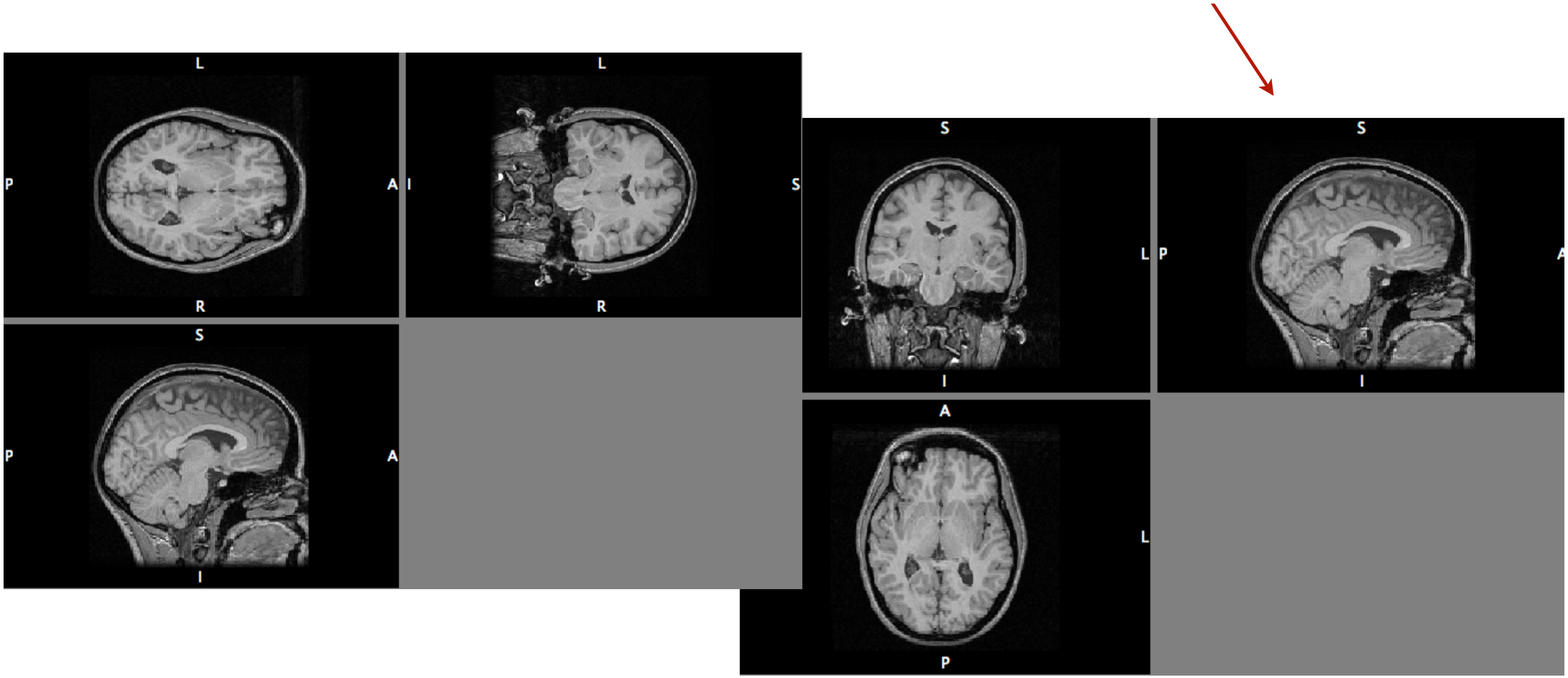
(FEAT, MELODIC & FDT)

*FMRI*和弥散*MRI*工具*(FEAT, MELODIC & FDT)*都会用到这两个工具

Preliminary Steps 初步步骤

Recommended steps: 推荐步骤：

- Reorientation (fslreorient2std) 重定位
- Brain Extraction (BET) 大脑提取
- Bias-field correction (FAST - see later) 偏置场校正



Note that labels are correct in both cases 请注意，两种情况下的标签都是正确的

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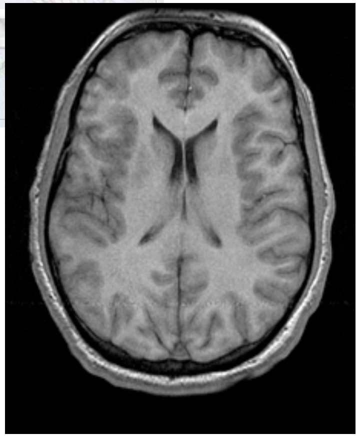
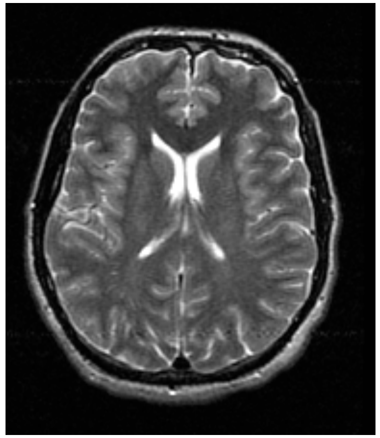


Case Study 案例分析



Scenario 场景:

Have two (or more) different types of images from the *same subject*

有两种或以上来自同一被试的不同类型的图像

For example, T_1-weighted and T_2-weighted images

例如，TI加权和T2加权图像

Objective 目的:

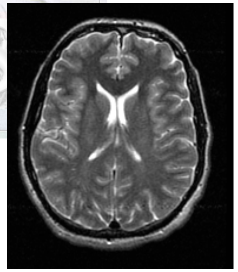
Have images aligned so that, for example, they can be used for multi-modal segmentation

将图像对齐以便进行后续分析，如将图像用于多模态分割

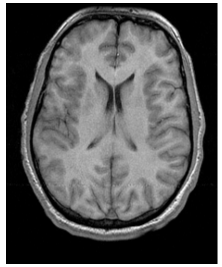
Solution 解决方法:

FLIRT with 6 DOF (rigid-body) 进行6自由度(刚体)的FLIRT处理

Single-stage Registration
单步配准

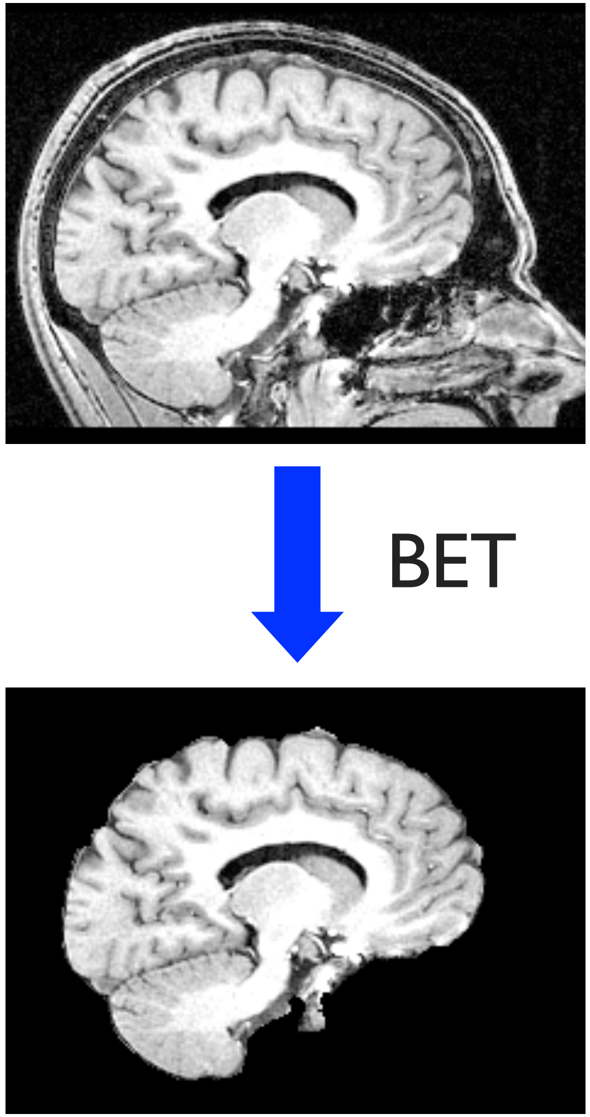


Input 输入



Reference 参考

- Single subject → 6 DOF = FLIRT
  单个被试 → 6自由度=FLIRT
- T_2-wt to T_1-wt → T2加权到T1加权 →
  multi-modal cost function
  (e.g. default of correlation ratio)
  多模态代价函数(如相关比率的默认值)
- Run *brain extraction* on *both images*
  对每个图像都进行大脑提取
- Choose image with better resolution or contrast as the reference
  选择分辨率或对比较好的图像作为参考
- Always check your output
  记得时刻检查你的输出结果



Artefaction Detection Device

伪影检测装置

LOOK AT YOUR DATA!

检查你的数据！

Visual Check 视觉检查

Always assess registration quality visually! **时刻**查看你的结果以评估配准质量！
Can use 可以使用:

- *FSLeyes* (using overlay or flicking between images)

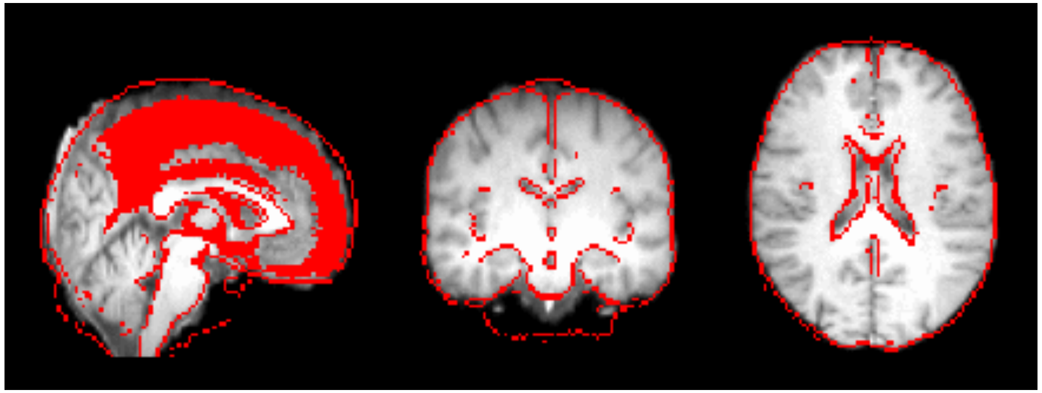
  (通过叠加图像或在图像间进行快速切换)

- *slices* for a static view use (as in FEAT)

  •查看图像的静态视图可用以下命令(如在FEAT中)

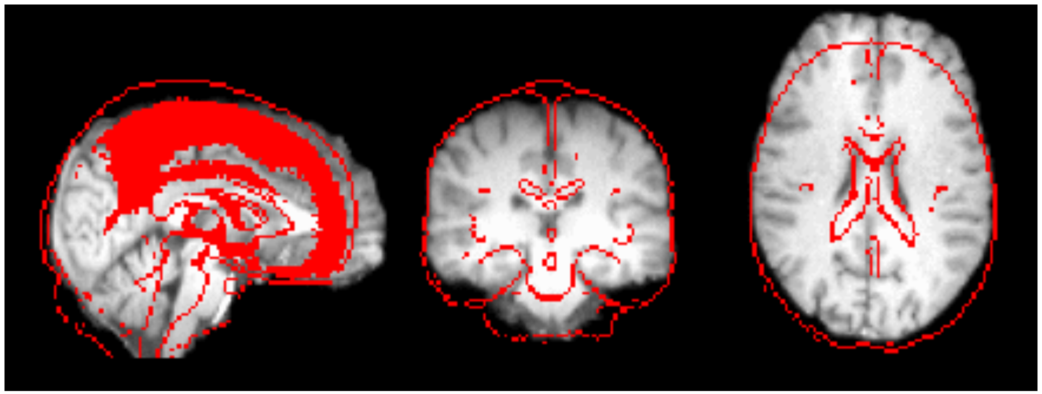
  slices T2_to_T1im T1im

Grayscale from first image
灰色部分来自第一张图



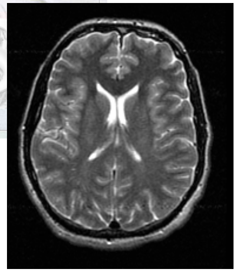
✔

Red edges from second image
红色部分来自第二张图

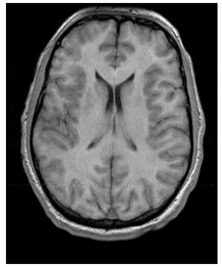


✘

Registration in FSL
在FSL中进行配准



***Input* 输入**



***Reference* 参考**

- In FSL the ***reference image*** controls the *FOV and resolution of the output image* 在FSL中，参考图像控制输出图像的视场和分辨率
- Transformations are given 变换方向:
  from input space ***to*** reference space 从输入空间到参考空间
- Inverse transformations can easily be calculated to go from reference space to input space when needed
  反变换的计算很容易，以便在需要时从参考空间变换至输入空间
- Can overlay images in FSLeyes with different FOV or resolution: i.e. images can be in different spaces and resolutions
  可在FSLeyes中叠加不同视场或分辨率的图像，即图像可存在于不同的空间和分辨率中。
- Images can be ***resampled*** into a different space by applying a previously derived transformation
  应用先前导出的变换可以将图像重采样到不同的空间中。

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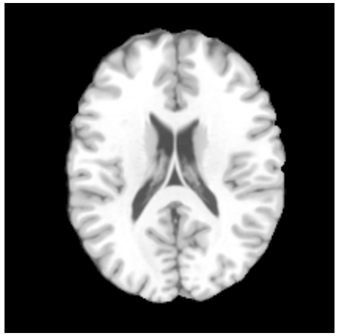


Case Study
案例分析

Scenario 场景:

Doing a functional (or diffusion) study 进行功能性(或弥散)研究

Have EPI and T_1-weighted of each subject 有对应每个被试的EPI或T1加权图像

Objective 目的:

Need to register images to a common (standard) space to allow the group study to be performed

需要将图片配准到一个标准空间从而进行组研究

Solution 解决方法:

2-stage registration with FLIRT & FNIRT (in FEAT)

使用(在FEAT中)FLIRT & FNIRT进行两步配准

Two Stage Registration 二级配准

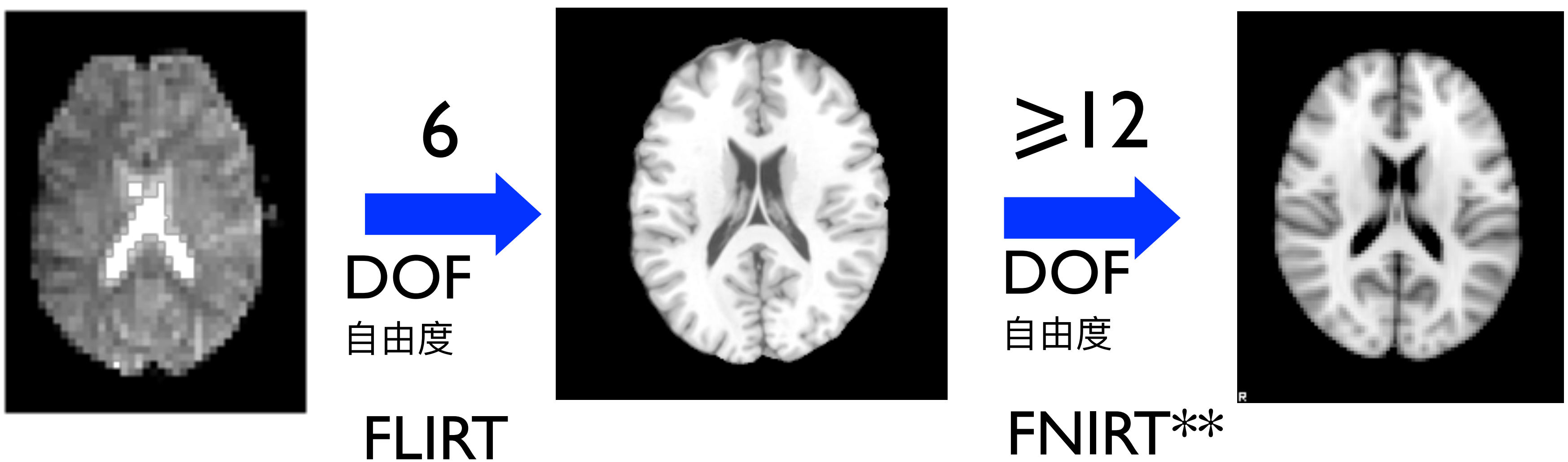
Registering very different images is difficult due to, 对不同图像进行配准的难点在于:

- Differences in individual anatomies 个体的解剖结构不同
- Different contrasts in various modalities 不同模态的对比不同
- Distortions which differ between images 不同图像间的变形不同

To register an EPI to a standard space template (e.g. MNI152) use a structural intermediate image. 要将EPI图像配准到标准空间模板(如MNI152)，请使用结构图像作为中介

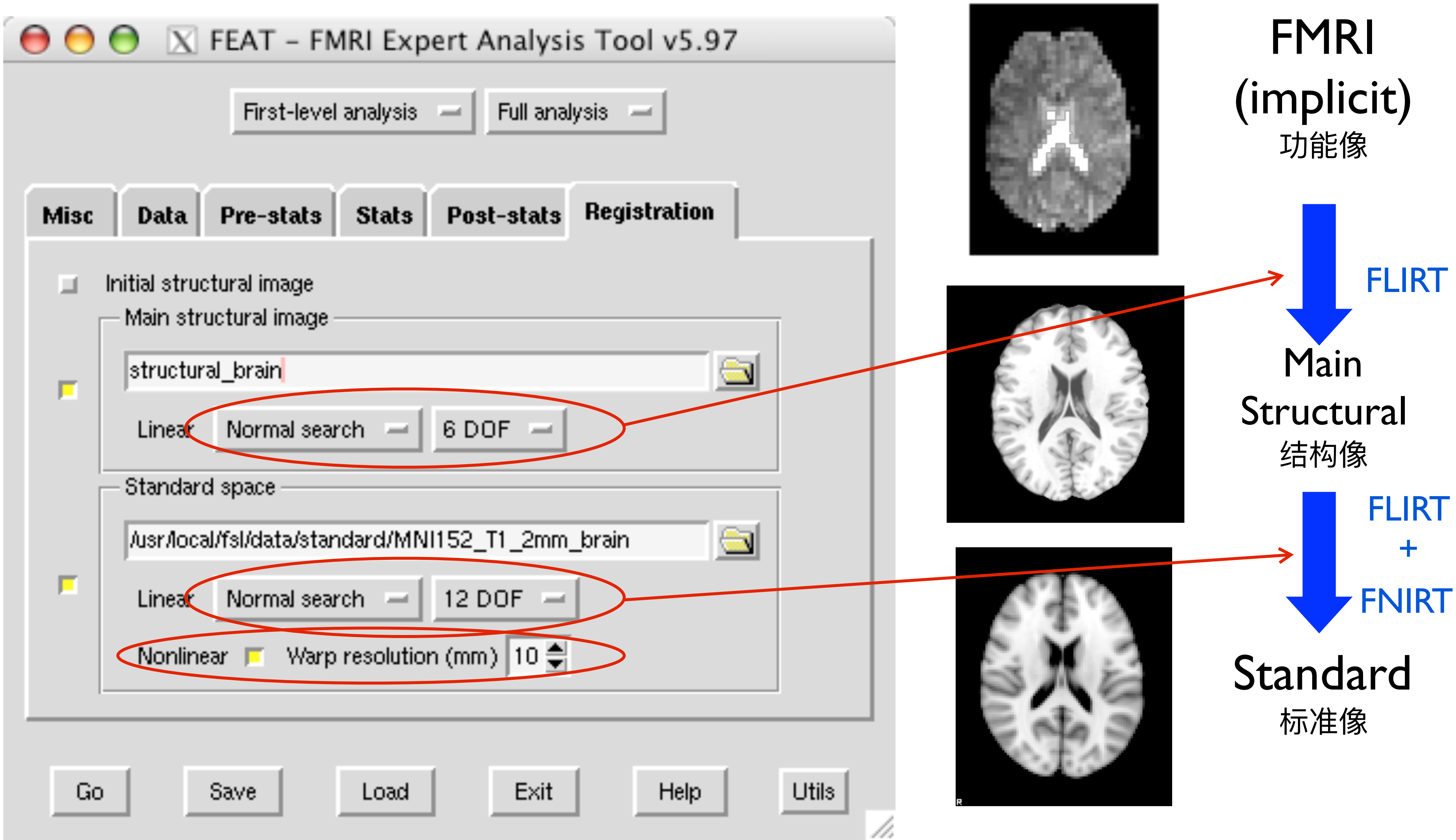
Automatically done by FEAT GUI (some user control)
由FEAT界面(通过某些用户控件)自动完成

Need to manually run brain extraction (not on EPI usually*)
需要手动运动动大脑提取(因为EPI图像通常不进行这一步处理)



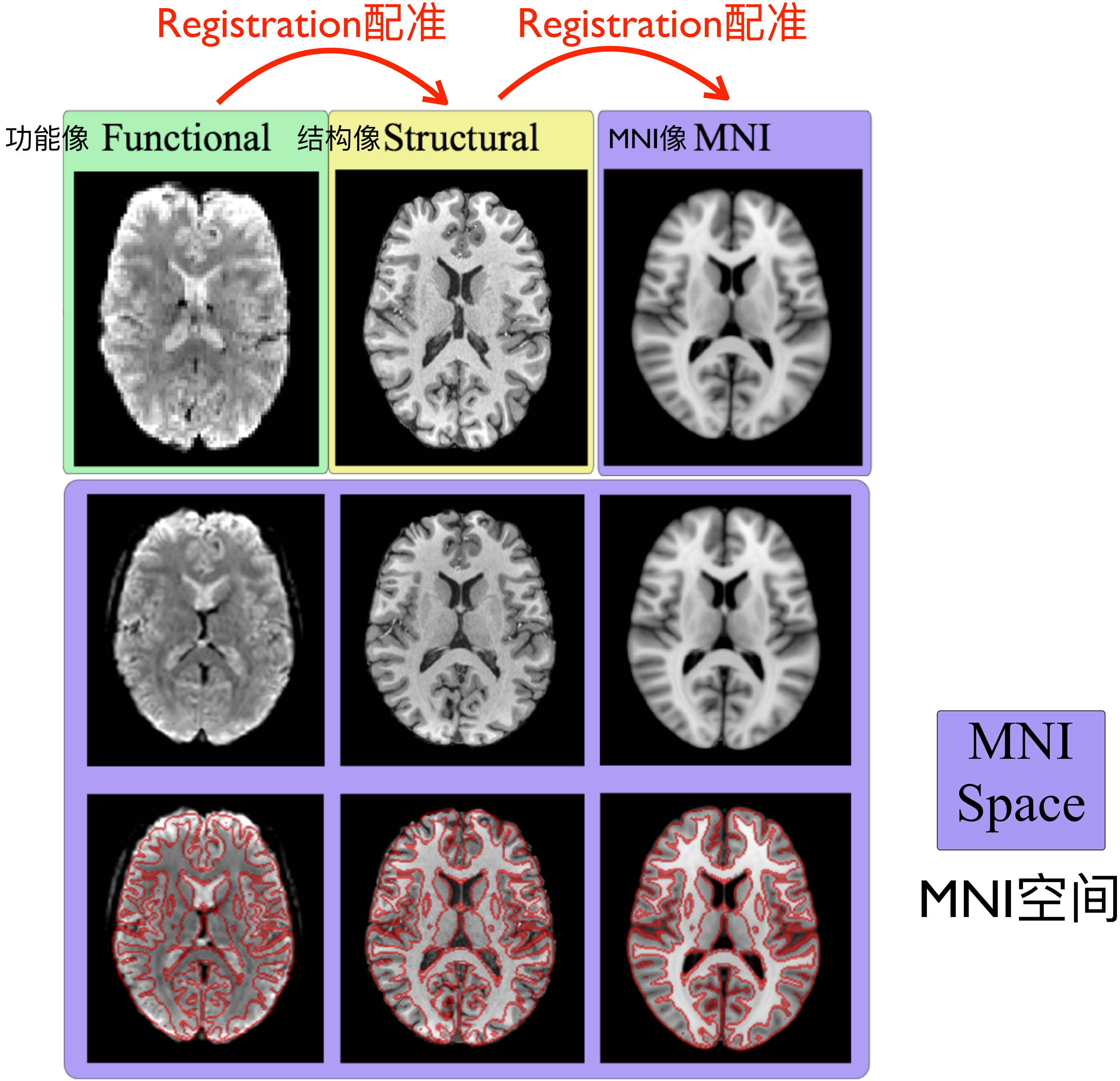
Registration for FMRI Analysis (FEAT)

