Registration Practical 配准实操

In this practical you will explore each of the registration steps within a standard two-step registration for functional images. We will first learn to use the registration tools within the FEAT GUI. Then we will see how to apply and invert transformations. Being able to achieve precise registrations is CRUCIAL for structural, functional and diffusion image analysis. If registrations are not accurate, further statistics at a structural or group level will not be accurate.

在本次实操中，你将探索功能图像的标准两步配准的每个步骤。我们将首先学习使用 FEAT 面板内的配准工具。然后，我们会学习如何应用和逆转变换。能够实现精确配准对结构图像、功能图像和弥散图像分析至关重要。如果配准不精确，进一步的结构或组水平统计分析也会不精确。

Contents:

目录：

• **3: Optional extra: Multiband data registration**

Include an extra registration step to register (low-contrast) multiband data. Many of you may not need to complete this section, but for those of you collecting multiband data this may be a helpful exercise. An extra (high-contrast) image is added as an intermediate step when registering between a functional EPI image and a structural image.

• **3：可选的附加内容：多频段数据配准**

包括一个额外的配准步骤用于配准（低对比）多频段数据。你们大多可能不需要学习这一部分的课程，但如果你采集了多频段数据，这一部分内容可能会是一个有用的练习。当在功能 EPI 图像和结构图像之间进行配准时， 添加一个额外的（高对比）图像作为中间步骤。

Two-stage Registration and Unwarping with FEAT

Take a look inside the data directory:

使用 FEAT 进行两步配准与去变形

先浏览一下数据目录：

```
cd ~/fsl_course_data/registration
ls
```

This directory contains the following images:

1. A structural scan: `STRUCT.nii.gz`
2. A functional scan: `FUNC.nii.gz`
3. A magnitude fieldmap image: `FMAP_MAG.nii.gz`
4. A phase fieldmap image: `FMAP_PHASE.nii.gz`
5. A text file containing the fieldmap information: `FMAPS.txt`
6. A folder containing an example registration (`EXAMPLE_REG` - we will use this a bit later)
7. A folder containing data for the optional section (`multiband_data`)

这一目录包括以下图像：

1. 一个结构扫描：STRUCT.nii.gz
2. 一个功能扫描：FUNC.nii.gz
3. 一个幅值场图图像：FMAP_MAG.nii.gz
4. 一个相位场图图像：FMAP_PHASE.nii.gz
5. 一个包含场图信息的文本文件：FMAPS.txt
6. 一个包含示例配准的文件夹：(EXAMPLE_REG -我们后面会用到它)
7. 一个包含可选课程数据的文件夹（multiband_data）

The objective of this practical is to become familiar with how to perform and evaluate the results of registration in the FEAT GUI (the main functional analysis GUI). This involves multi-stage registration and fieldmap-based unwarping, and requires the images to be suitably prepared. Registration in other FSL GUIs (e.g. for ICA or diffusion analysis) works very similarly.