用于FMRI分析(FEAT)的配准



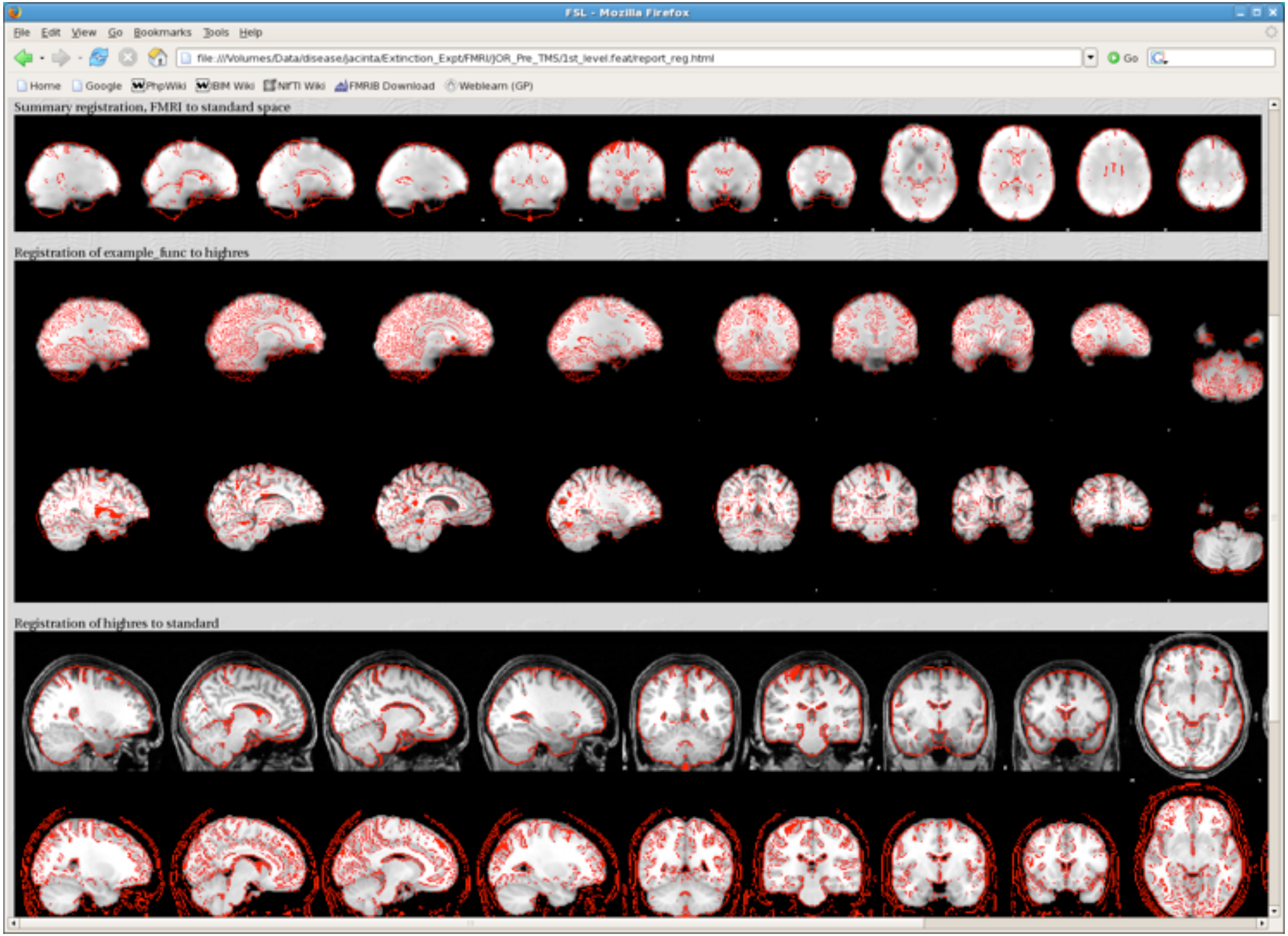
NB: actually need brain extracted ***and*** original images for FNIRT

注意：需要为FNIRT提供大脑提取后的图像和原始图像

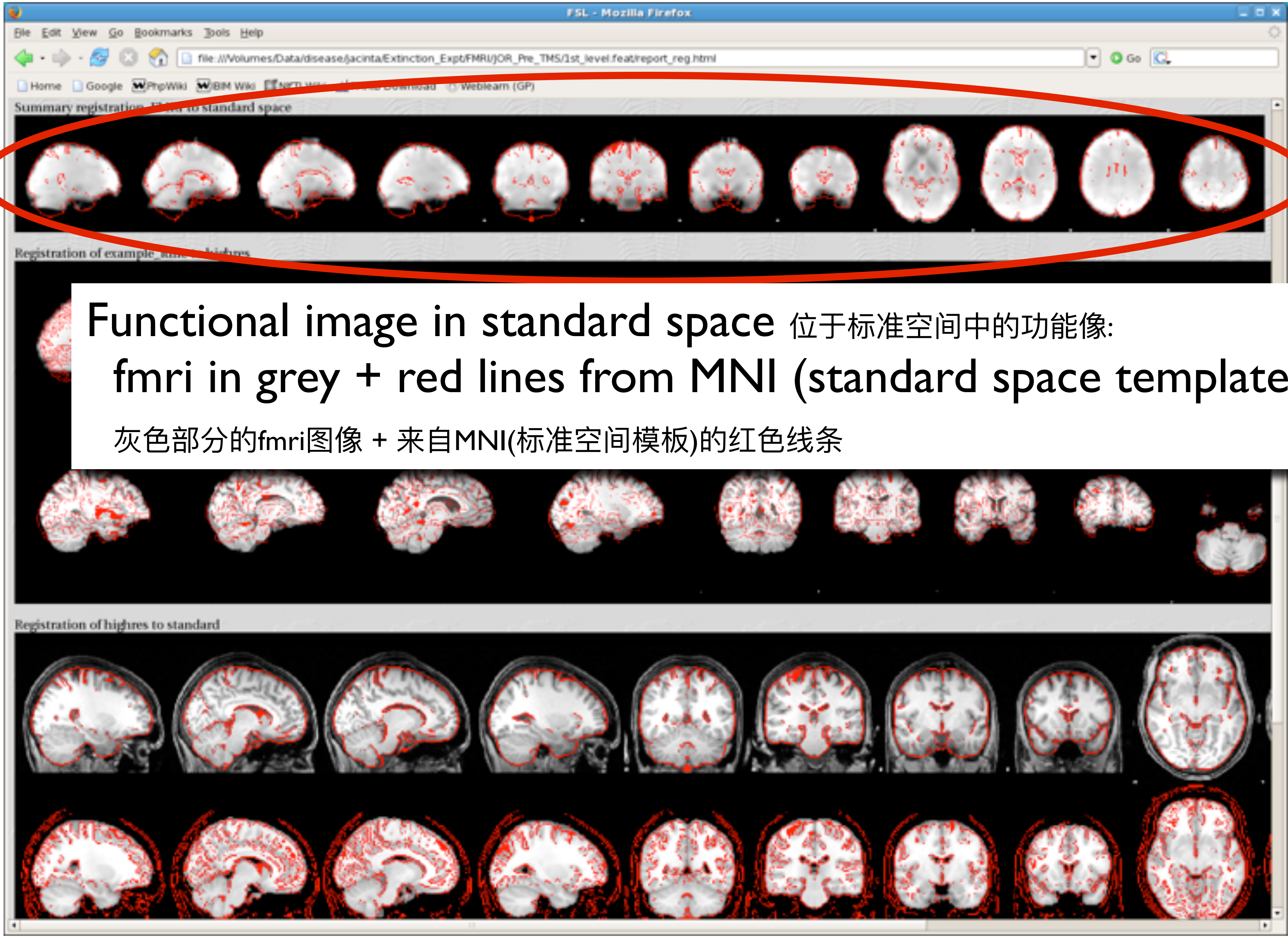


Registration配准
Registration配准
功能像 Functional
结构像Structural
MNI像 MNI
MNI Space
MNI空间

Registration for FMRI Analysis 用于FMRI分析的配准



Registration for FMRI Analysis 用于FMRI分析的配准

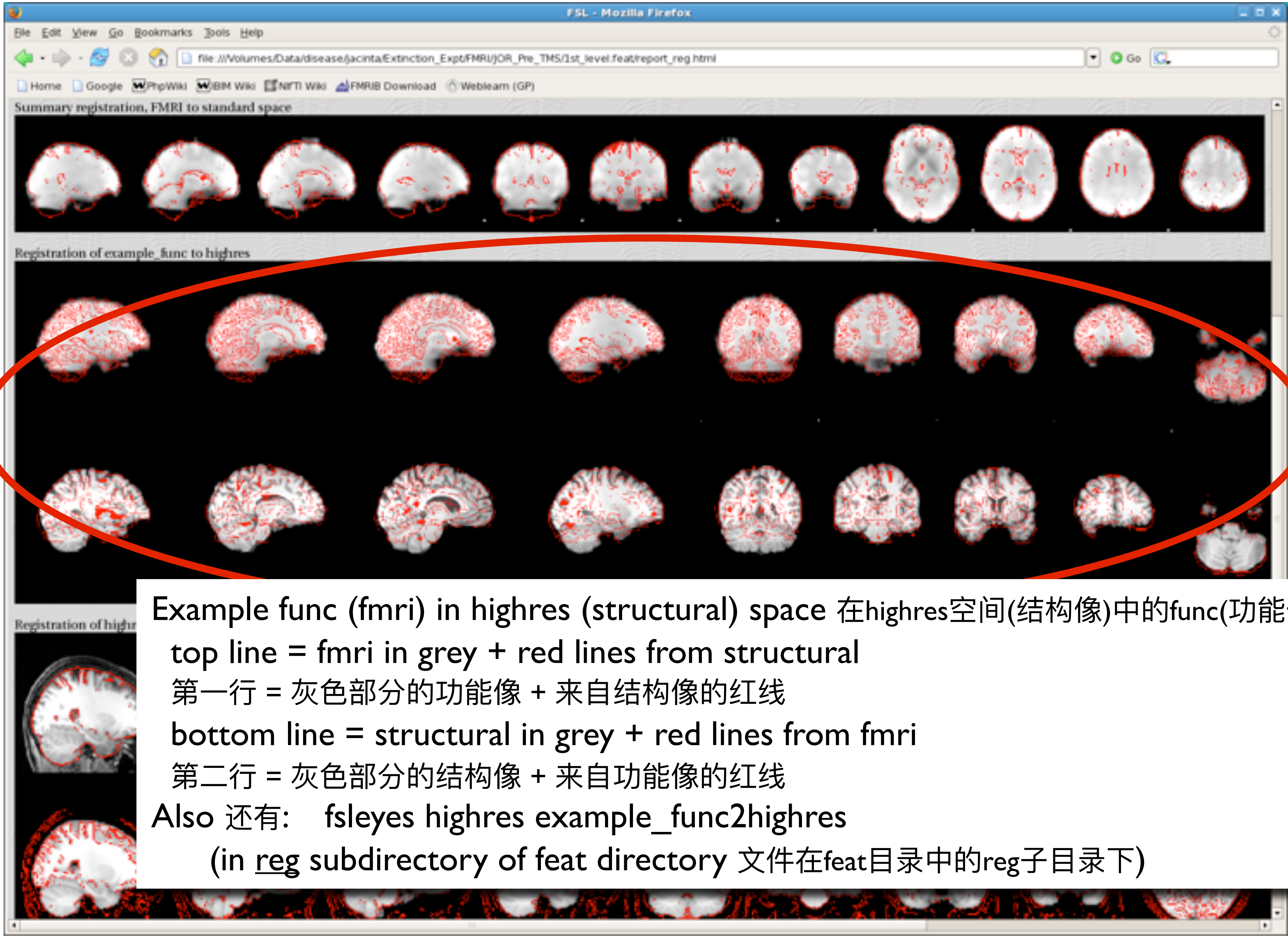


Functional image in standard space 位于标准空间中的功能像:

fmri in grey + red lines from MNI (standard space template)

灰色部分的fmri图像 + 来自MNI(标准空间模板)的红色线条

Registration for FMRI Analysis 用于FMRI分析的配准



Example func (fmri) in highres (structural) space 在highres空间(结构像)中的func(功能像):

top line = fmri in grey + red lines from structural

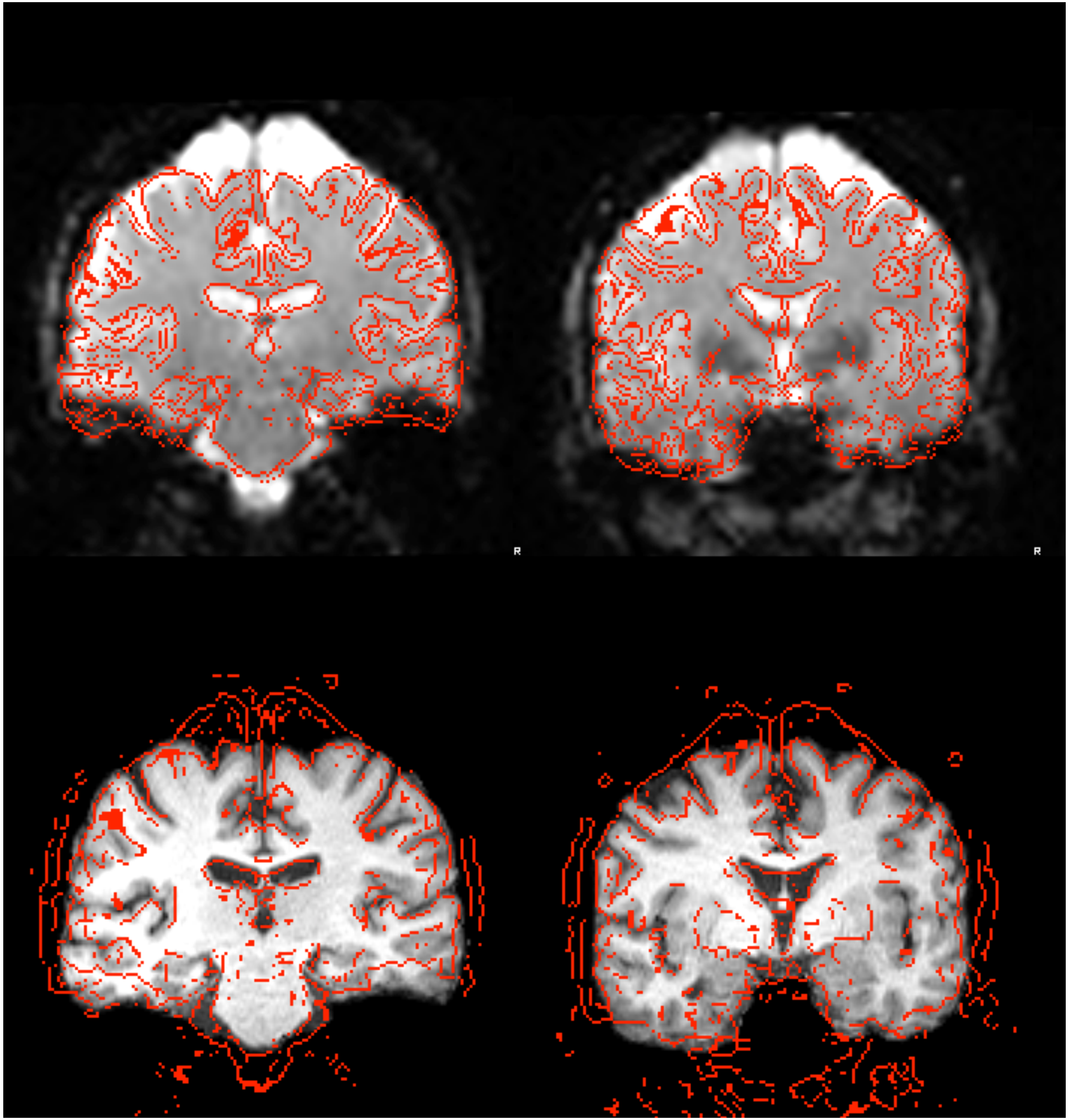
第一行 = 灰色部分的功能像 + 来自结构像的红线

bottom line = structural in grey + red lines from fmri

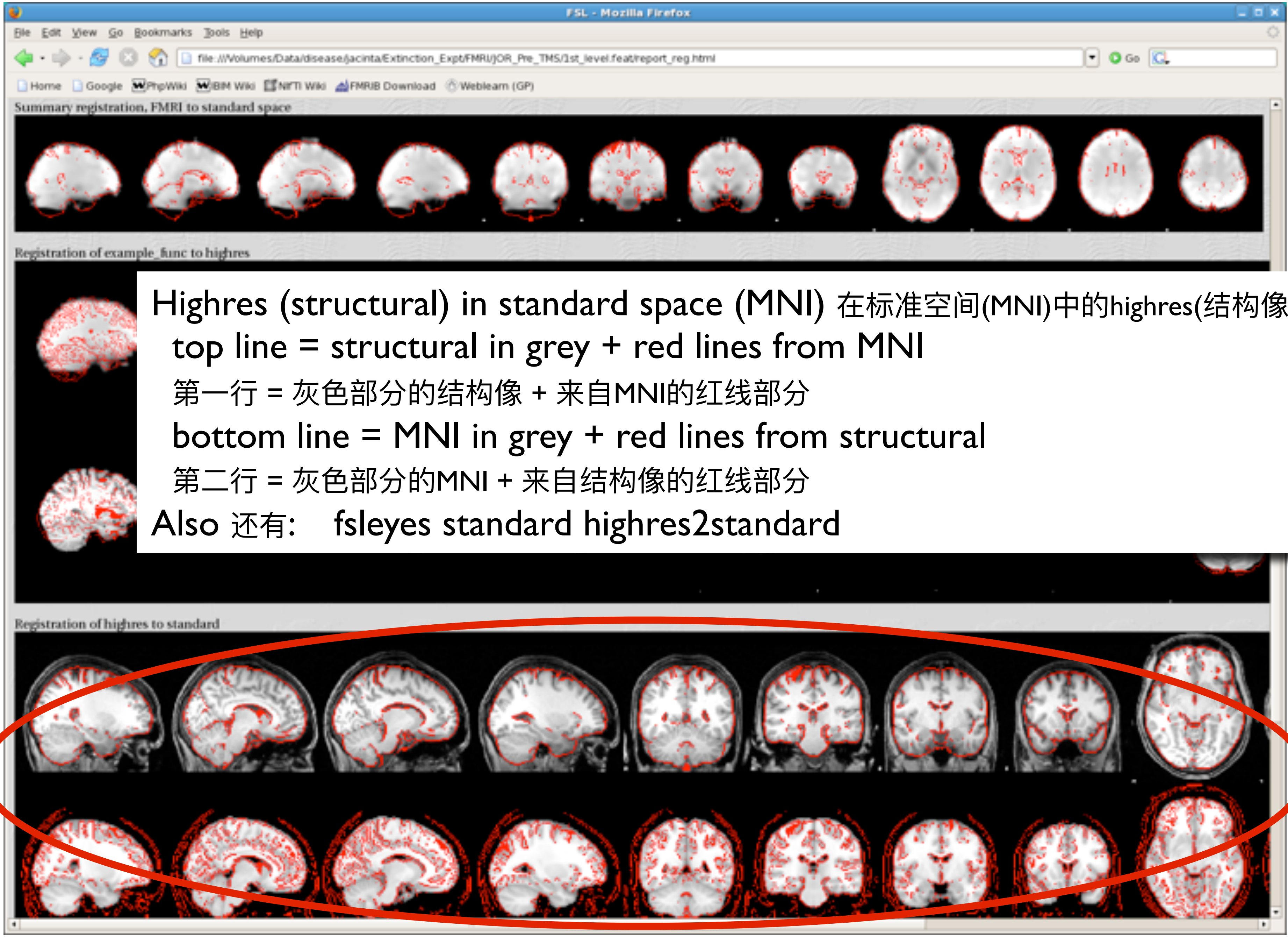
第二行 = 灰色部分的结构像 + 来自功能像的红线

Also 还有: fsleyes highres example_func2highres

(in reg subdirectory of feat directory 文件在feat目录中的reg子目录下)


R
R

Registration for FMRI Analysis 用于FMRI分析的配准



Highres (structural) in standard space (MNI) 在标准空间(MNI)中的highres(结构像)

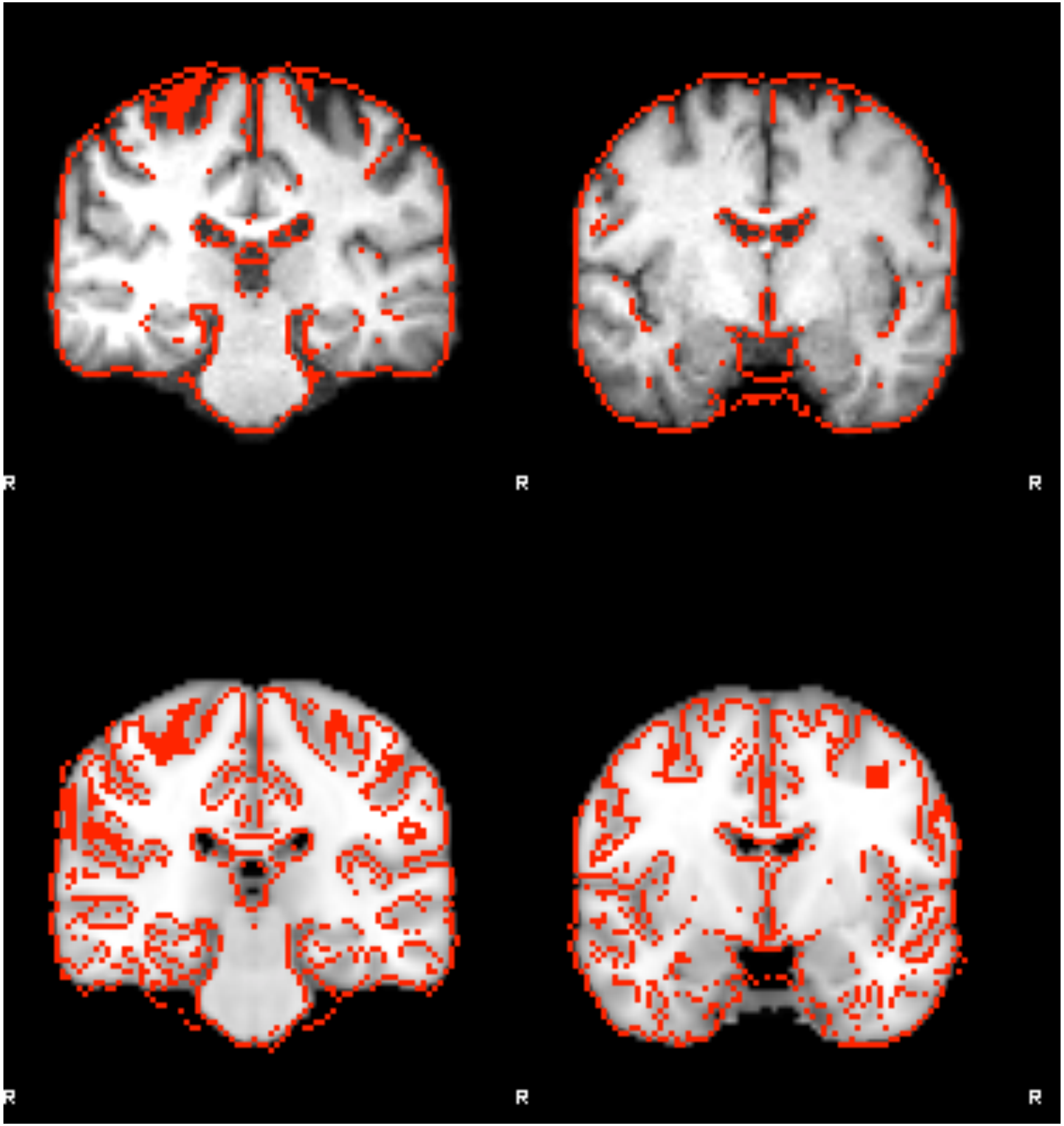
top line = structural in grey + red lines from MNI