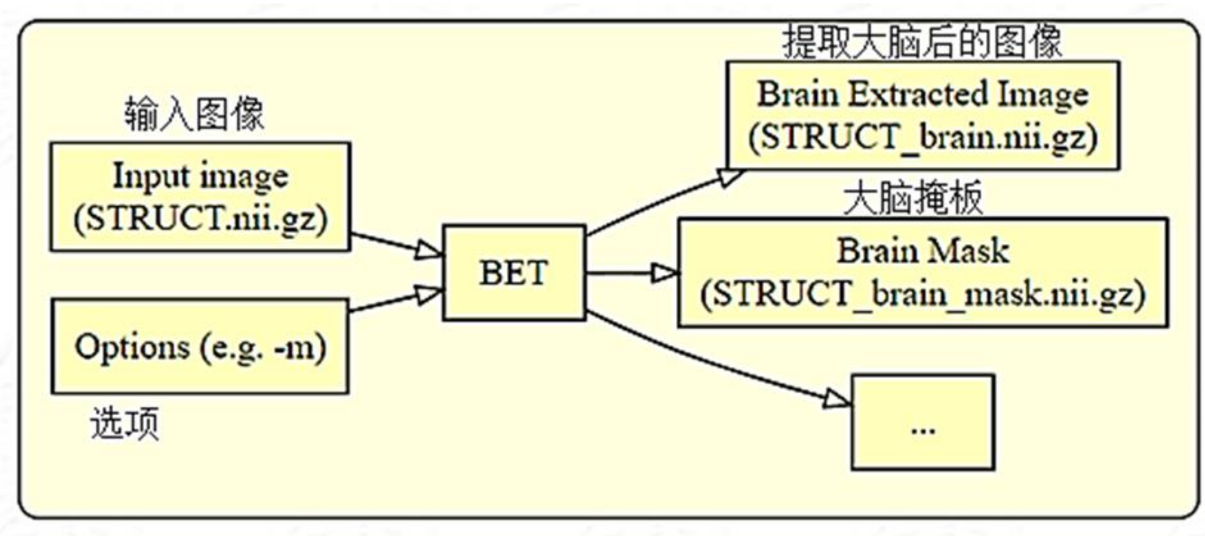
这部分实操的目的是让你熟悉如何在 FEAT 面板(主要功能分析面板）中执行和评估配准结果。这包括多步配准和基于场图的去变形，并需要适当准备图像。在其他 FSL 面板（例如 ICA 或弥散分析）中进行的配准操作与此处十分相似。

Preparing the structural image

We need to perform brain extraction on the structural image prior to using it for registration (as explained in the lecture). To do this run BET on the image `STRUCT.nii.gz`, and save the result as `STRUCT_brain.nii.gz`. Check the results with FSLeyes.

准备结构图像

我们需要先对结构图像进行大脑提取，再将其用于配准（正如课程中解释的那样)。完成这步操作需要对 STRUCT.nii.gz 运行 BET，并将结果保存为 STRUCT_brain.nii.gz。使用 FSLeyes 检查结果。



Fieldmap images

There are two images that the Siemens scanner saves from a fieldmap sequence. These are (in this case, renamed nicely for you):

```
FMAP_MAG.nii.gz
FMAP_PHASE.nii.gz
```

where the first image represents the standard magnitude image from the fieldmap acquisition, and the second image represents a phase difference (between two different echo times, calculated internally as part of the fieldmap acquisition). The second image is proportional to a map of the distortions. Have a quick look at these with FSLeyes. We will need to use both magnitude and phase images.

Processing the fieldmap magnitude image

We will start by brain extracting the first magnitude image. Run brain extraction on the magnitude image and save the result as `FMAP_MAG_brain.nii.gz`. We will then erode this image (shaving off one voxel from all edges) as this image contains noisy partial volume voxels in the phase difference image near the edge of the brain (you will see this below, whereas in practice you would look first in order to decide whether to erode or not). To do the erosion we run:

场图图像

西门子扫描仪从一个场图序列中保存了两张图像。它们是（在此处已经为你很好地重命名了）：

FMAP_MAG.nii.gz

FMAP_PHASE.nii.gz

第一张图代表场图采集的标准幅值图像，第二张图代表（两个不同的回波时间之间的）相位差（作为场图采集的一部分，通过内部计算得出）。第二张图与变形图成比例。使用 FSLeyes 快速浏览这些图片。我们将在后续操作中使用它们。

加工场图幅值图

我们先对第一张幅值图像进行大脑提取，并将结果保存为 FMAP_MAG_brain.nii.gz。然后我们会修剪该图像（在所有边界处剔除一个体素），因为该图像包含了靠近大脑边缘的相位差图像中的部分噪音体积的体素（你将在后续内容中看到，但在实际操作中，你应该先看这部分内容以决定是否要进行图像修剪）。我们执行以下操作进行图像修剪：

```
fslmaths FMAP_MAG_brain -ero FMAP_MAG_brain_ero
```

*Aside：Typically the magnitude image will have 2 volumes and will need to be reduced to 1 volume before using BET. You can use fslroi to do this.

*备注：通常，幅值图会包含两个体积，并且需要在运行 BET 之前减少 1 个体积。你可以使用 fslroi 来完成这步操作。

This performs an erosion operation (stripping one voxel from the edge) with the general tool `fslmaths` which acts as an image calculator, taking input images and performing operations on them and then saving them as a new image (the last name specified). Check what the results look like in FSLeyes:

这一步使用通用工具 fslmaths 执行了修剪操作（在所有边界处剔除一个体素），该工具充当了图像计算器，获取输入图像并对其执行操作，然后将其另存为一张新的图像（指定命名后缀）。使用 FSLeyes 检查结果：

```
fsleyes FMAP_MAG -cm greyscale \
  FMAP_MAG_brain -cm red-yellow \
  FMAP_MAG_brain_ero -cm blue-lightblue &
```

Add the phase (FMAP_PHASE.nii.gz) to the viewer to see why we needed to erode the brain in order to avoid the noisy voxels at the edge. Note that the "lost" voxels will have fieldmap values filled in by extrapolating from the nearest voxel inside the mask, which is quite accurate for fieldmaps as the field variations are quite smooth (you cannot see this in these images as it happens in the later processing).

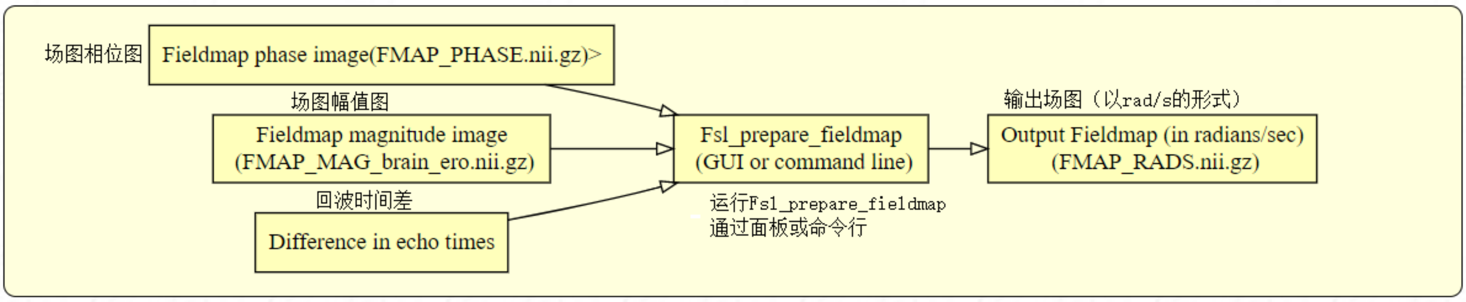
添加相位图(FMAP_PHASE.nii.gz)到查看器中，查看我们为何需要修剪大脑来避免边界上的噪音体素干扰。注意这些“丢失的”体素的场图值将通过外推其在掩板内部的最近体素来填补上，这种操作对于场图来说是比较准确的，因为场变化都比较平滑（这一点你在这些图像中很难看出，因为它将在后续操作中发生）。

Processing the fieldmap phase difference image

Here we need to take this raw scanner output, which is scaled in a strange way (0 to 360 degrees are mapped to 0 to 4096), and convert it into radians per second image (this is equivalent to an image in Hz multiplied by 2*pi). For this we need the phase difference image, the brain extracted (and eroded) magnitude image and the difference in the echo times of the fieldmap acquisitions. This latter value is 2.46ms and can be found in the text file `FMAPS.txt`, which is conveniently given here but will not exist normally. Therefore it is important to record this echo time difference when you scan (your scanner operator will be able to give you the value, and although it can usually be determined later on, it is much easier to record it at the time when the scanner operator is present).