第一行 = 灰色部分的结构像 + 来自MNI的红线部分

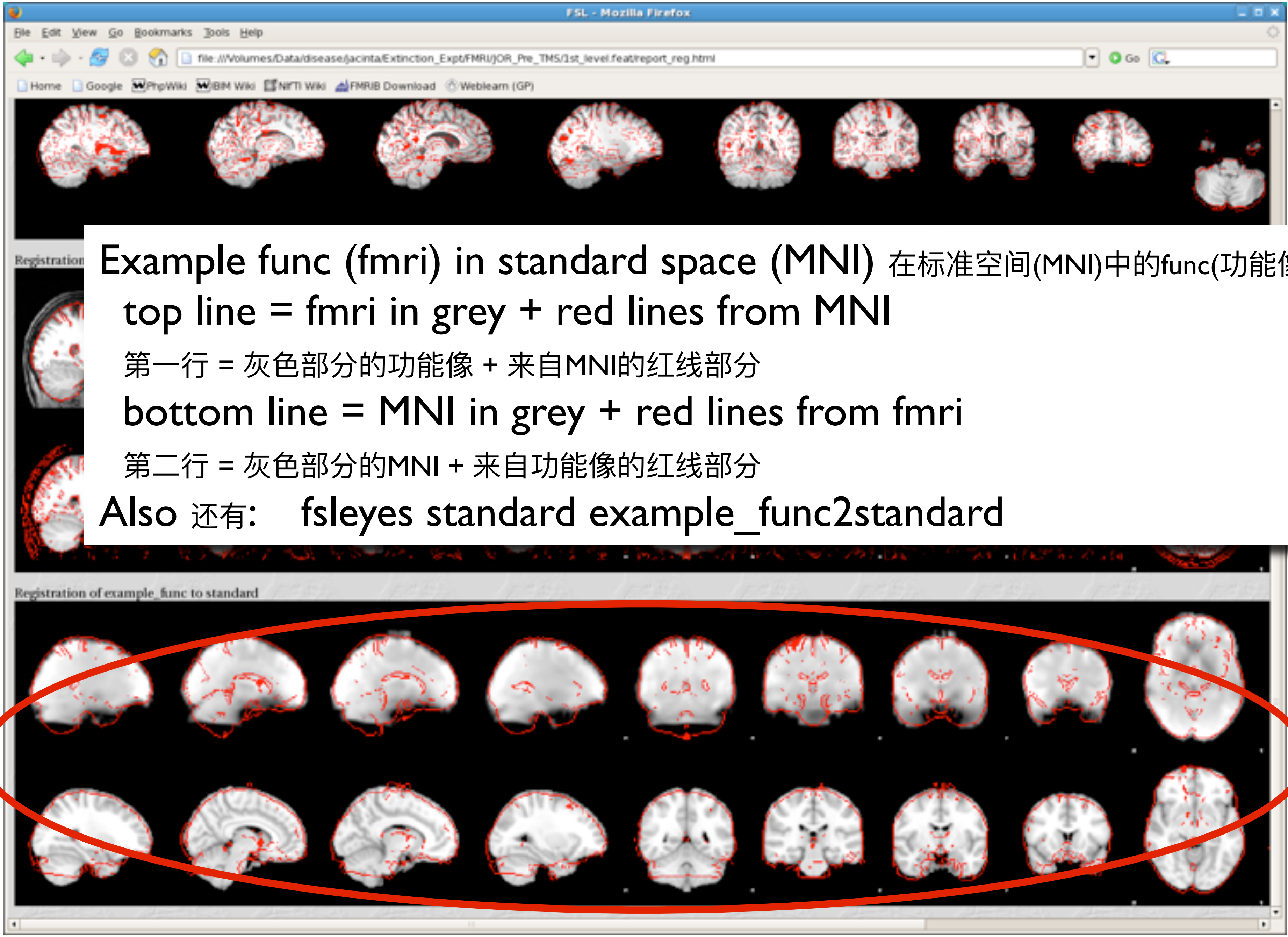
bottom line = MNI in grey + red lines from structural

第二行 = 灰色部分的MNI + 来自结构像的红线部分

Also 还有: fsleyes standard highres2standard


R
R
R
R
R
R

Registration for FMRI Analysis 用于FMRI分析的配准



Example func (fmri) in standard space (MNI) 在标准空间(MNI)中的func(功能像)

top line = fmri in grey + red lines from MNI

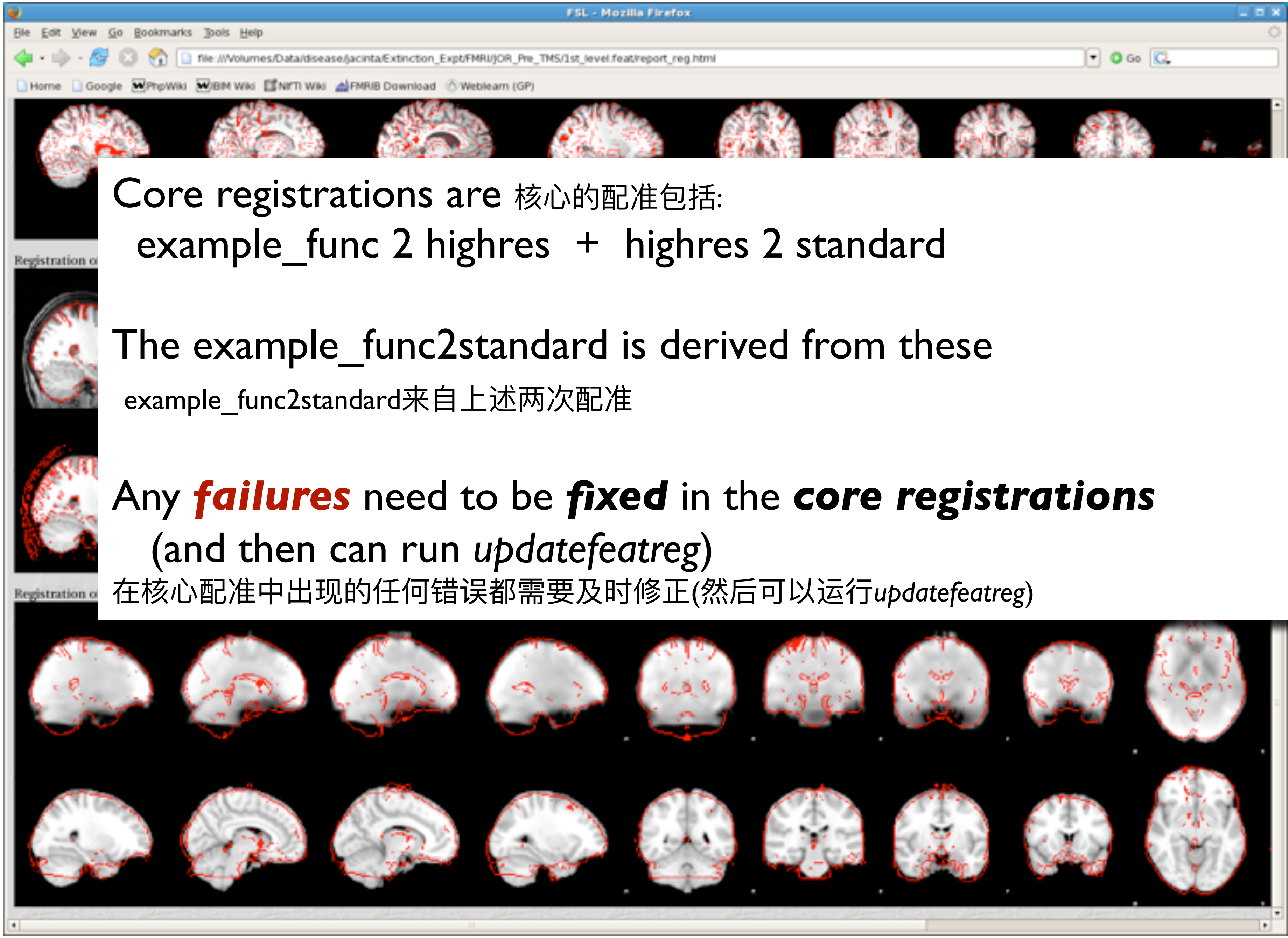
第一行 = 灰色部分的功能像 + 来自MNI的红线部分

bottom line = MNI in grey + red lines from fmri

第二行 = 灰色部分的MNI + 来自功能像的红线部分

Also 还有: fsleyes standard example_func2standard

Registration for FMRI Analysis 用于FMRI分析的配准



Core registrations are 核心的配准包括:

example_func 2 highres + highres 2 standard

The example_func2standard is derived from these

example_func2standard来自上述两次配准

Any ***failures*** need to be ***fixed*** in the ***core registrations***

(and then can run *updatefeatreg*)

在核心配准中出现的任何错误都需要及时修正(然后可以运行*updatefeatreg*)

Overview 概述

- Brain Extraction (BET) 大脑提取（BET）
- Registration concepts (FLIRT & FNIRT) 配准概念(FLIRT & FNIRT)
- Practical applications (FLIRT & FNIRT) 实际应用(FLIRT & FNIRT)
  - Single-stage registration 单步配准
  - Multi-stage registrations 两步配准
  - EPI distortion correction EPI变形校正
  - Pathological image registration 病理异常图像配准

Case Study 案例分析

Scenario 场景:

Doing a functional (or diffusion) study

进行功能性(或弥散)研究

Objective 目的:

Want to correct for distortions in EPI

as otherwise the registrations are inaccurate

修正EPI图像中的变形，否则无法精确配准

Solution 解决方法:

Fieldmap-based correction using FUGUE/FEAT

使用FUGUE/FEAT进行基于场图的修正

Registration of EPI EPI配准

Problem 问题:

- EPI images distorted and suffer signal loss

  EPI图像出现变形和信号损失

- standard registration does not work well

  无法很好地进行标准配准

Solution 解决方法:

- undo distortion by "unwarping"

  通过"去变形"消除变形

- ignore areas of high signal loss

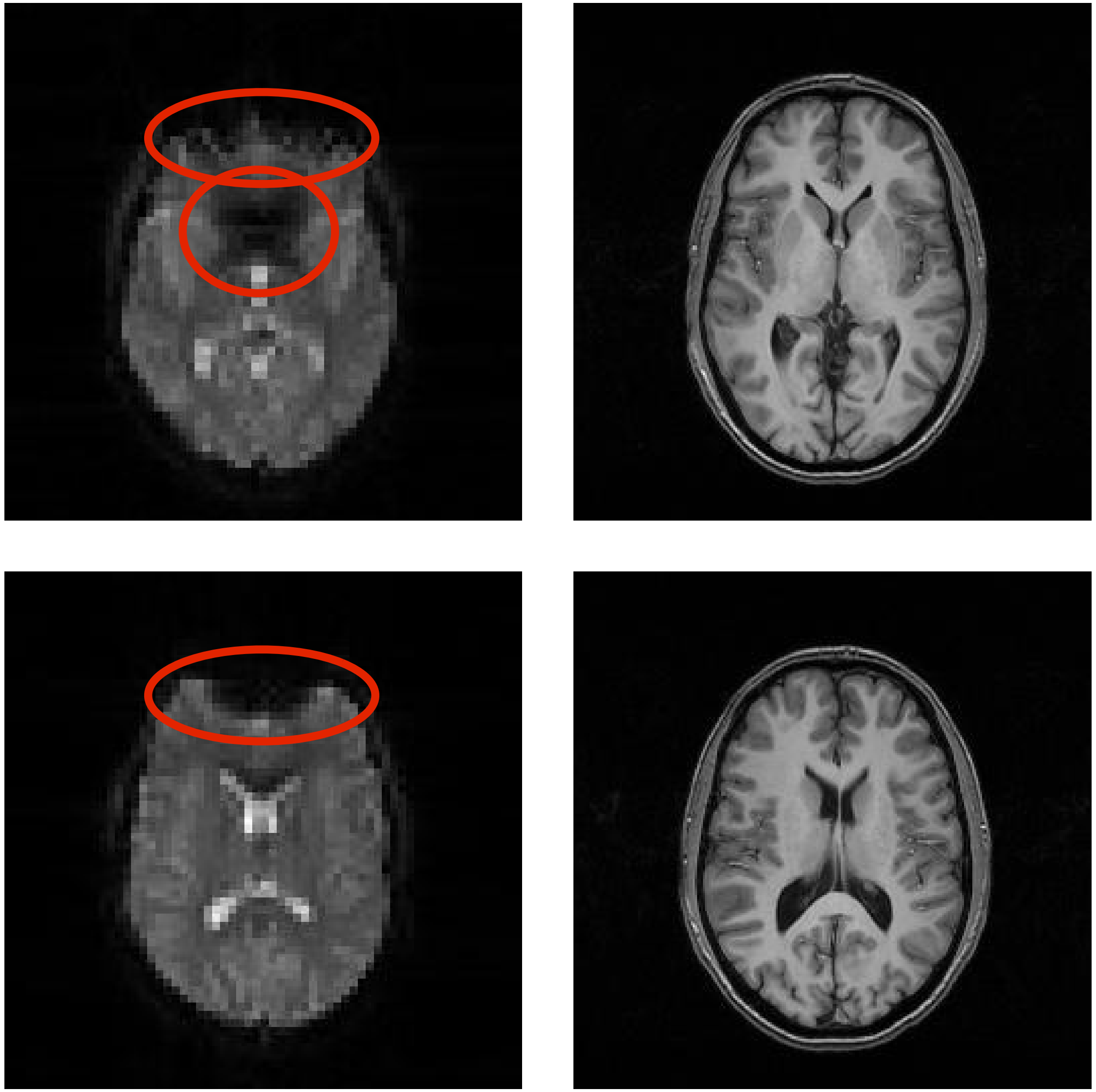
  忽略高信号损失区域

- *needs a* **fieldmap** (special acquisition)

  需要一个场图(专门采集)

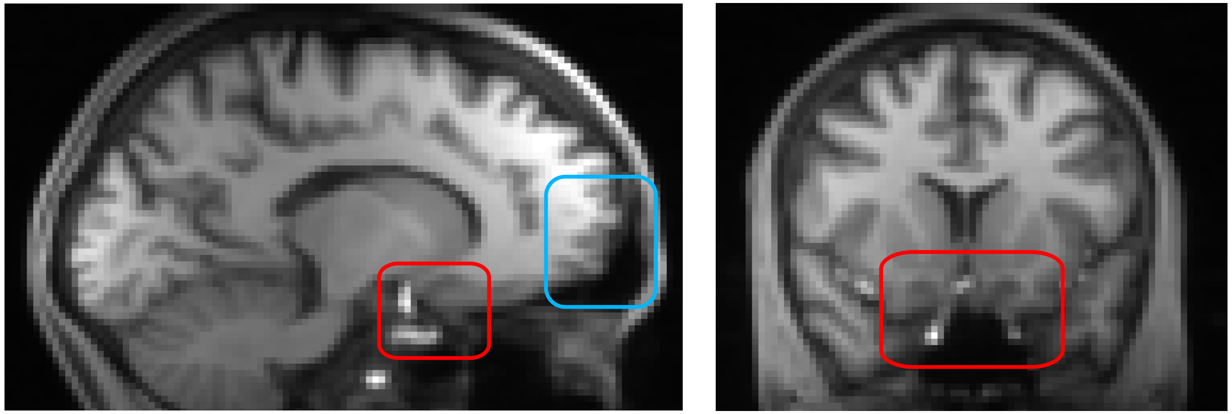
EPI
平面回波成像

T_1-weighted anatomical
T1加权解剖结构



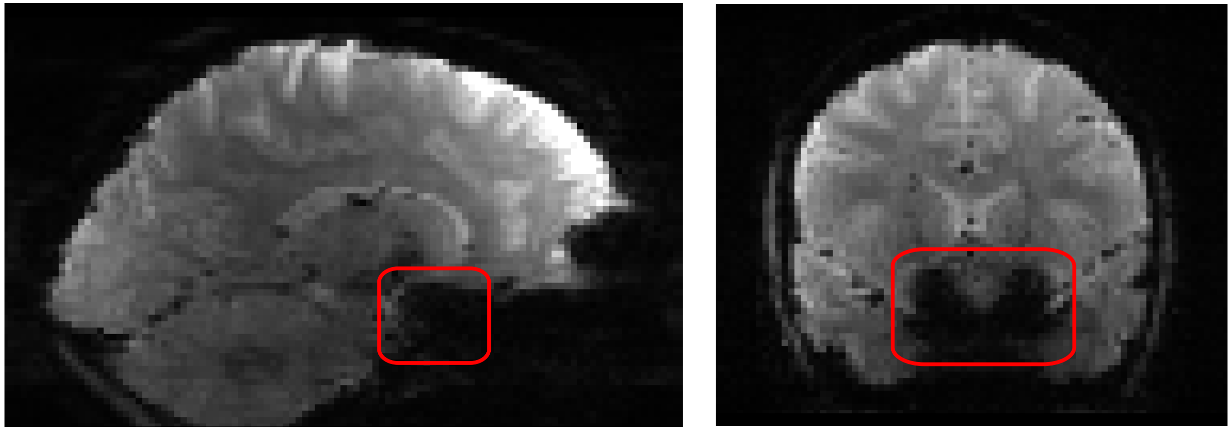
T1-weighted (aligned)

T1加权(已对齐)



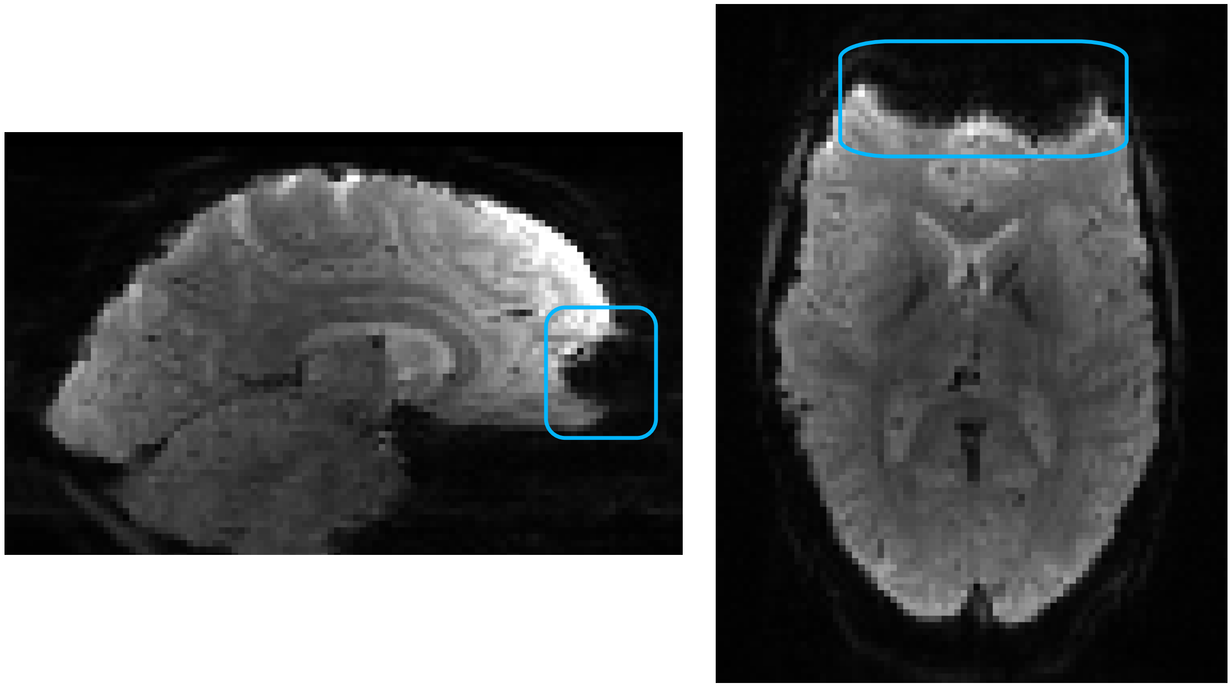
Signal Loss

信号损失



Distortion

变形



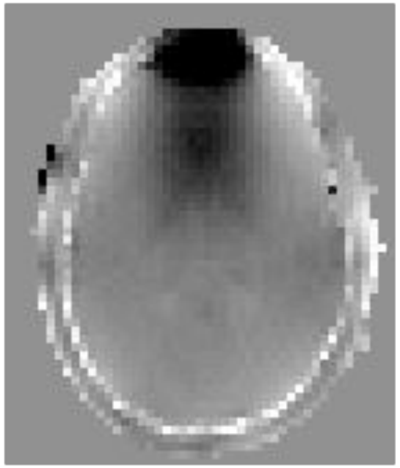
B_0 Field Inhomogeneities B_0场不均匀性

EPI is very sensitive to any deviations from a perfectly uniform B_0 field
EPI对任何偏离均匀B_0场的情况都很敏感

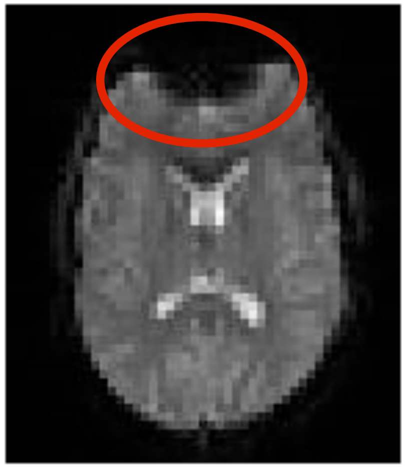
Air-tissue interfaces cause magnetic disturbances
空气-组织边界引起磁场干扰

A separate ***fieldmap*** image measures the B_0 deviations
单独的场图可以测量B_0偏离

fieldmap 场图

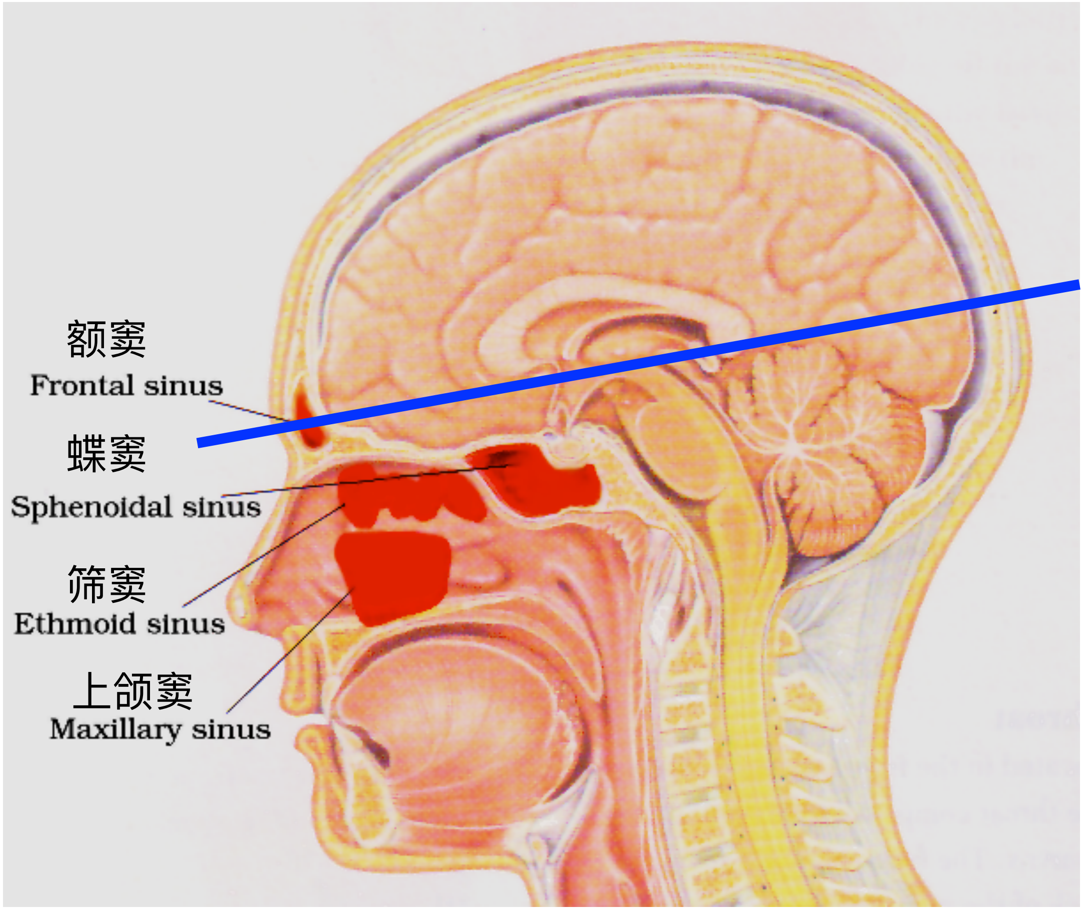


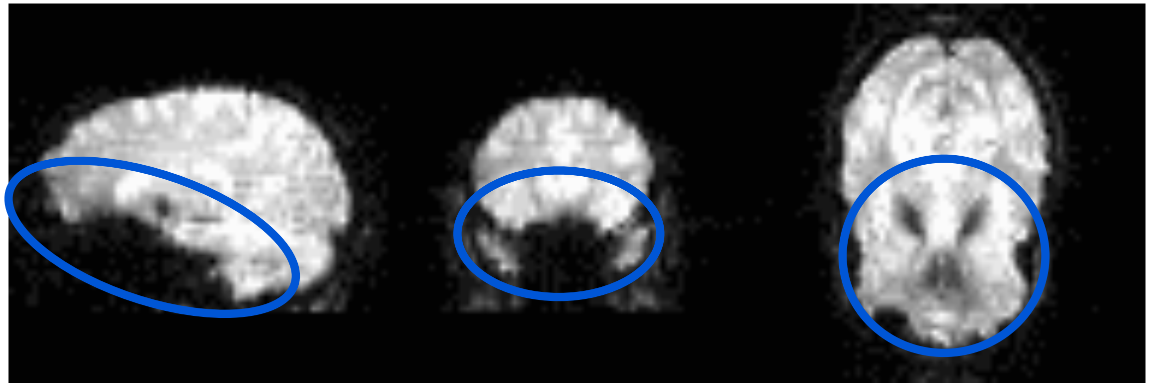
EPI



distortion 变形

signal loss 信号损失





Courtesy of D. Greve, MGH

Using Fieldmaps 场图使用

From the fieldmap image we get:
从场图中我们可以获得：

Magnitude of spatial distortions 空间变形的幅度

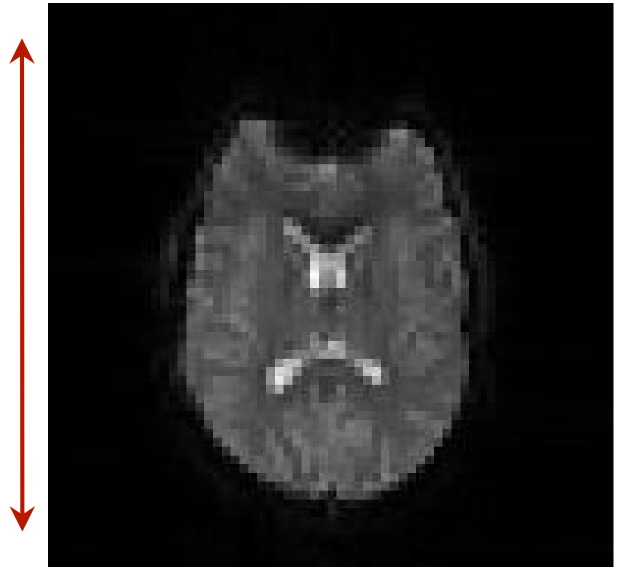
(phase-encode direction only 仅限相位编码方向)