加工场图相位变化图像

在这里，我们需要获取此原始扫描仪输出，它以一种奇怪的方式进行了缩放(将 0-360 度映射为 0-4096 度)，并将其转换为弧度每秒（rad/s）的图像（这相当于一张 Hz 乘以 2*pi 的图像）。为此，我们需要相位差图像，大脑提取后（且修剪后）的幅值图像和场图采集的回波时间差。最后这个值为 2.46ms，你可以在文本文件 FMAPS.txt 找到该值。在这里，我们为你提供了该值，但通常文件内不会包含该信息。因此，请务必在你扫描的时候记录该回波时间差（你的扫描员能够为你提供该值。尽管我们通常可以在后面确定它，但从扫描员处获取记录该值要容易方便得多）。



Armed with this information, all we need to do is run the GUI called `Fsl_prepare_fieldmap`. Note that these images come from a Siemens scanner. Set up all the information required in the GUI, (phase image is FMAP_PHASE.nii.gz and the brain extracted magnitude image is FMAP_MAG_brain_ero.nii.gz) calling the output FMAP_RADS, and press **Go**. View the output with FSLeyes and check that most of the brain has small values (less than 200 rad/s) while in the inferior frontal and temporal areas the values are larger (either large and positive or large and negative).

有了这些信息之后，我们要做的就是运行 `Fsl_prepare_fieldmap` 面板。注意这些图像都来自一台西门子扫描仪。设置面板需要的所有信息(相位图是 FMAP_PHASE.nii.gz，大脑提取后的幅值图是 FMAP_MAG_brain_ero.nii.gz)，将输出命名为 FMAP_RADS，然后点击 Go。使用 FSLeyes 查看输出结果，并检查是否大部分的脑组织都为小值（小于 200 rad/s）但下额叶和下颞叶区域的值较大（较大的正值，或负的较大值）。

Using the FEAT GUI

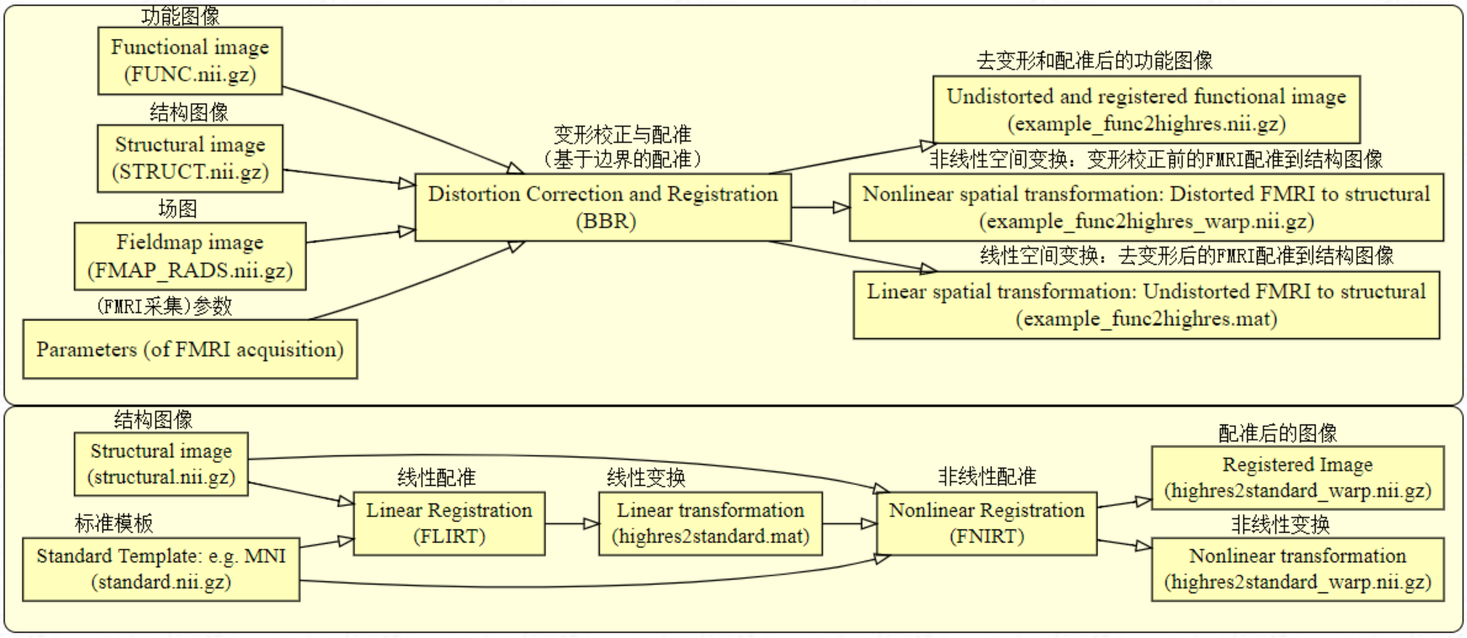
With the fieldmap processed and the structural image brain extracted we are now ready to use the FEAT GUI for registration. Note that the "unwarping" of images using fieldmaps is done in the **Pre-stats** tab of the FEAT GUI.

使用 FEAT 面板

在场图加工和结构图像大脑提取完成后，我们就可以使用 FEAT 面板来进行配准。注意，使用场图进行图像“去变形”是在 FEAT 面板的 Pre-stats 选项卡里。

Start the FEAT GUI by typing Feat in the terminal. From the drop-down list in the top right corner select **Preprocessing**. We now need to set up the GUI to run our registration with unwarping.

在终端里输入 Feat 打开 FEAT 面板。在右上角的下拉菜单里选择 Preprocessing。然后设置面板参数来进行去变形和配准。



We will start with the main **Data** tab. To begin with click on the **Select 4D data button** and select the image `FUNC.nii.gz`. Once this is done, click on the file browser for the **Output directory** and make sure the directory is set to somewhere in your home directory. Then, in the **Selection** box at the bottom type "`test_reg`" and press **OK** (if you leave it empty, it would normally default to something like `~/fsl_course_data/registration/FUNC.feat`).

我们从主选项卡 Data 开始。点击 Select 4D data 按钮，选择图像 FUNC.nii.gz。然后点击文件浏览器选择 Output directory，并确保目录设置在你的 home 目录下。然后在底部的 Selection 栏里输入“test_reg”并点击 OK（如果该栏留白，那么默认的输出格式将类似~/fsl_course_data/registration/FUNC.feat）。

Now go to the **Pre-stats** tab and click the **B0 unwarping** button. Note that all other parts of this tab (e.g. motion correction) are set to their default values and we will leave them with these settings. Now go through and populate the relevant parts:

现在来到 Pre-stats 选项卡下，点击 B0 unwarping 按钮。注意，该栏的其他部分（例如头动校正）都已设置为默认值，我们将保留这些参数不变。然后浏览并填充相关部分：

- **Fieldmap**: `FMAP_RADS` (select this using the file browser that the folder icon opens)
- **Fieldmap mag**: `FMAP_MAG_brain`
- **Effective EPI echo spacing**: 0.49ms (taken from the `FMAPS.txt` file here, but in general you need to take note of this value when scanning - ask your operator - and if you are using parallel acceleration then it needs to be divided by the acceleration factor).
- **EPI TE**: 30ms
- **Unwarp direction**: "-y" (again your operator can tell you whether the unwarp direction, or phase encode direction, is x, y or z, but whether it is + or - needs to be determined, currently, by trial and error, which has already been done here)
- **% Signal loss threshold**: Leave at the default value of 10%.

- **Fieldmap**: FMAP_RADS (使用文件夹图标打开的文件浏览器选择该文件)
- **Fieldmap mag**: FMAP_MAG_brain
- **Effective EPI echo spacing**: 0.49ms (此处可从 FMAPS.txt 文件中获得该值，但通常来说你需要在扫描时-询问你的扫描员-记录该值，如果你使用了平行加速，你需要除以加速度因子来获得该值。)
- **EPI TE**: 30ms
- **Unwarp direction**: "-y" (同样地，你的扫描员可以告诉你去变形方向或相位编码方向是 x，y 或 z，但究竟是+或-目前需要通过反复试验来确定，在此处我们已经为你完成了试验。)
- **% Signal loss threshold**: 保留默认值 10%即可。

Go to the **Registration** tab and click on the **Main structural image** button. Open the file browser and select `STRUCT_brain`. Make sure the options underneath are set to *Normal search* and *BBR*. In the **Standard space** box, make sure the image `MNI152_T1_2mm_brain` is selected in the correct directory. (This reference image is part of FSL. In general, to find out where FSL is installed, type `echo $FSLDIR` into a terminal. The standard space reference images are in `data/standard/` inside that directory.) We will not select the *Nonlinear* button in the **Standard space** section for this part of the practical in order to save time, but you normally would use this setting as it gives the best results.