Estimate of signal loss 估计信号损失

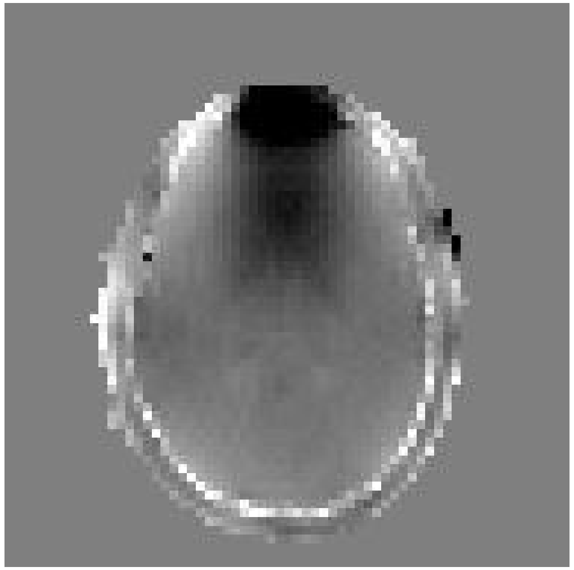
Only takes a few minutes to acquire one fieldmap - and it *massively* improves registration
只需要花几分钟采集一个场图就能大大地改善配准质量

Need a new fieldmap for each scanning session as it changes
(e.g. it depends on head orientation)
每一次扫描会话都需要采集一个新的场图，因为场图会随着扫描的更新而变化(如它取决于头的朝向)

PE



EPI



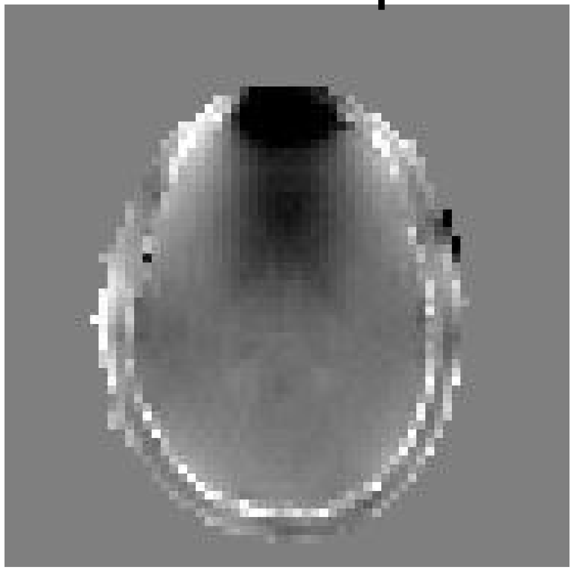
B_0 Fieldmap 场图

Unwarping with FUGUE
使用FUGUE进行去变形

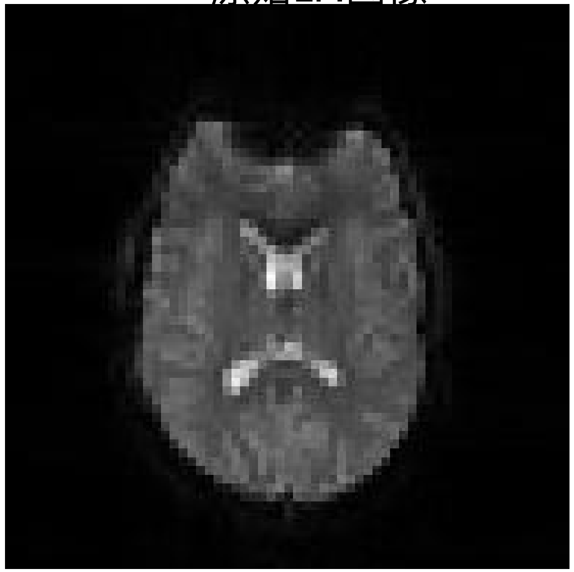
Used to improve **registration** of EPI and structural scan
用于提高EPI和结构像的配准质量

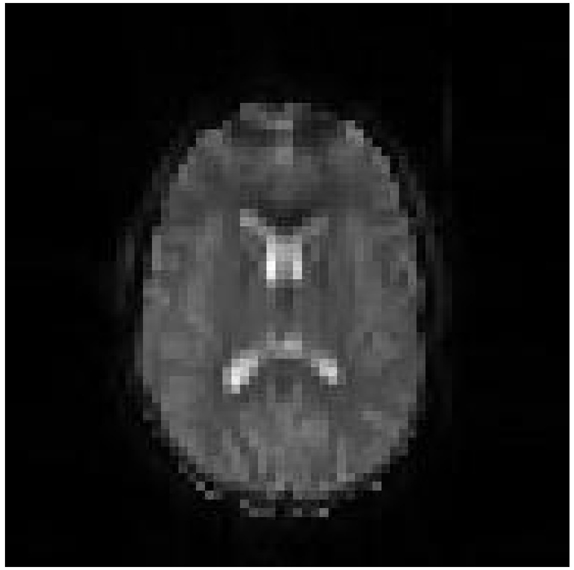
It **does not** restore signal in the frontal lobe
不能恢复额叶的信号

Fieldmap 场图



Original EPI
原始EPI图像





Unwarped EPI 去变形后的EPI图像

Unwarping with FUGUE

使用FUGUE进行去变形

Used to improve **registration** of EPI and structural scan
用于提高EPI和结构像的配准质量

It **does not** restore signal in the frontal lobe
不能恢复额叶的信号

It **does not** do anything about motion correction
没有进行头动校正

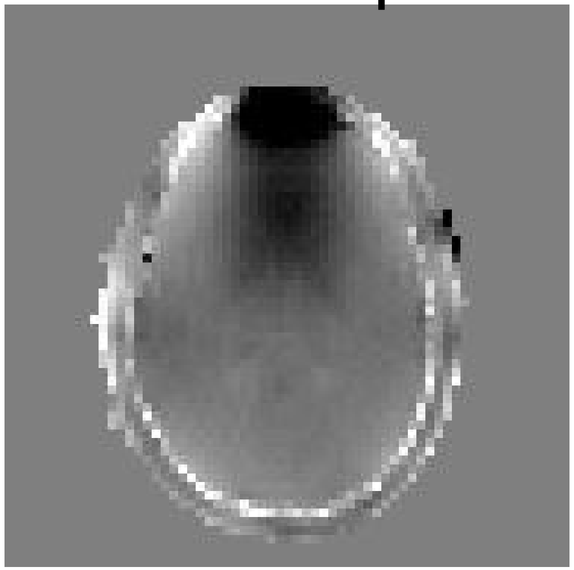
It **does** use fieldmap image to calculate distortion and “unwarp” EPI

使用场图来计算变形和对EPI图像进行“去变形”

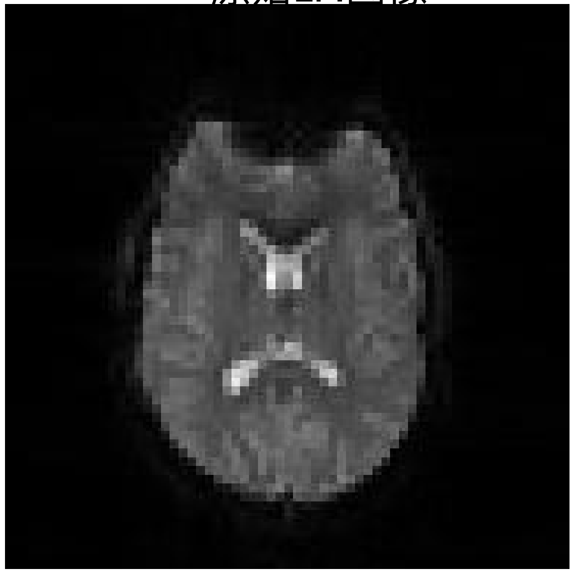
It **does** deweight areas with substantial signal loss *in the registration*

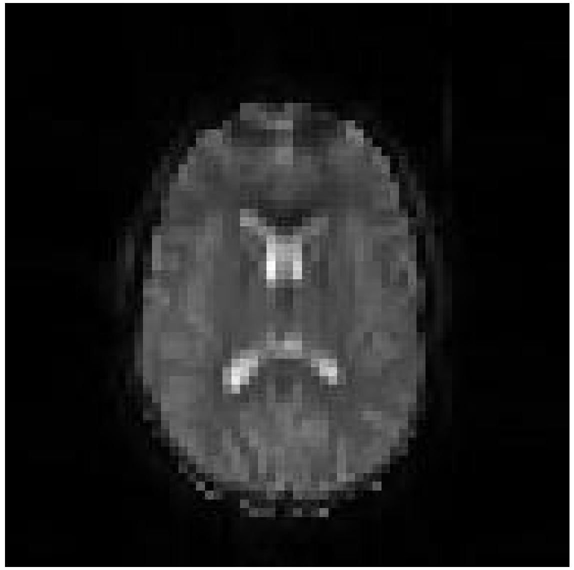
减少了在配准时出现大量信号丢失的区域的权重

Fieldmap 场图



Original EPI
原始EPI图像





Unwarped EPI 去变形后的EPI图像

Fieldmap Acquisition 场图采集

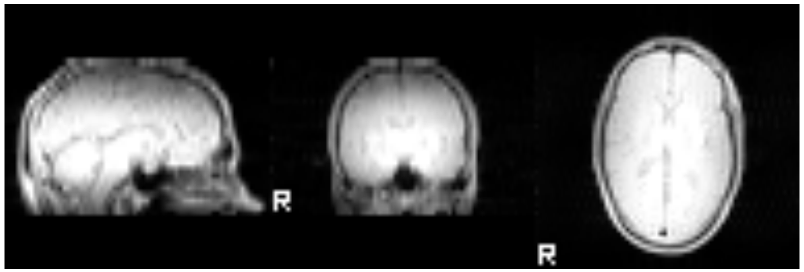
Fieldmaps are not yet standard sequences 场图采集目前还不是标准的序列

Only takes a few minutes to acquire - best either immediately before or after EPI scans (but this is not crucial)
只需要花几分钟采集-最好紧接在EPI扫描之前或之后(但这并不重要)

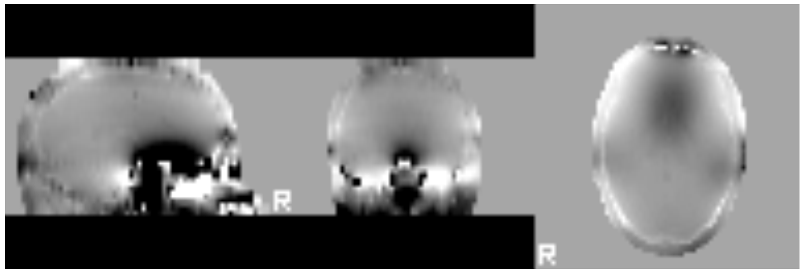
Three main types of acquisitions 有四种主要的采集方式:

- Gradient Echo 梯度回波 ✔
- Asymmetric Spin Echo 不对称自旋回波 ✔
- EPI 平面回波成像 ✘ Distortion & Signal Loss 变形&信号丢失
- Blip-reversed b=0 pair (EPI) 目标翻转b=0对(EPI) ✔

Each based on a pair of images with different TE (record these TE values)
每一种方法都基于一对具有不同回波时间TE的图像(记录这些TE值)



Magnitude part of fieldmap 场图的幅值部分



Phase difference of images 图像间的相位差异

Crucially requires the *phase information* (not only the magnitude, unlike the vast majority of other images) 关键的是需要相位信息（与绝大多数其他图像不同，不仅仅需要幅值信息）

Boundary-Based Registration (BBR)
基于边界的配准(BBR)

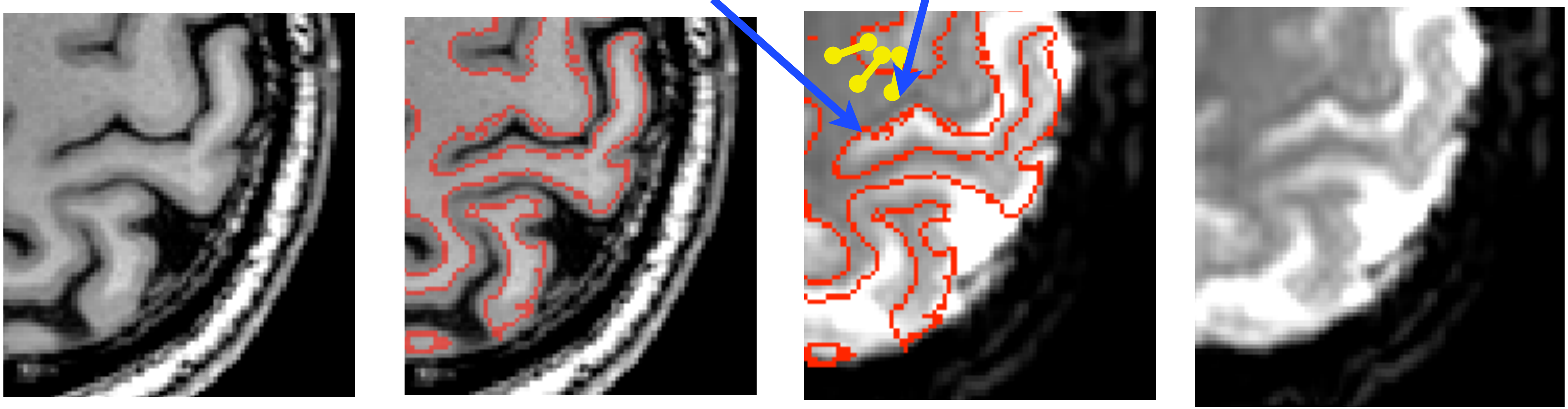
- *EPI to structural registration* (Greve & Fischl, NeuroImage, 2009)
  将EPI配准到结构空间
  - incorporates ***fieldmap*** correction (previously FUGUE)
    包括场图校正(之前提到的FUGUE)
  - used in FEAT (B0 unwarping) 在FEAT中使用(B0去变形)
- Uses ***white-matter boundaries*** (via T1w segmentation)
  使用白质边界(通过T1加权分割)
  - Need good structurals (not too much bias field) 需要好的结构像(没有太多的偏置场)
  - Also ***requires anatomical contrast in the EPI*** **还需要*EPI*中的解剖学对比**
  - Driven by intensity difference across boundary (samples) 由跨边界(样本)的强度差驱动
- More robust to pathologies and artefacts in EPI 较不受EPI图像的病理学异常和伪影的影响

T1w
T1加权

T1w + boundaries
T1加权+边界

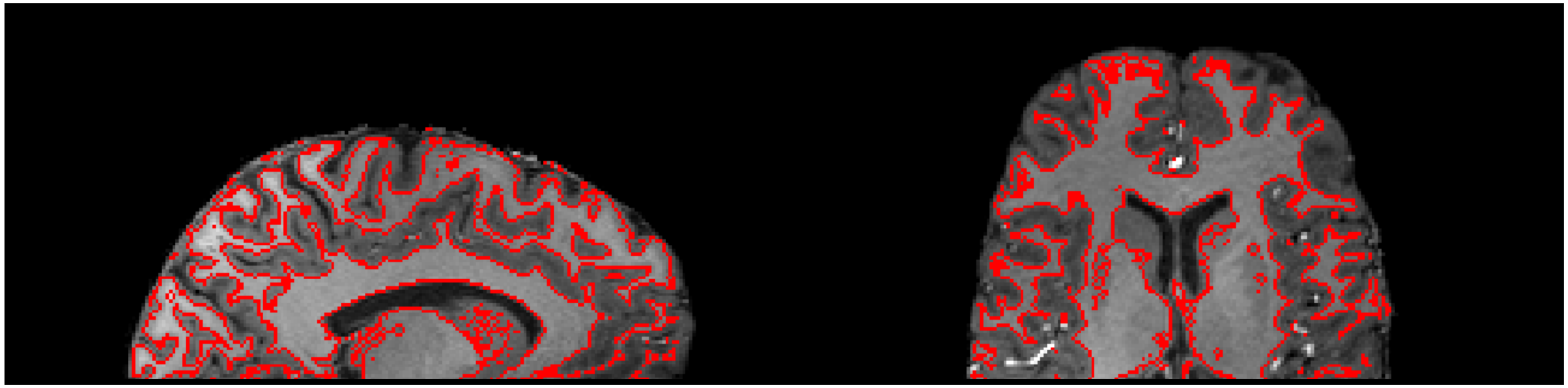
EPI + boundaries
EPI + 边界

EPI

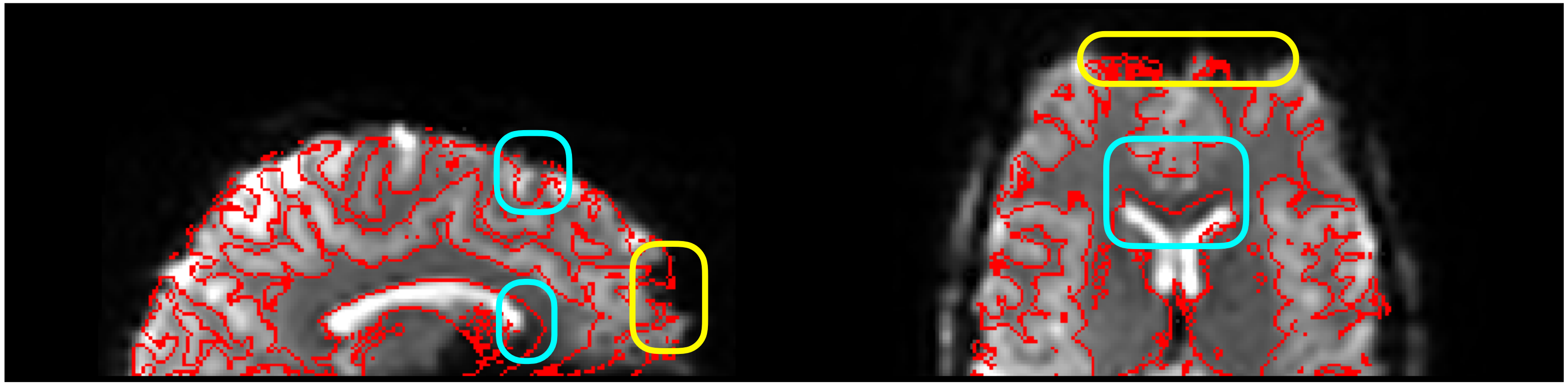


Distortion Correction 变形校正

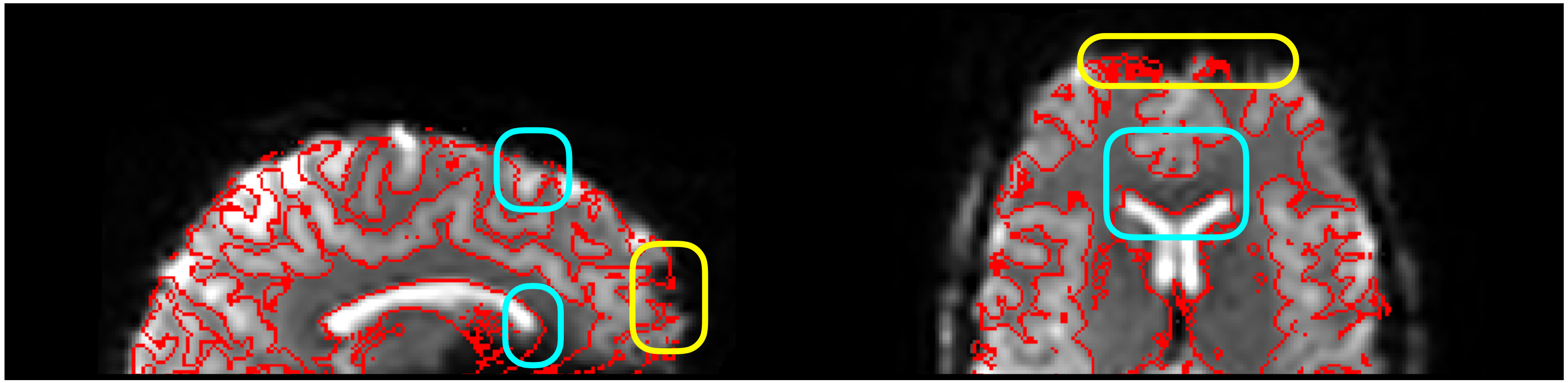
Structural Image 结构像



Registration without Distortion Correction 不做变形校正的配准

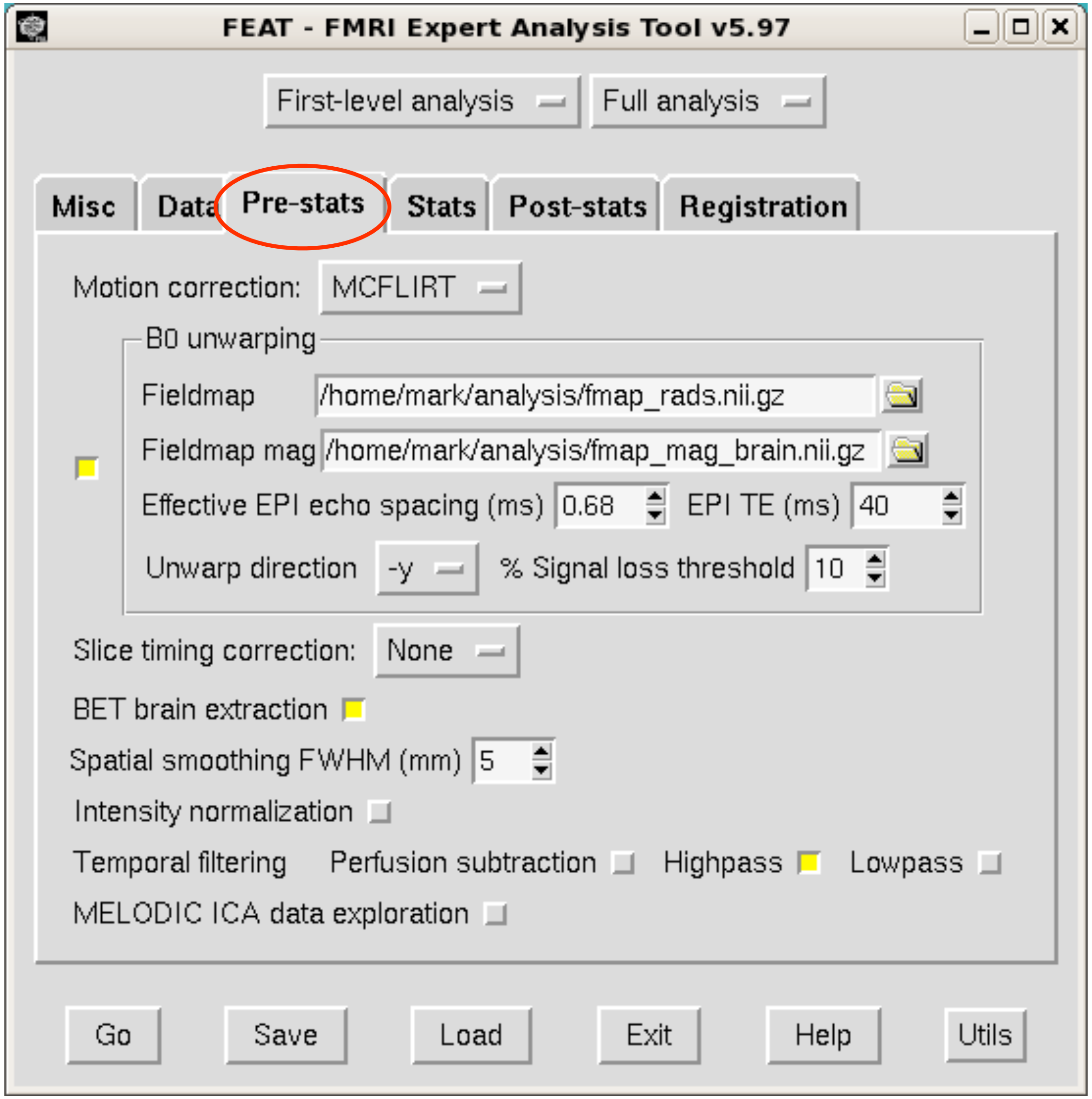


Registration with Distortion Correction 做了变形校正的配准



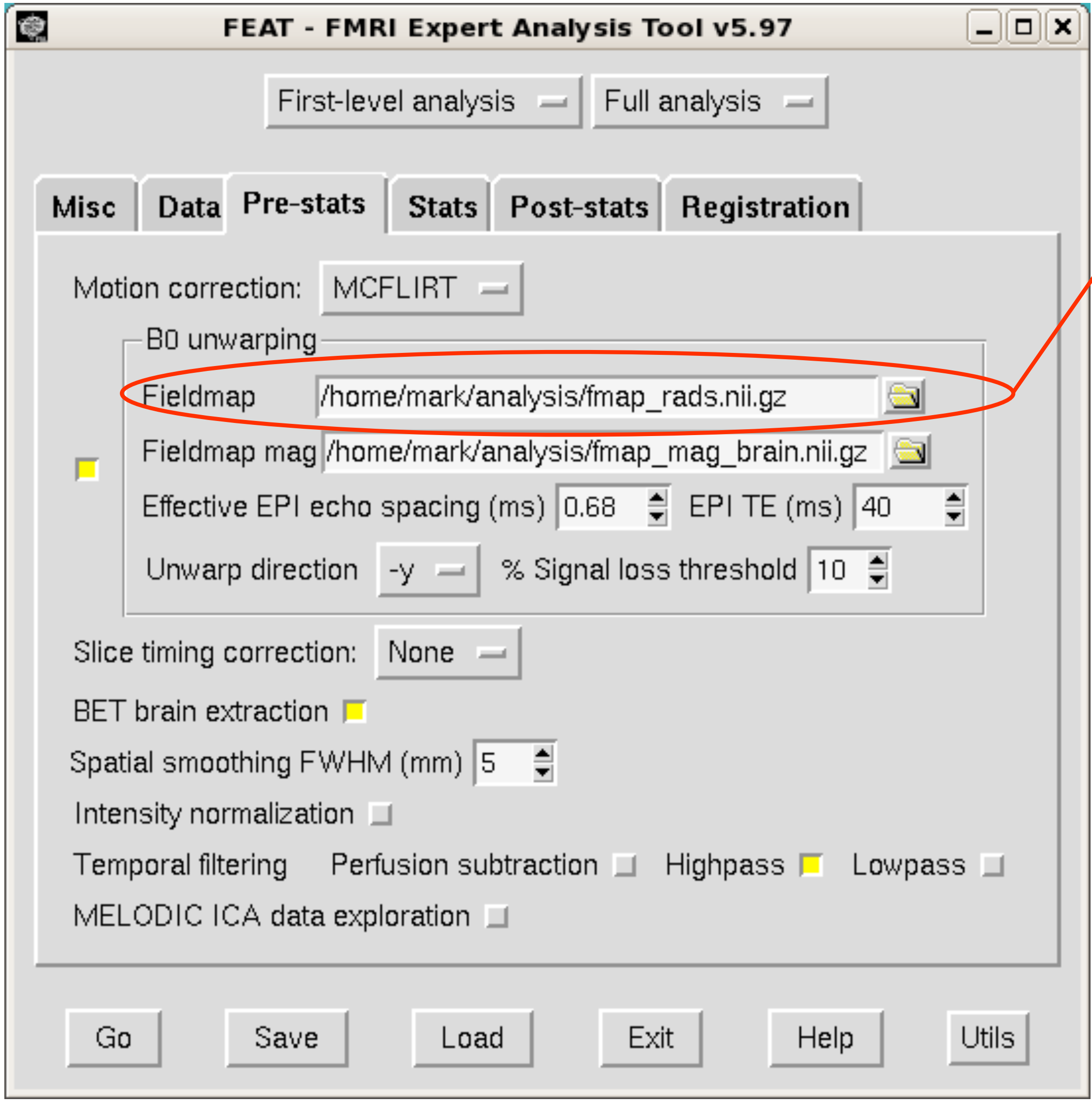
Distortion Correction within FEAT

在FEAT中进行变形校正



Distortion Correction within FEAT

在FEAT中进行变形校正



Fieldmap in rad/s

以rad/s为单位的场图

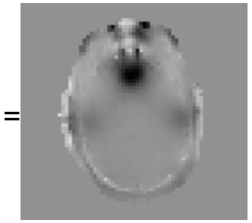
Phase difference (rad)

相位差(rad)

/ TE difference (sec)

TE差(s)

=

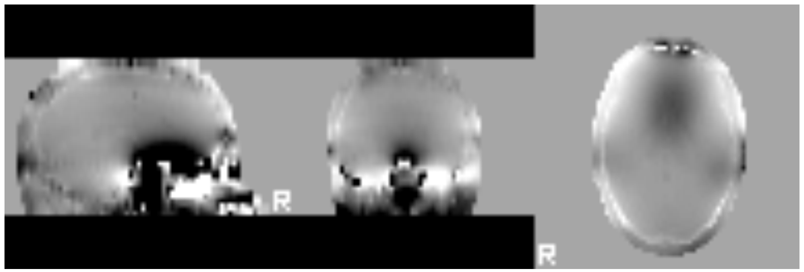


B_0 Field

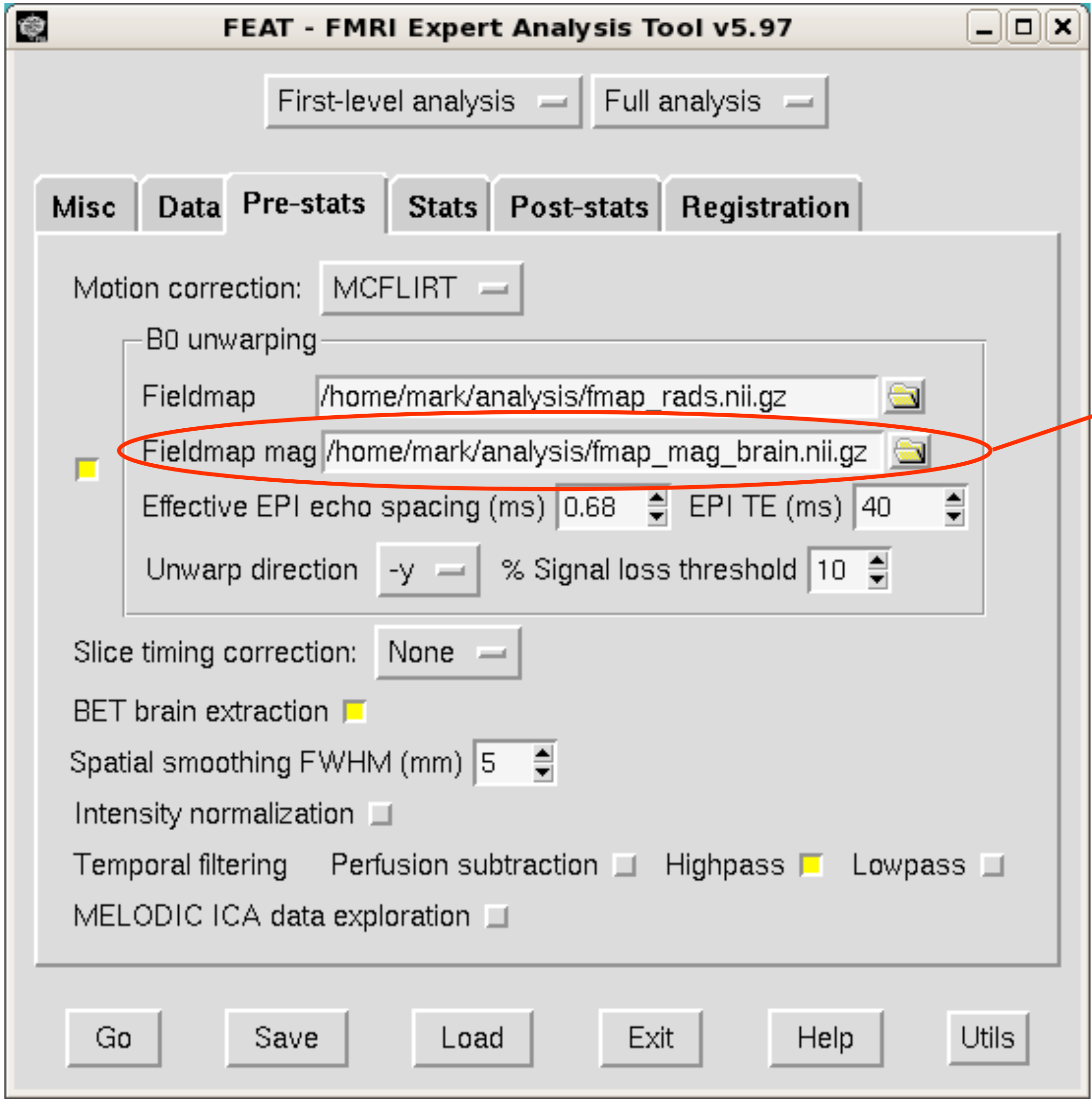
B0场(rad/s)

Need to prepare the fieldmap image 需要准备场图:

Fsl_prepare_fieldmap (for Siemens 西门子)



Distortion Correction within FEAT
在FEAT中进行变形校正



Input file = brain extracted file 输入文件=提取大脑后的文件

but also needs to find original* 也需要原文件*

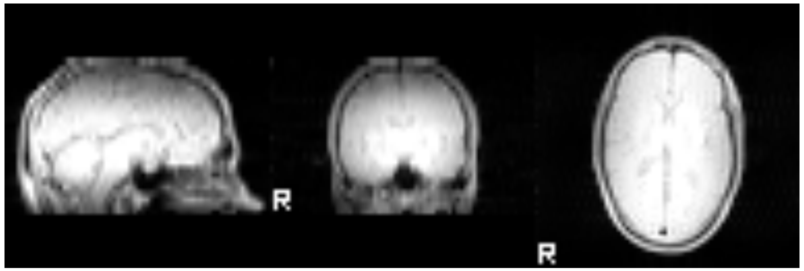
Fieldmap in rad/s

以rad/s为单位的场图

Fieldmap Magnitude

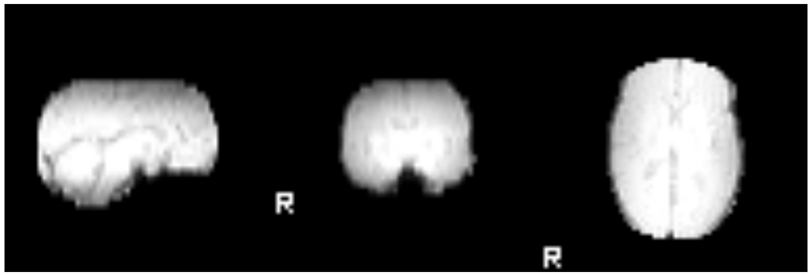
场图幅值

... needs this 需要这个 ...



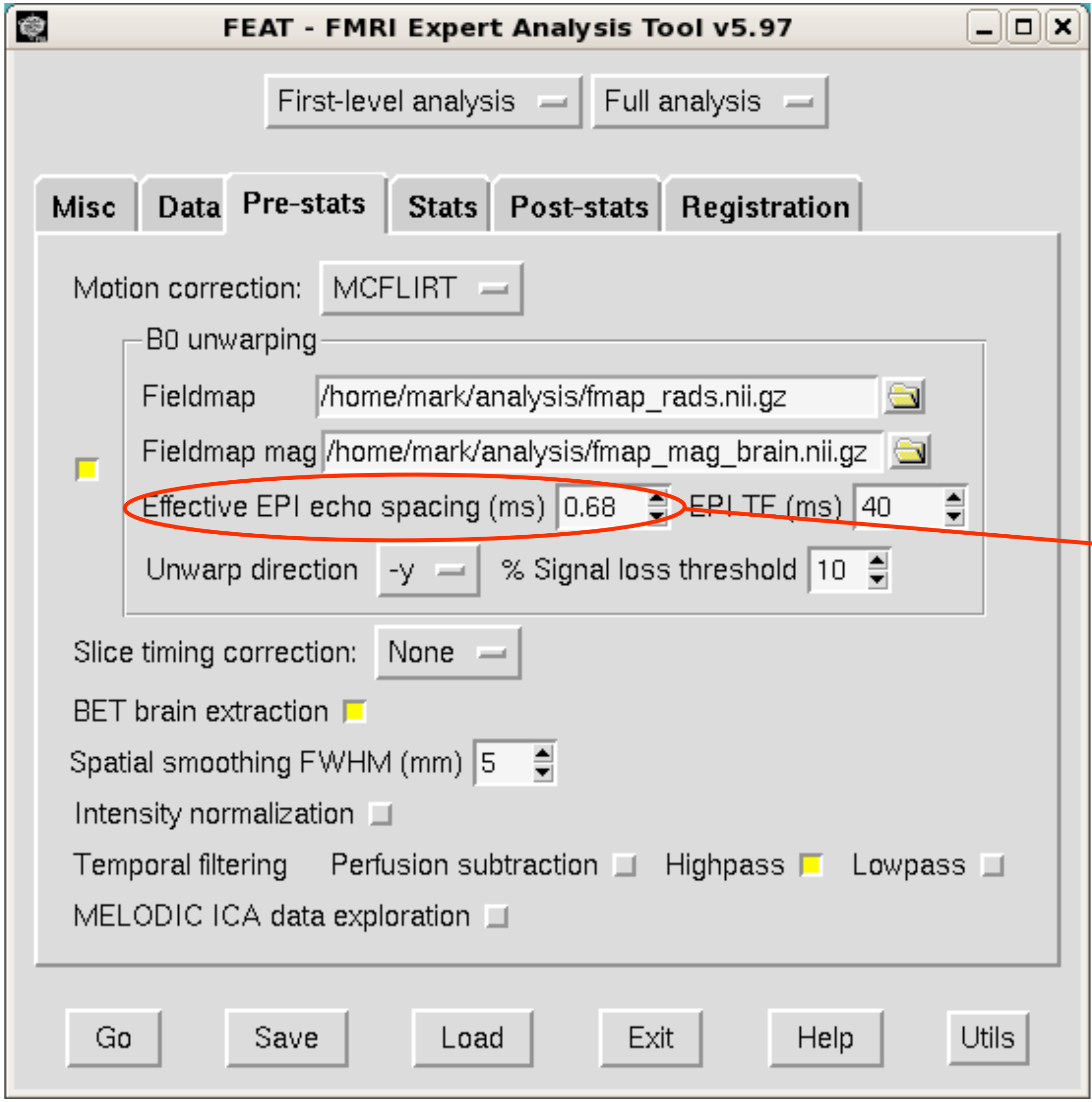
... and aggressive BET (leave **no** non-brain) for best performance

和BET(去除所有非脑组织)来获得最佳结果



Distortion Correction within FEAT

在FEAT中进行变形校正



Fieldmap in rad/s

以rad/s为单位的场图

Fieldmap Magnitude

场图幅值

EPI echo spacing (ms)

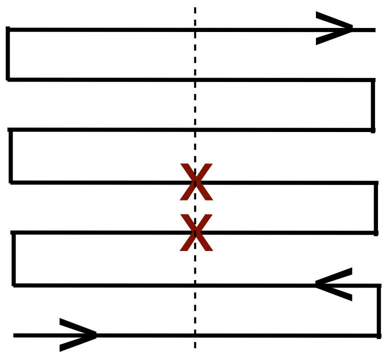
EPI回波间隔(ms)

Also called dwell time

也称停留时间

Normally about 0.5-0.7ms

通常约0.5-0.7ms



Time between echos in k-space

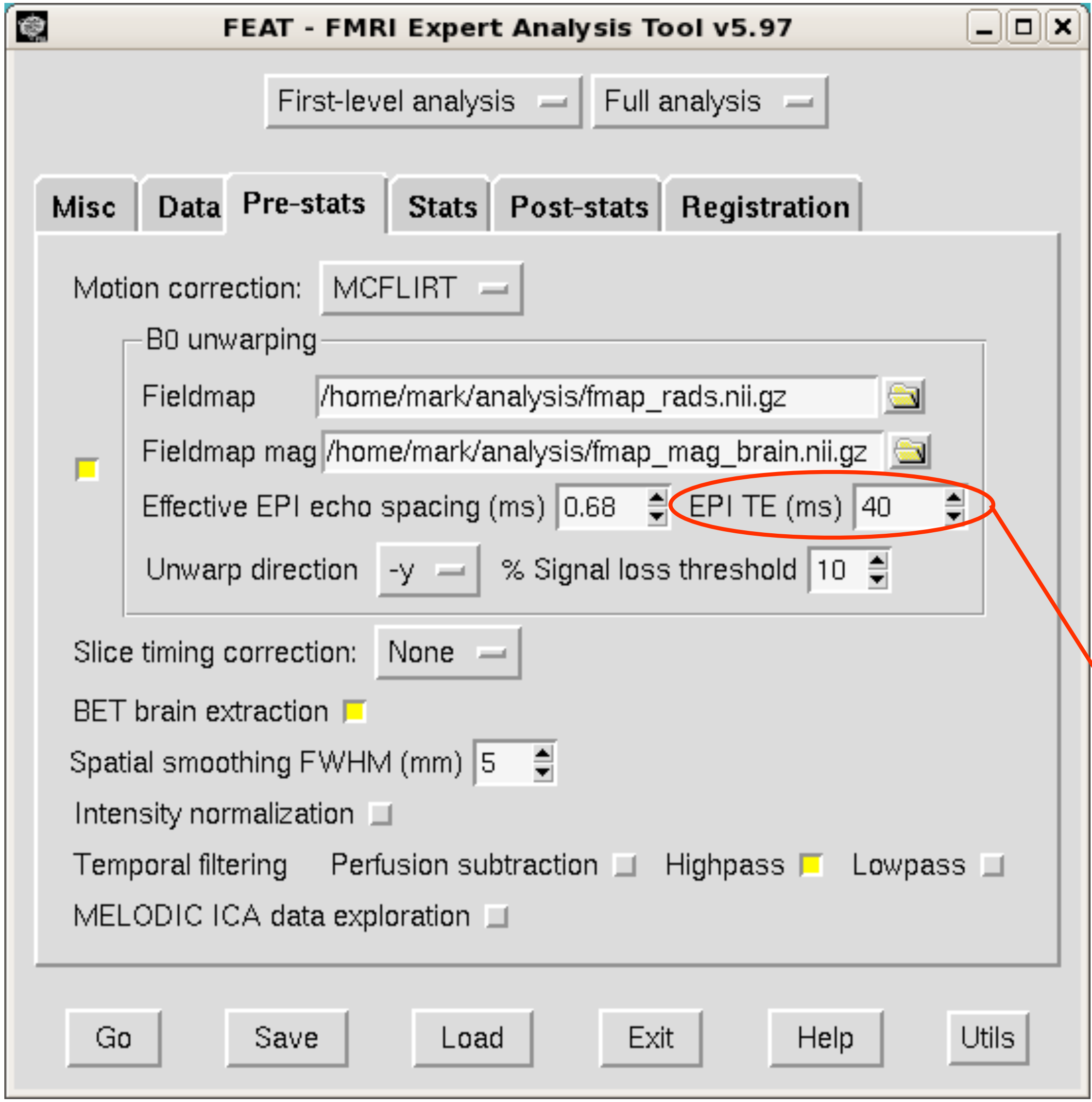
k空间内的回波间隔时间

Divide value by any acceleration factor

除以任何加速系数

Distortion Correction within FEAT

在FEAT中进行变形校正



Fieldmap in rad/s

以rad/s为单位的场图

Fieldmap Magnitude

场图幅值

EPI echo spacing (ms)

EPI回波间隔(ms)

EPI echo time (ms)

EPI回波时间(ms)

Normally about 30-40ms at 3T

在3T中通常约30-40ms

Distortion Correction within FEAT

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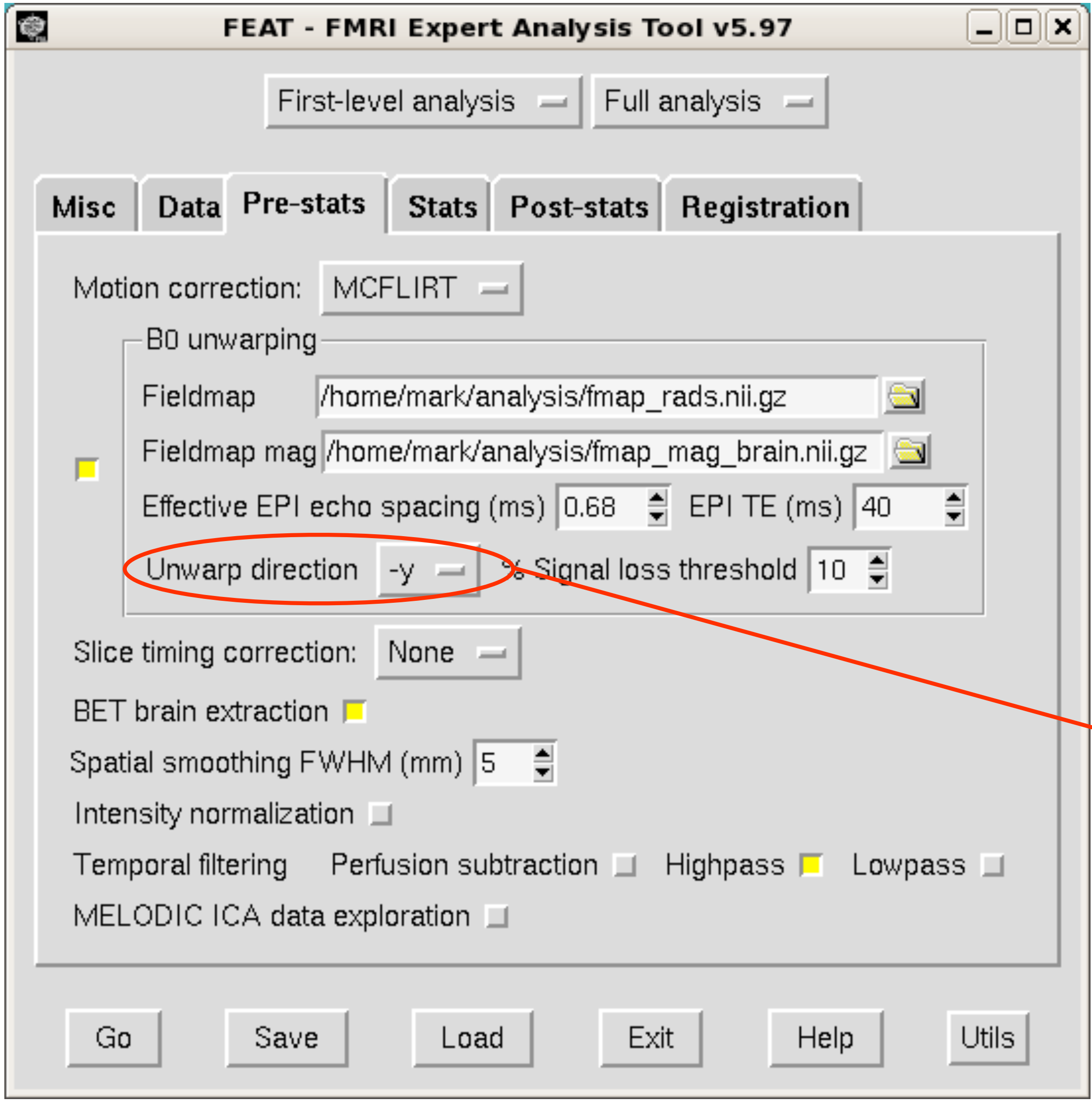


Fieldmap in rad/s
以rad/s为单位的场图

Fieldmap Magnitude
场图幅值

EPI echo spacing (ms)
EPI回波间隔(ms)

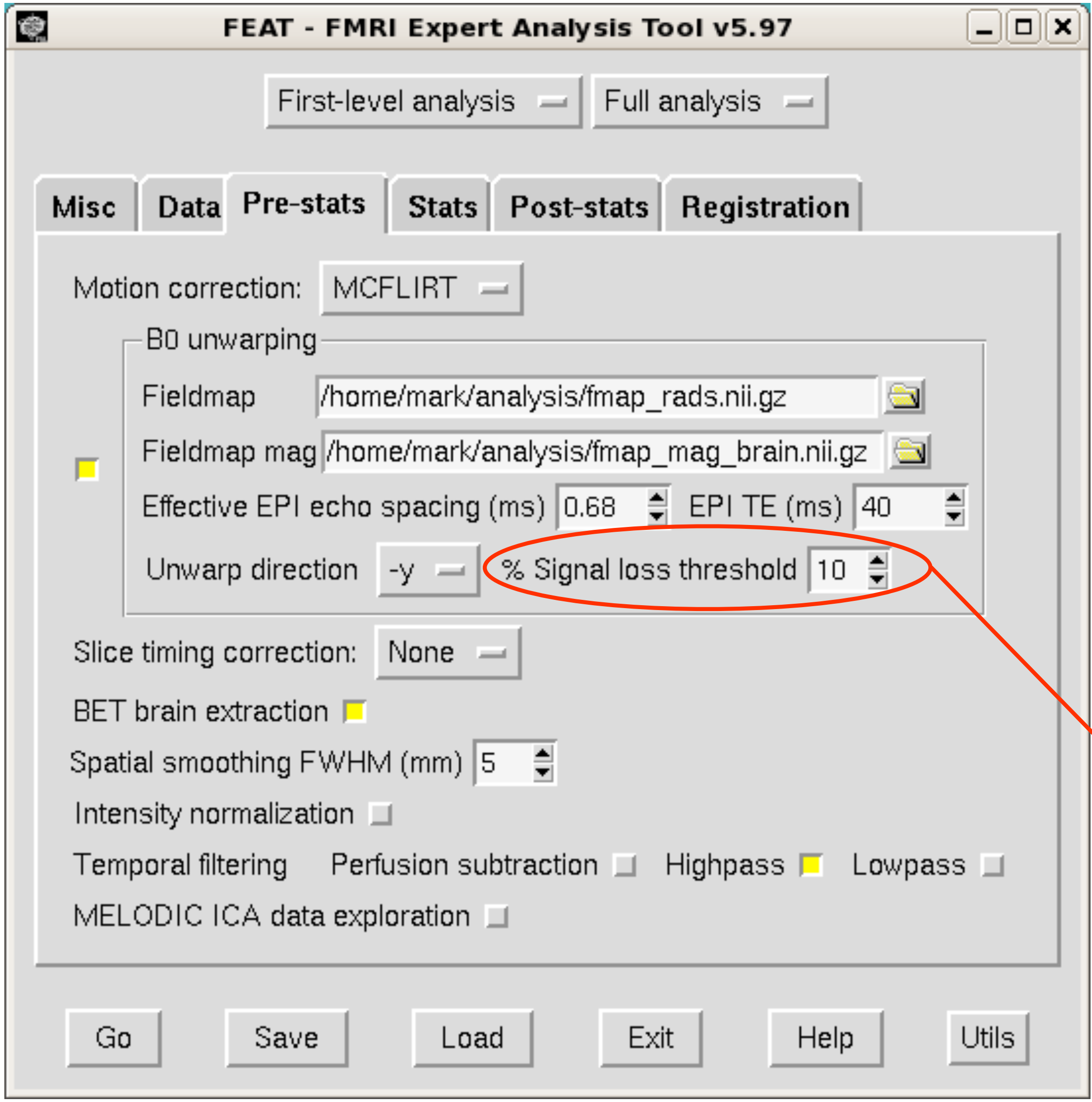
EPI echo time (ms)
EPI回波时间(ms)

Unwarp (PE) direction
去变形(PE)方向

- Often A-P but can be anything
  通常为A-P但也可能是其他方向
- Cannot tell if it is + or -
  很难分辨究竟是+或-
- *Try both* and see what works (see practical)
  建议两者都尝试以下，看看哪一个有效(见实操)

Distortion Correction within FEAT

在FEAT中进行变形校正



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EPI echo spacing (ms)
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EPI echo time (ms)
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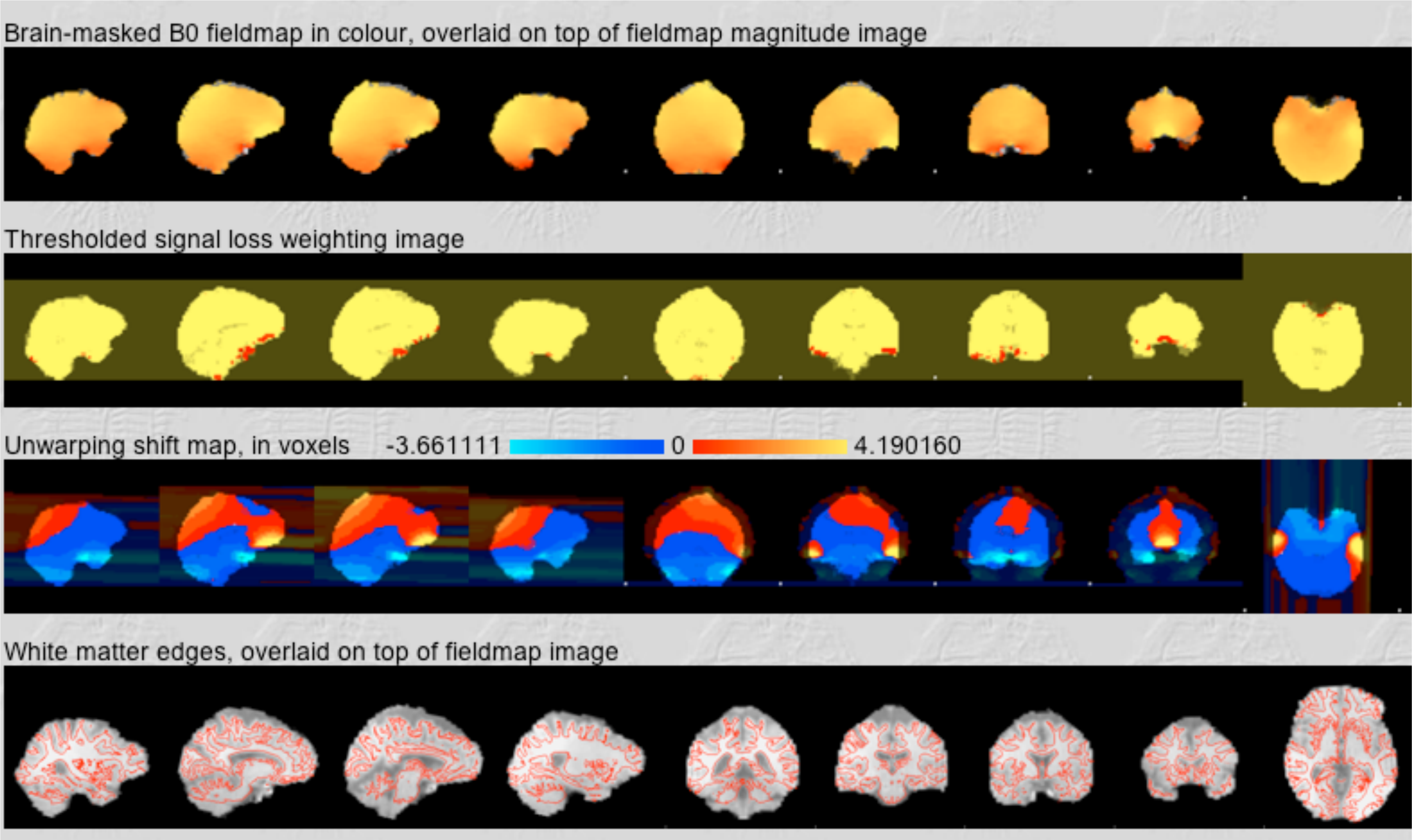
Unwarp (PE) direction
去变形(PE)方向

Signal loss thresh %
信号损失阈限%

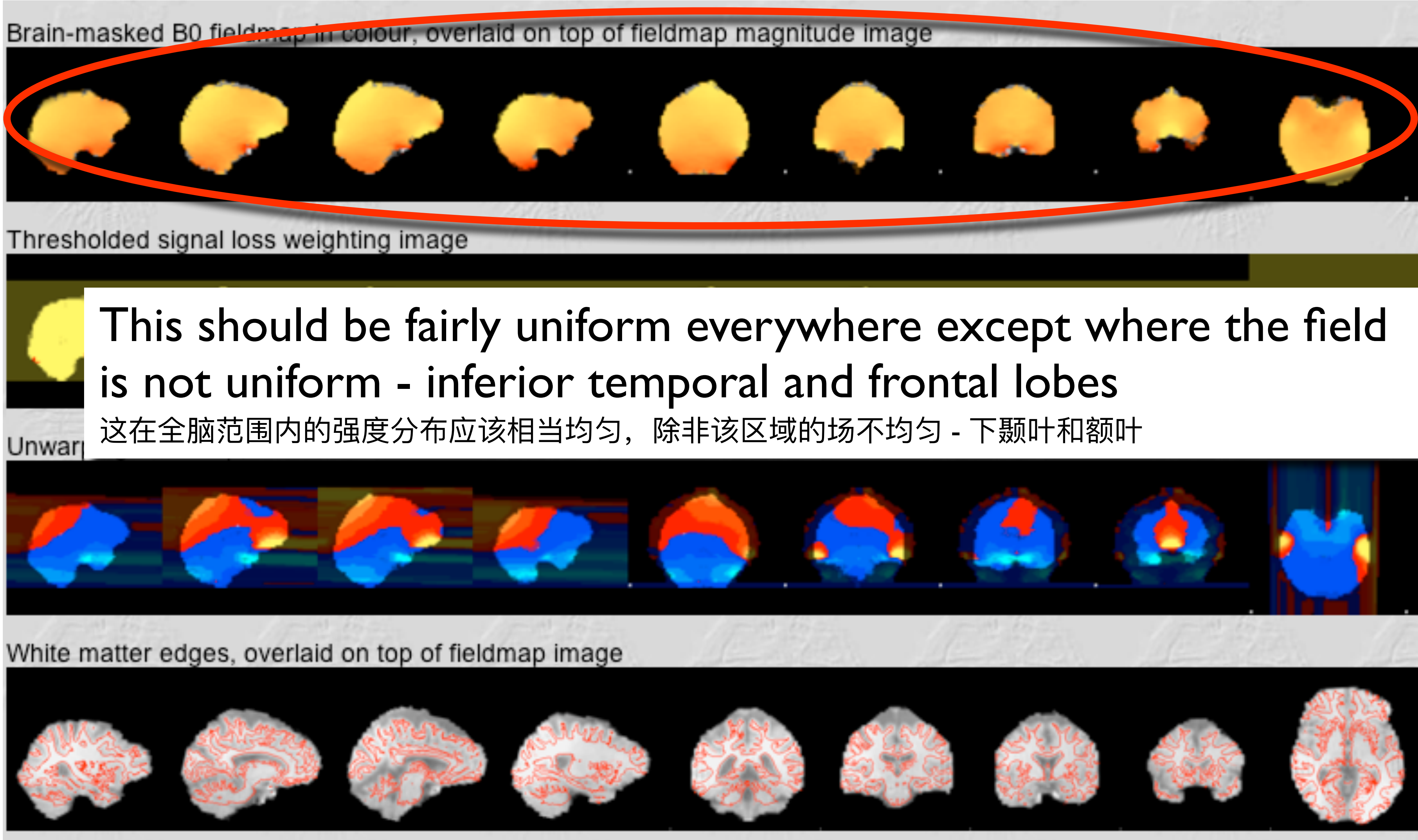
Ignore voxels with more than this signal loss in registration
在配准中忽视信号损失大于该值的体素

Fieldmap use in FEAT

场图在FEAT中的使用



Fieldmap use in FEAT
场图在FEAT中的使用

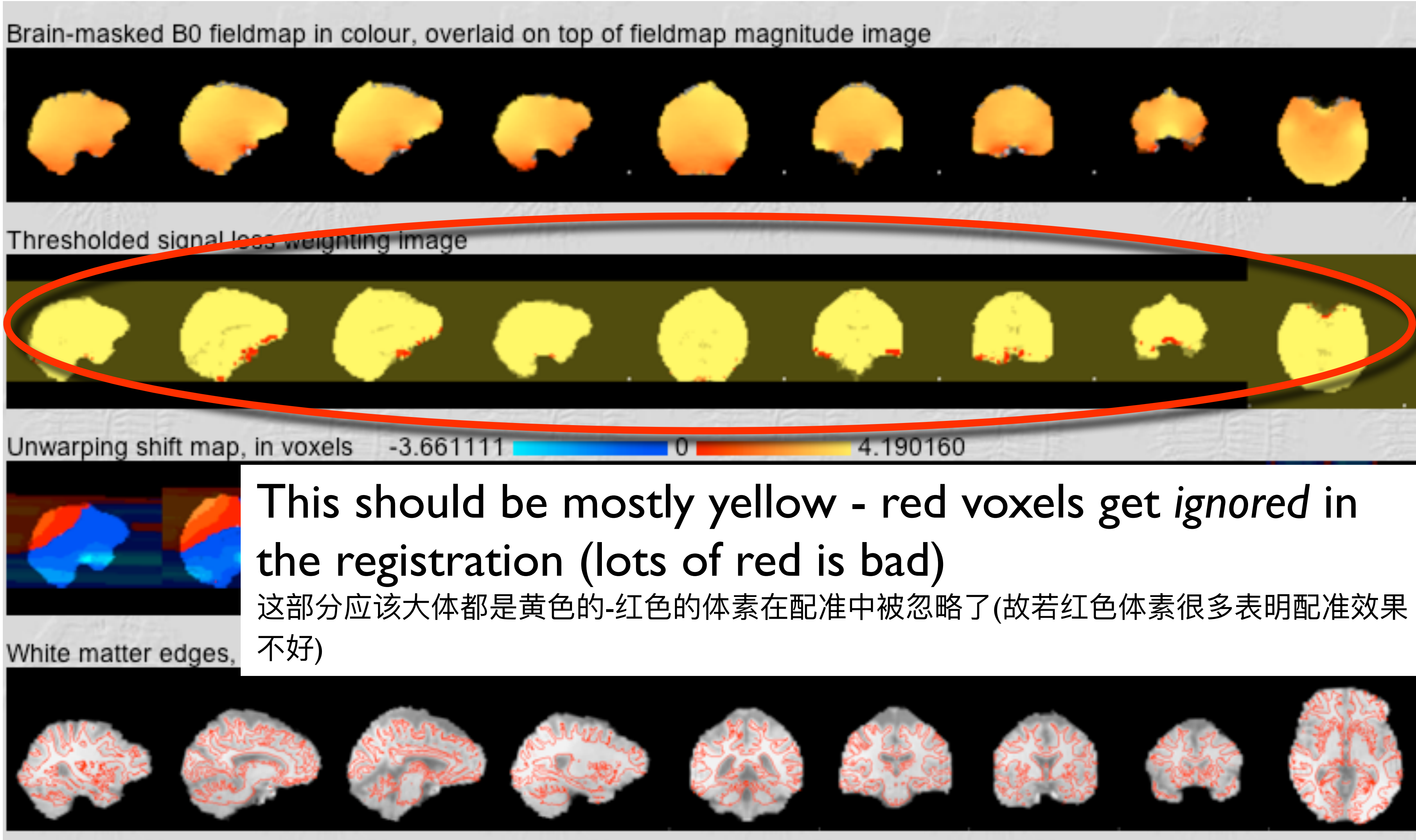


This should be fairly uniform everywhere except where the field is not uniform - inferior temporal and frontal lobes

这在全脑范围内的强度分布应该相当均匀，除非该区域的场不均匀 - 下颞叶和额叶

Fieldmap use in FEAT

场图在FEAT中的使用

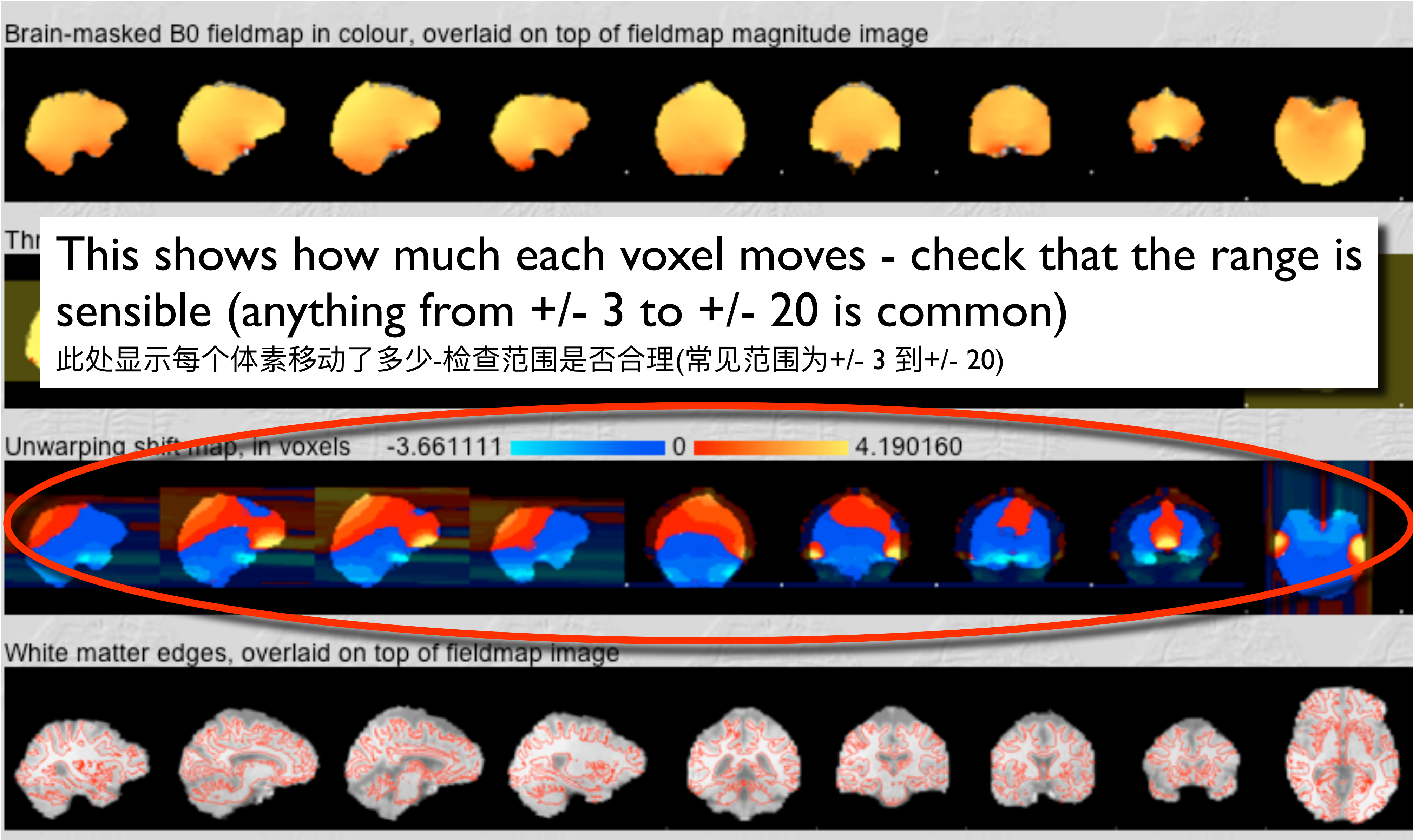


This should be mostly yellow - red voxels get *ignored* in the registration (lots of red is bad)

这部分应该大体都是黄色的-红色的体素在配准中被忽略了(故若红色体素很多表明配准效果不好)

Fieldmap use in FEAT

场图在FEAT中的使用

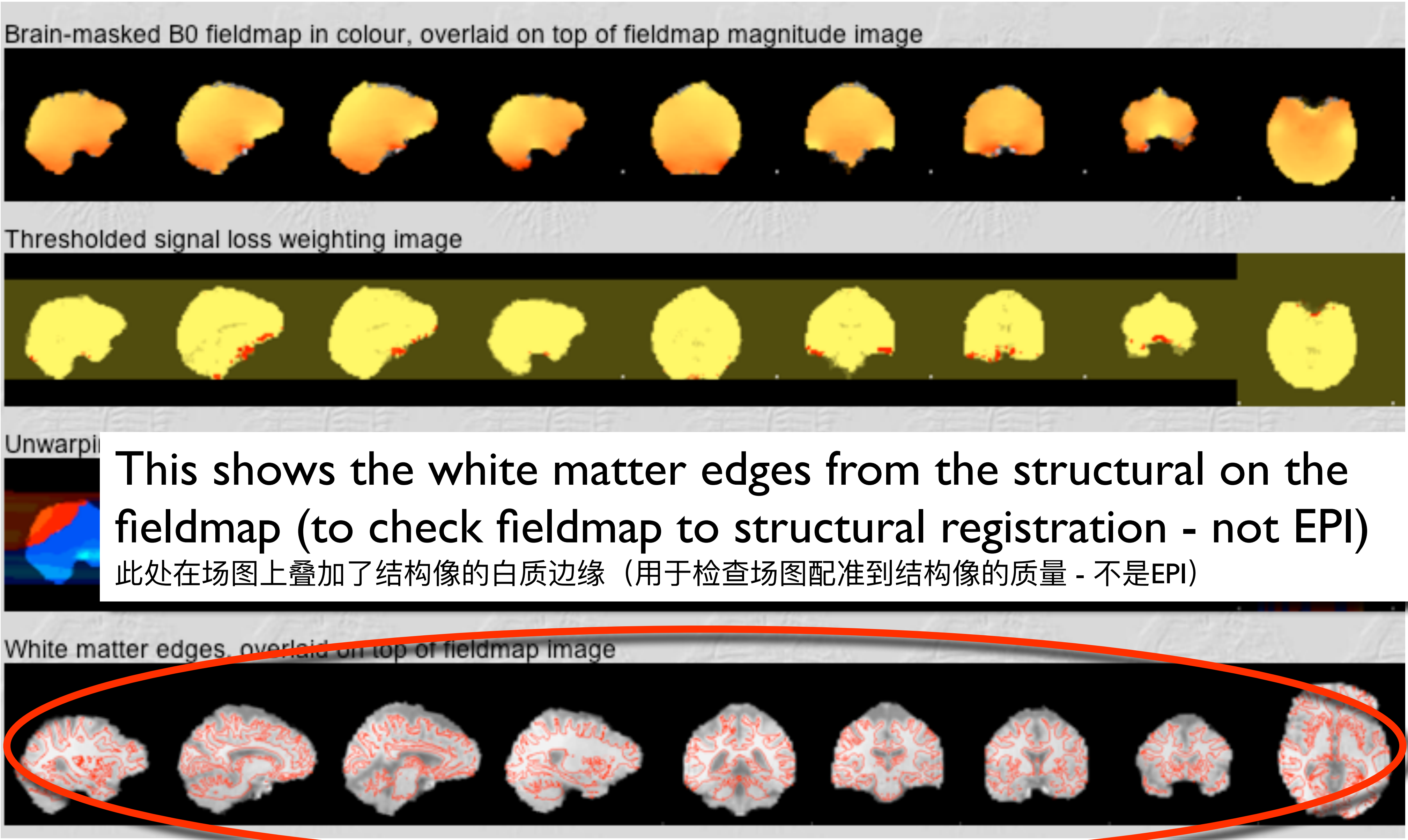


This shows how much each voxel moves - check that the range is sensible (anything from +/- 3 to +/- 20 is common)

此处显示每个体素移动了多少-检查范围是否合理(常见范围为+/- 3 到+/- 20)

Fieldmap use in FEAT

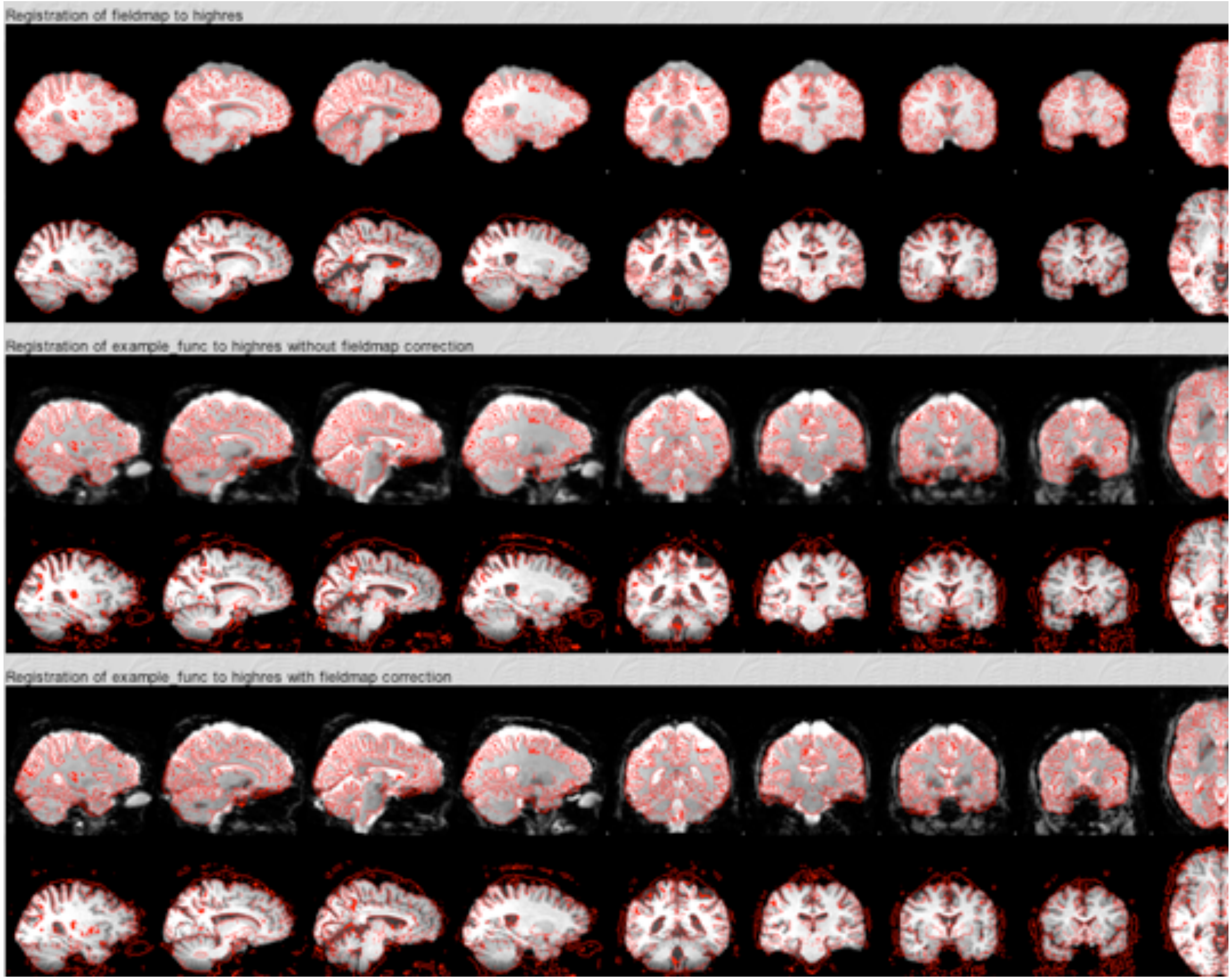
场图在FEAT中的使用



This shows the white matter edges from the structural on the fieldmap (to check fieldmap to structural registration - not EPI)

此处在场图上叠加了结构像的白质边缘（用于检查场图配准到结构像的质量 - 不是EPI）

Fieldmap use in FEAT
场图在FEAT中的使用

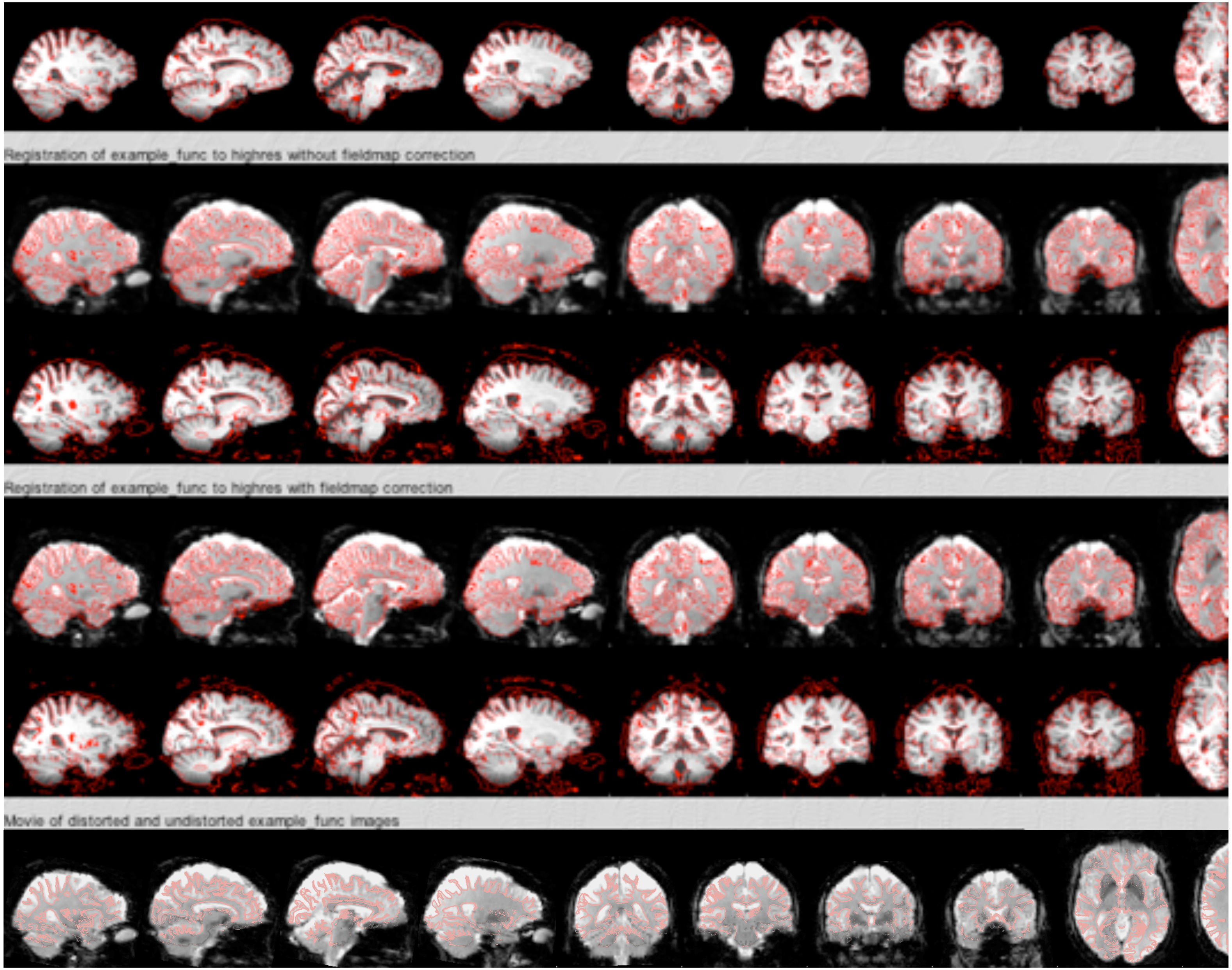


Fieldmap to highres (structural)
场图配准到highres(结构像)

Functional (EPI) to highres (structural)
- no correction
功能像(EPI)配准到highres(结构像)
- 无校正

Functional (EPI) to highres (structural)
- with fieldmap correction
功能像(EPI)配准到highres(结构像)
- 有场图校正

Fieldmap use in FEAT
场图在FEAT中的使用



Functional (EPI) to highres (structural)
- no correction

功能像(EPI)配准到highres(结构像)
- 无校正

Functional (EPI) to highres (structural)
- with fieldmap correction

功能像(EPI)配准到highres(结构像)
- 有场图校正

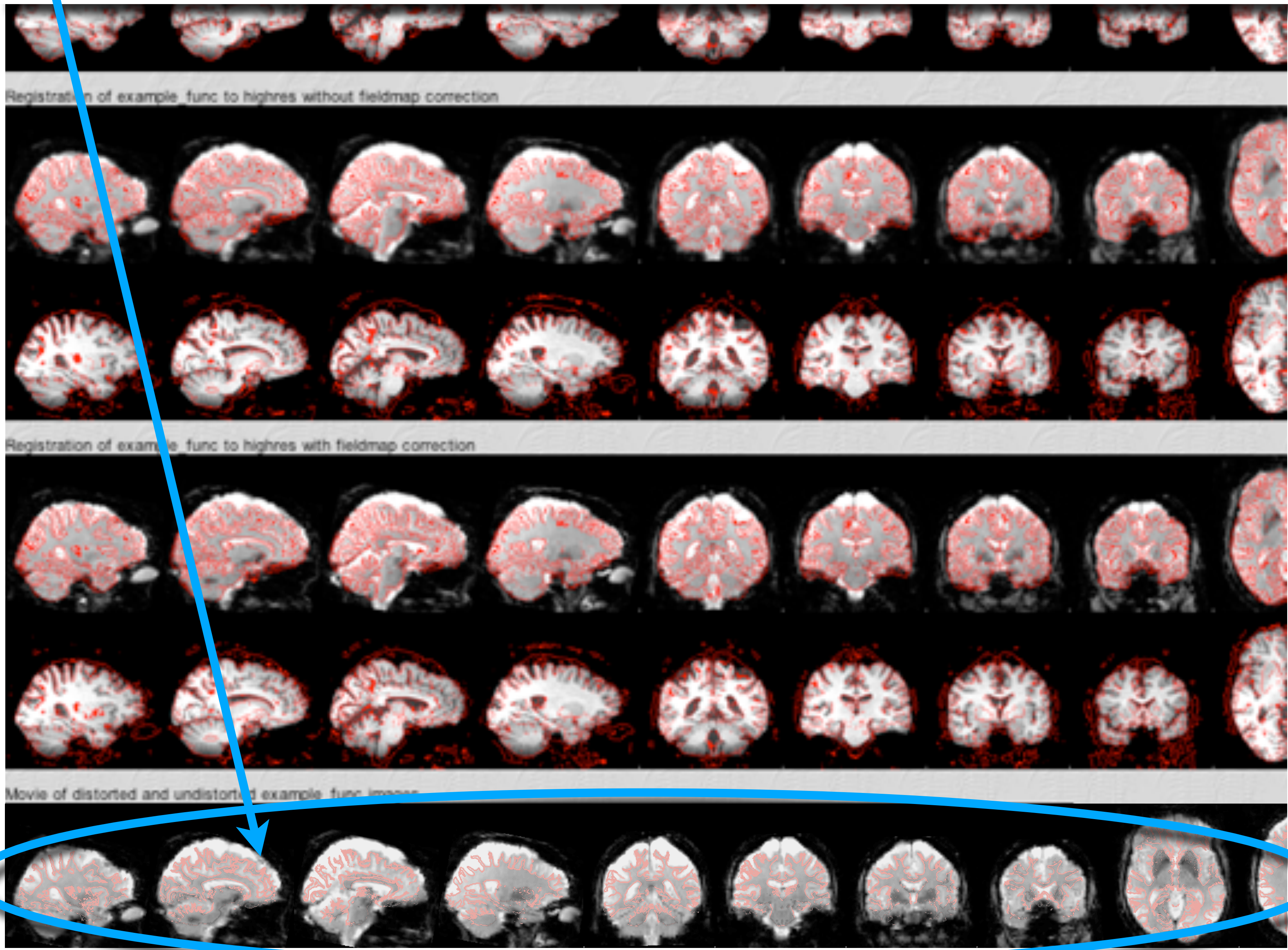
Movie of EPI with and without correction

EPI校正前后的影片

Fieldmap use in FEAT

场图在FEAT中的使用

Look for areas where unwarping (correction) changes brain shape
检查去变形(校正)改变了哪些区域的大脑形状



Functional (EPI) to highres (structural) - no correction
功能像(EPI)配准到highres(结构像) - 无校正

Functional (EPI) to highres (structural) - with fieldmap correction
功能像(EPI)配准到highres(结构像) - 有场图校正

Movie of EPI with and without correction
EPI校正前后的影片

Fieldmap use in FEAT

场图在FEAT中的使用

Look for areas where unwarping (correction) changes brain shape
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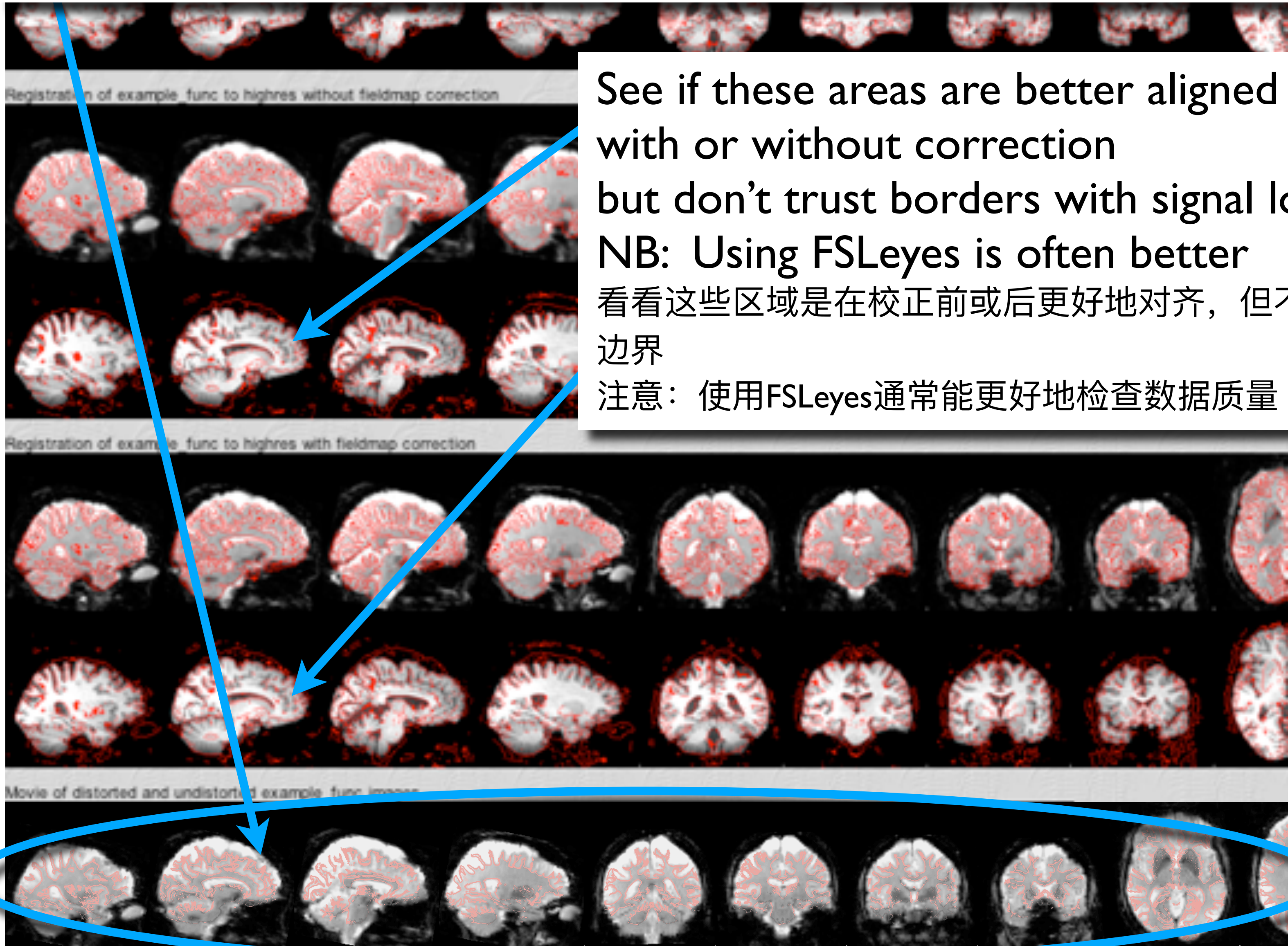


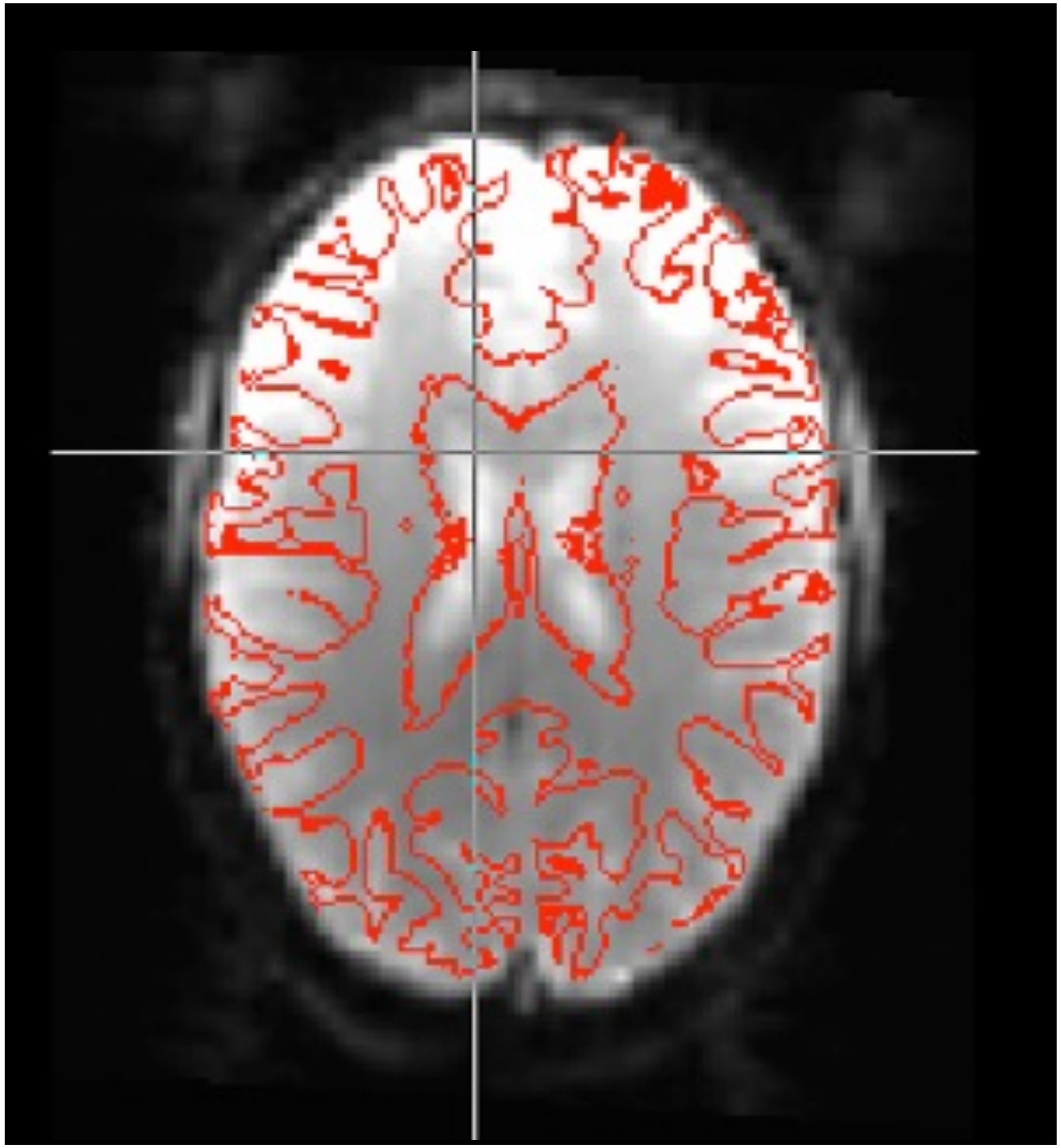
See if these areas are better aligned
with or without correction
but don't trust borders with signal loss areas
NB: Using FSLeyes is often better
看看这些区域是在校正前或后更好地对齐，但不要相信信号丢失区域的边界
注意：使用FSLeyes通常能更好地检查数据质量

highres (structural)
- with fieldmap correction
功能像(EPI)配准到
highres(结构像)
- 有场图校正

Movie of EPI with and without correction
EPI校正前后的影片

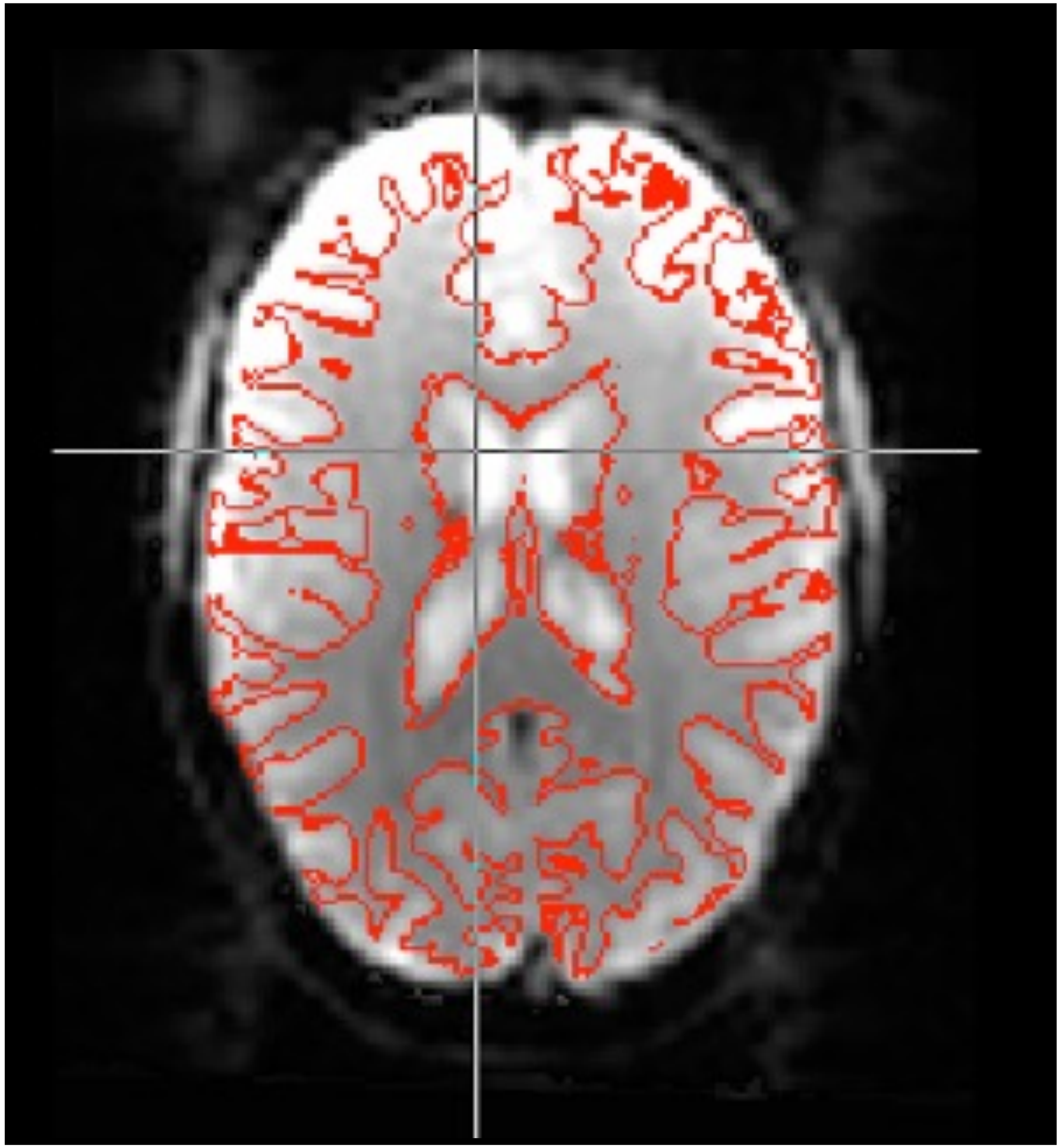
BBR and Fieldmaps
基于边界的配准和场图

Standard FLIRT
标准FLIRT



BBR and Fieldmaps
基于边界的配准和场图

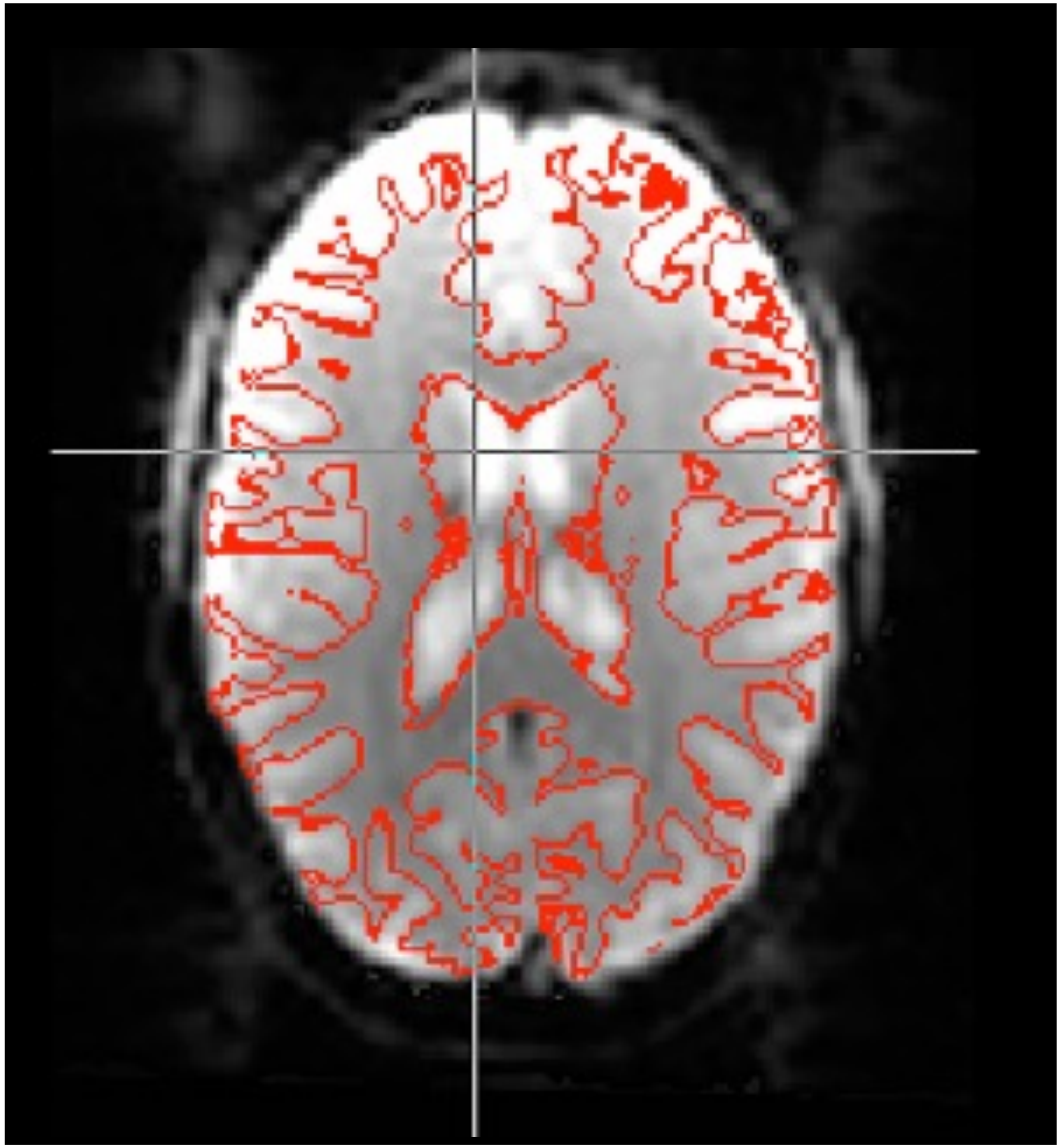
BBR FLIRT



BBR and Fieldmaps

基于边界的配准和场图

BBR FLIRT
with Fieldmap
使用了场图的BBR FLIRT

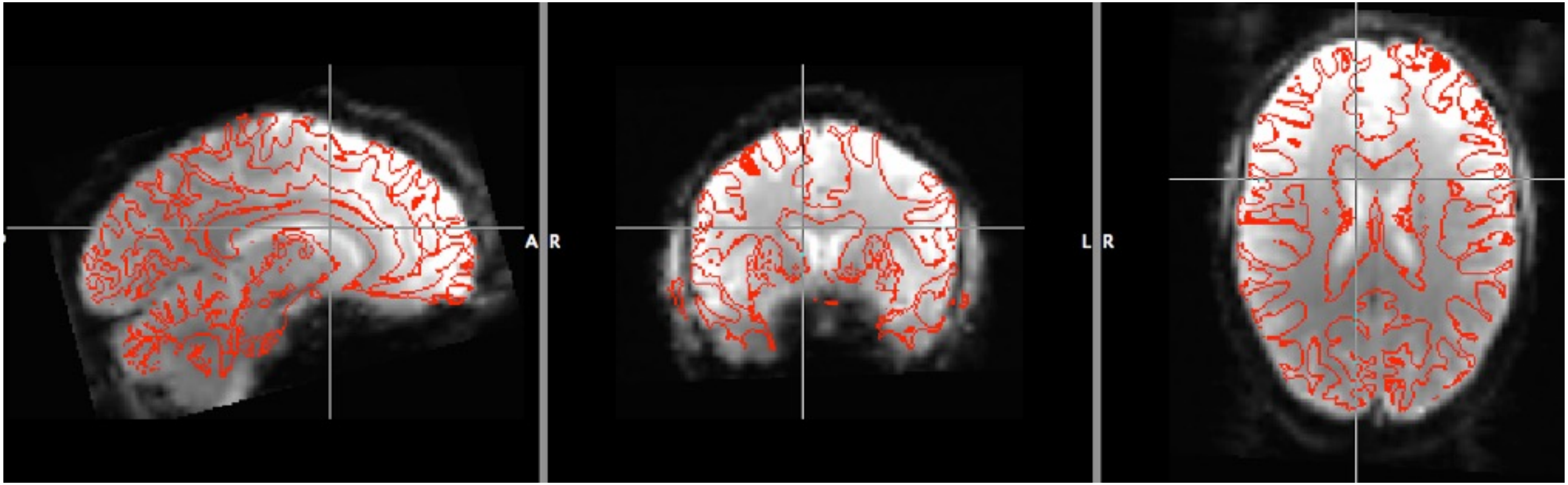


BBR and Fieldmaps

基于边界的配准和场图

Standard FLIRT

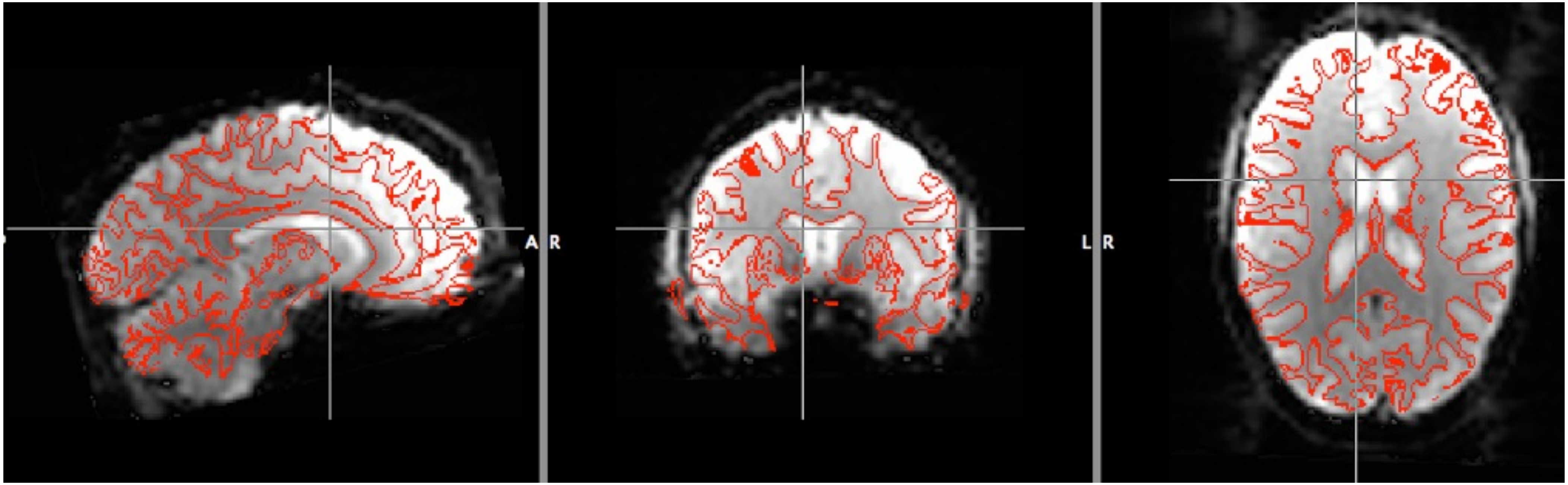
标准 FLIRT



BBR and Fieldmaps

基于边界的配准和场图

BBR FLIRT

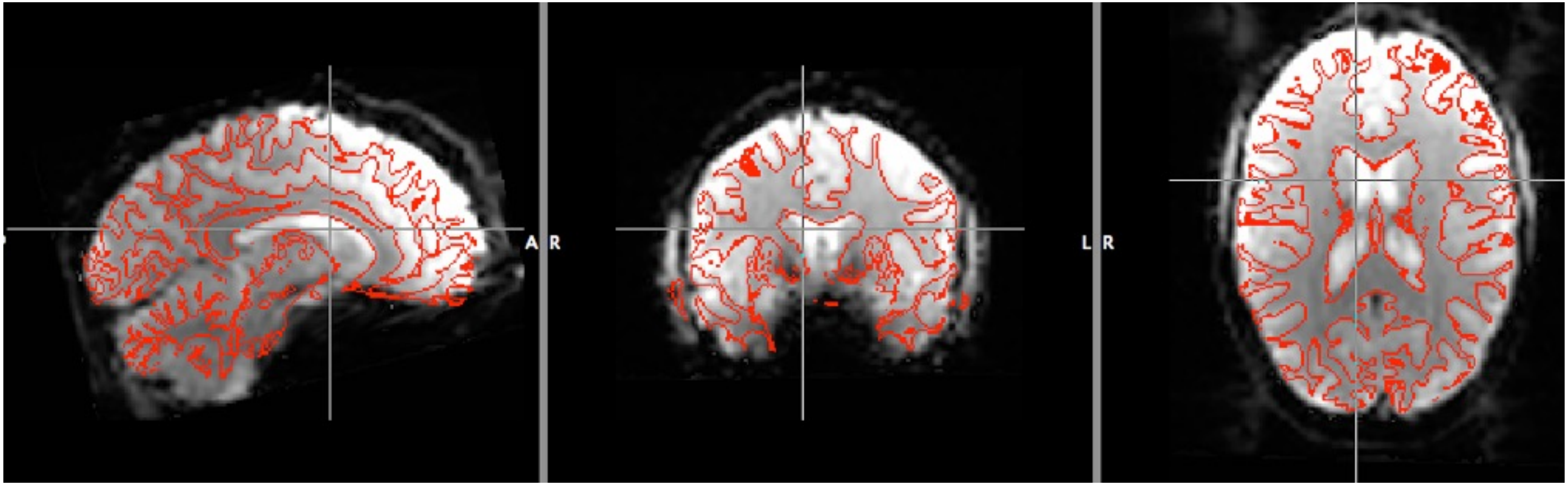


BBR and Fieldmaps

基于边界的配准和场图

BBR FLIRT with Fieldmap

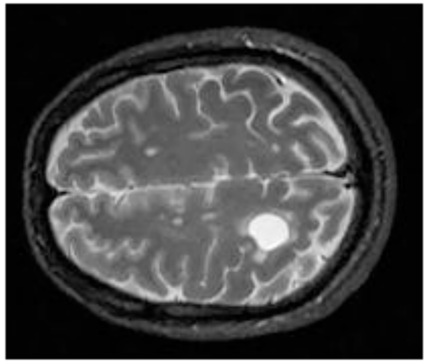
使用了场图的BBR FLIRT



Overview 概述

- Brain Extraction (BET) 大脑提取（BET）
- Registration concepts (FLIRT & FNIRT) 配准概念(FLIRT & FNIRT)
- Practical applications (FLIRT & FNIRT) 实际应用(FLIRT & FNIRT)
  - Single-stage registration 单步配准
  - Multi-stage registrations 两步配准
  - EPI distortion correction EPI变形校正
  - Pathological image registration 病理异常图像配准

Case Study 案例分析



Scenario 场景:

Have images containing a known pathology (or artefact) which looks different in different images

图像中包含一些不同于其他图像的未知病理学异常(或伪影)

For example, some sequences (e.g. FLAIR) highlight lesions that are hard to see in other sequences

例如某些序列(如FLAIR)会突出其他序列很难发现的损伤

Objective 目的:

Align the images based on the healthy tissue, but “ignoring” the area of the pathology (or artefact)

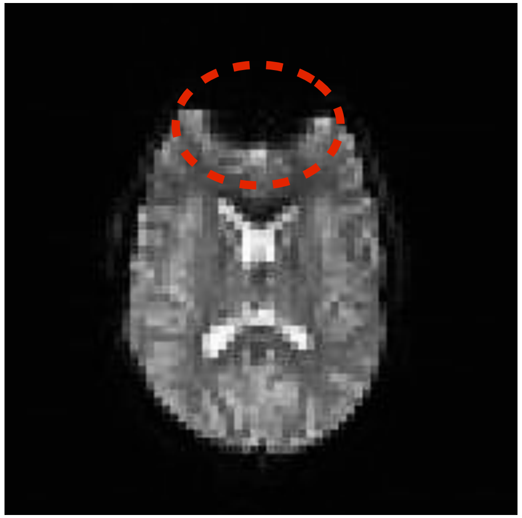
基于健康组织，“忽视”异常(或伪影)区域来对齐图像

Solution 解决方法:

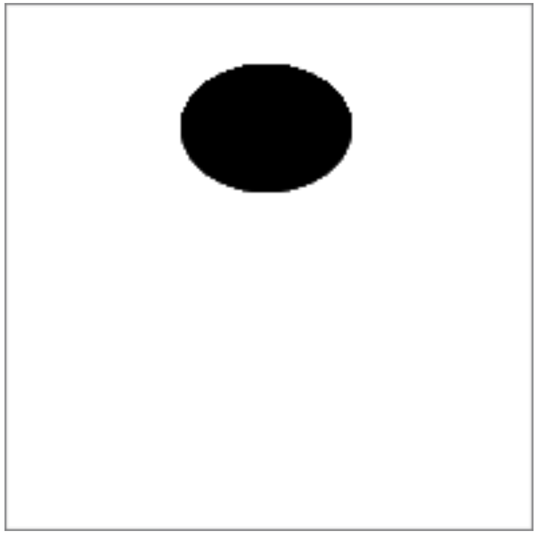
Cost-Function Weighting (FLIRT or FNIRT)

代价函数加权(FLIRT或FNIRT)

Cost Function Weighting 代价函数加权



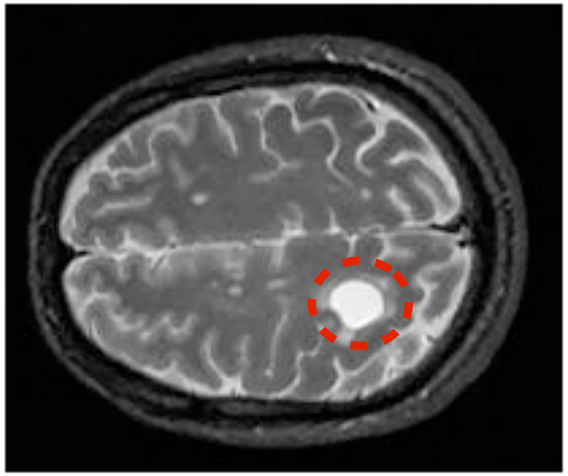
weighting image
加权图像



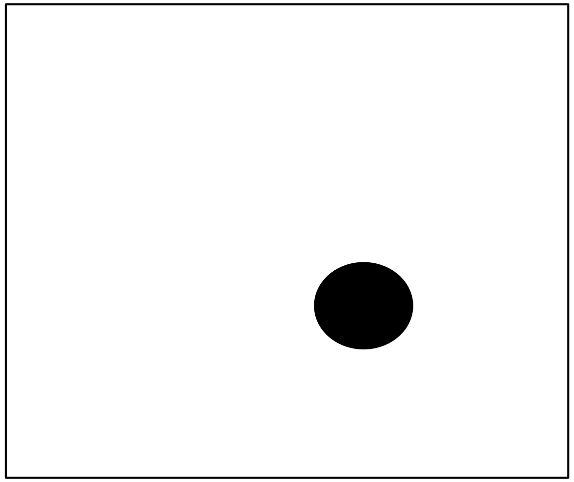
Artefacts and pathologies introduce *non-matching* image regions
伪影和病理学异常引入了不匹配的图像区域

Cost (similarity) functions assume that all of the images can be matched
代价(相似性)函数假设所有图像都可以进行匹配

Use a *weighting image* to down-weight non-matching regions
使用加权图像来减少不匹配区域的权重



weighting image
加权图像



black黑=0; white白=1

Cost Function Weighting 代价函数加权

- *All* FLIRT & FNIRT cost functions can be weighted
  所有FLIRT & FNIRT代价函数都可以进行加权
- Weighting for reference image, input image or both
  可对参考图像，输入图像分别或同时进行加权
- Voxel weights are *relative*, reflecting its importance in overall matching
  体素的权重都是相对的，反映了它们在整体匹配中的重要性
  - Zero, or small, values for corrupted areas 将异常区域的权重设为0或小值
    e.g. gross pathology or artefact 例如病理学异常区域或伪影
  - Large values for important areas/regions 将重要区域的权重设为大值
    e.g. ventricular matching 例如脑室匹配
- Do *not* assign zero to the background as then the brain/background contrast is lost
  不要将背景设定为0，因为这样会导致大脑/背景对比丢失

Troubleshooting Registrations
配准故障排除

- *Check the images:* voxel sizes, artefacts, large bias field
  检查图像：体素大小，伪影，大的偏置场
- *Check the brain extraction:* look for large/consistent errors
  检查大脑提取：检查大范围的/一致的错误
- *For EPI:* acquire and use fieldmap to unwarp distortion
  对于EPI:采集并使用场图来校正变形
- *For FMRI or diffusion:* use multi-stage registration (e.g. via GUIs) with a structural image for best results
  对于*FMRI*或弥散*:* (如通过面板)使用结构像来进行两步配准以获得最佳结果
- *If pathologies/artefacts exist:* use cost-function deweighting
  如果存在病理学异常/伪影：使用代价函数去权重
- *If images are nearly aligned:* try limiting the search
  如果图像本身几乎已对齐：尝试限制搜索
- *For FLIRT:* can try different cost functions 对于FLIRT：可以尝试不同的代价函数
- *For FNIRT:* check initial affine alignment is OK 对于FNIRT：检查初始仿射对齐是否正常
- *For small FOV:* acquire whole-brain EPI for multi-stage reg
  对于小的视角：采集全脑EPI来进行两步配准

Advanced Registration 高级配准

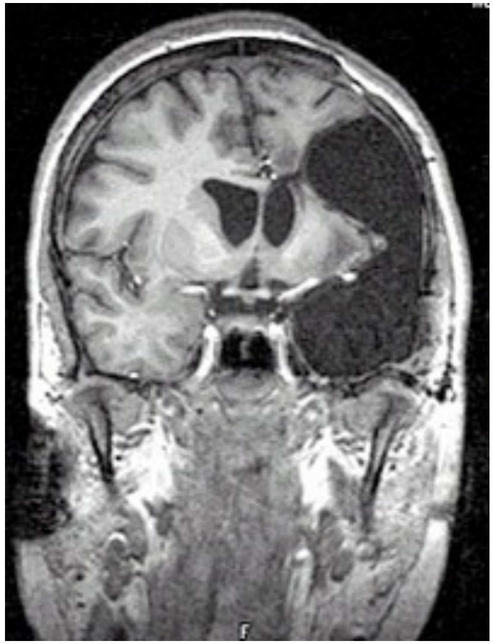
2D - 3D Registration 2D-3D配准

Severe Pathology 严重的病理学异常

Surface-based Registration 基于表面的配准

e.g. connectivity-driven (FMRI)

例如连接驱动的(FMRI)



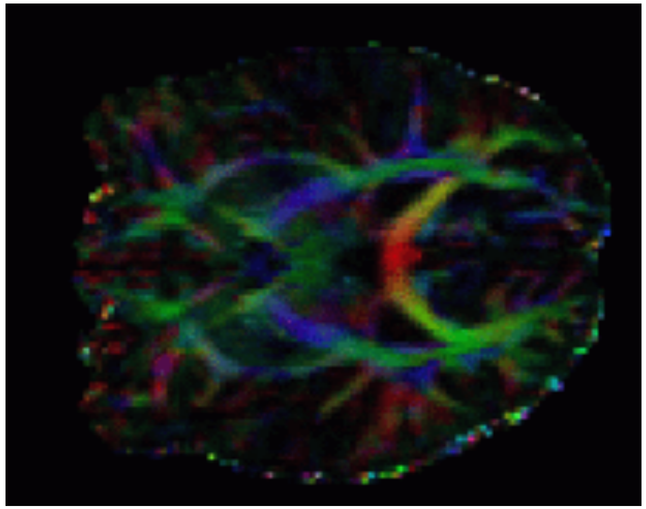
Other Image Modalities 其他图像模态

e.g. diffusion imaging data

例如弥散成像数据

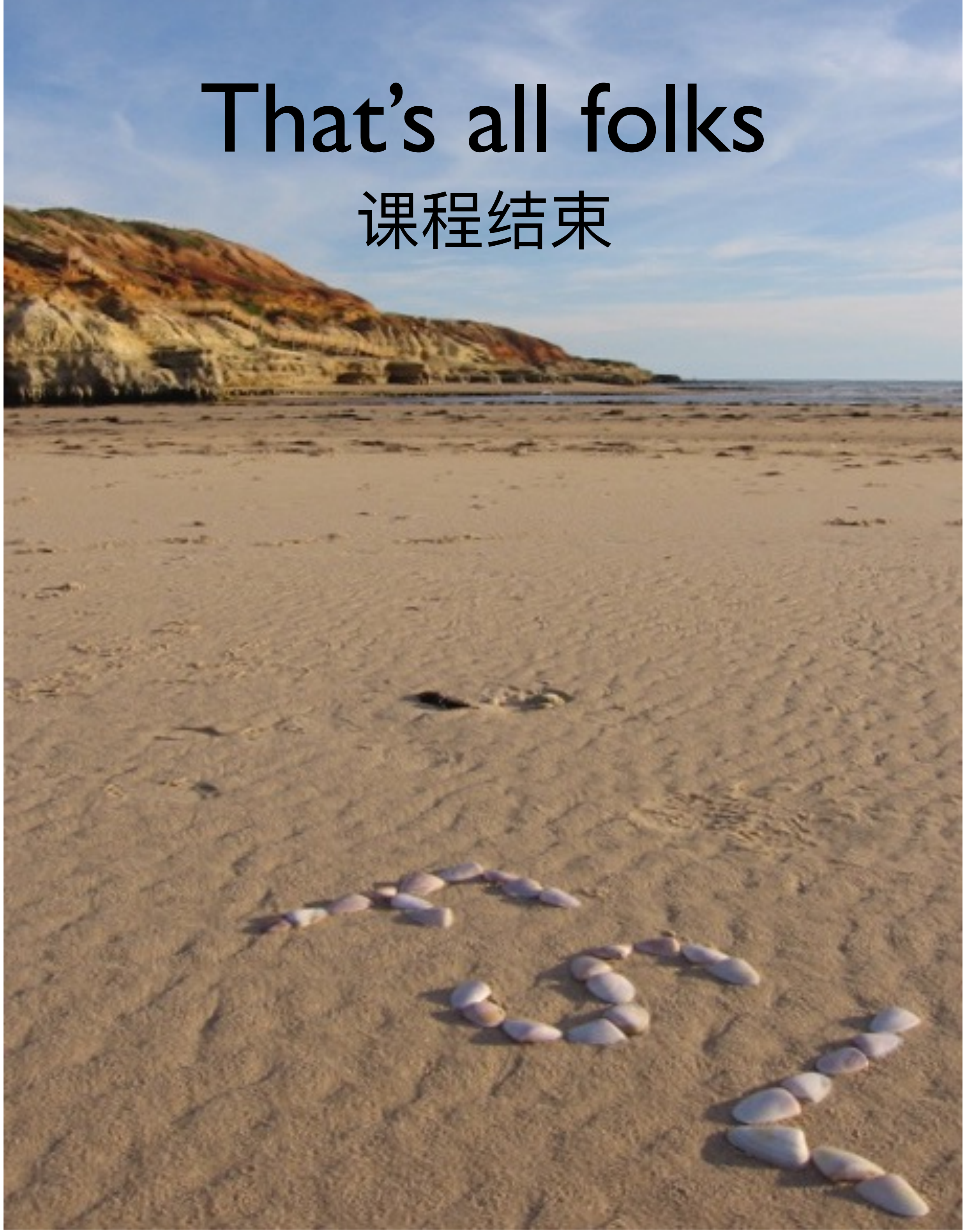
MR Spectroscopic Imaging (MRSI)

磁共振波谱成像（MRSI)



That's all folks

课程结束



Practicals 实操

To get the most out of the practicals, make sure to ask us lots of questions!

为了充分利用实操时间，请务必向我们提问！

Time for practical sessions is a bit tight, but:
Data & practicals available online after the course

课程中的实操时间有点紧张，但课后可在线获取相关数据和操作信息

Registration Practical 配准实操

Open browser and click on the Registration practical

打开浏览器，点击Registration practical

Follow the practical instructions

遵循说明进行操作

Ask lots of questions!

欢迎向我们提问!

Our black t-shirt crew
黑色衣服的工作人员组

We all have different areas & levels of expertise
If one of us might not know the answer, we'll point you to someone who does
工作人员有着不同的专长领域和专业水平
如果我们无法解答你的疑问，我们会请来另一位工作人员帮助你解答

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