来到 Registration 栏，点击 Main structural image 按钮。打开文件浏览器并选择 STRUCT_brain。确保下方的选项设置为 Normal search 和 BBR。在 Standard space 栏中，确保选择了正确目录下的 MNI152_T1_2mm_brain。（这一参考图像文件为 FSL 自带。我们可在终端中输入 echo $FSLDIR 查询 FSL 安装目录，所有标准空间参考图像都在该目录的 data/standard/里。）此处为了节省时间我们不勾选 Standard space 下方的 Nonlinear 按钮，但通常你应该勾选该选项来获得最佳结果。

OK, that's everything we need to register the functional image to standard space. So double-check that the **Pre-stats** and **Registration** tabs look correct and when you are happy press the **Go** button at the bottom. This should start up a web browser showing the progress of FEAT - although it may take a minute for this to appear.

上述操作就是我们将功能图像配准到标准空间时需要的。因此请再次确认 Pre-stats 和 Registration 选项卡下的所有设置参数准确无误，然后再点击下方的 Go 按钮。这时应该会弹出一个网页显示 FEAT 的运行进度-有时可能需要一点时间才会弹出页面。

Now go back to the FEAT GUI, and we are going to run a comparison registration *without fieldmap unwarping*. So go to the **Pre-stats** tab and de-select the **B0 unwarping** button. In the **Data** tab, re-name the output to something like `test_reg_no_fmap`. Everything else stays the same, and once you are happy with all the setting press the **Go** button again.

现在回到 FEAT 面板，我们将运行一个不使用场图做去变形的配准来作为比较。故来到 Pre-stats 选项卡，取消选择 B0 unwarping。来到 Data 选项卡，将输出重命名为 test_reg_no_fmap。其余设置保持不变，然后点击 Go。

While you wait

The FEAT jobs will take about 15 minutes to finish. In the meantime we can have a look at the registrations provided in the `EXAMPLE_REG` subject directory. Change to this directory, and open the webpage report for the registration:

在你等待的时候

FEAT 需要约 15 分钟来完成操作。与此同时，我们可以浏览一下 EXAMPLE_REG 目录里的配准结果。来到该目录下，打开配准报告的网页：

```
cd ~/fsl_course_data/registration/EXAMPLE_REG/example_reg.feat
firefox report_reg.html &
```

Look carefully at the results of the registrations in the web page report and in the **Unwarpin**g page for the cases where fieldmap-based correction was run. Do these registrations seem accurate to you? Note that you should not trust borders with signal loss areas as these are not true anatomical boundaries but artificial borders.

仔细查看网页报告中的配准结果，对于运行了基于场图的校正的配准，还要仔细观察 Unwarping 页面下的结果。你认为这些配准精确吗？注意，你不该相信信号丢失区域的边界，因为这些边界不是真实的解剖边界而是伪边界。

It is also highly recommended to use FSLeyes to look in more detail. We can look at each of the two registration steps separately (functional to structural, and structural to standard), but remember when these two steps are combined to produce a functional to standard transformation, the functional image is only resampled ONCE into standard space. Let's first look at the initial registration step (functional to structural) in FSLeyes. Load the structural image into FSLeyes using the following command:

我们同样强烈推荐你使用 FSLeyes 来对结果进行更细致的检查。我们可以分别查看两个配准步骤的结果（功能空间到结构空间，结构空间到标准空间），但记住当这两个步骤被结合在一起来生成功能空间到标准空间的变换时，功能图像仅会被重采样到标准空间上。让我们先在 FSLeyes 中查看初始配准步骤的结果（功能空间到结构空间）。使用下列命令将结构图像加载到 FSLeyes 中：

```
cd reg
fsleyes highres.nii.gz &
```

This `highres.nii.gz` image is created in the `reg` folder by FEAT from the T1 structural image we specified.

这张 highres.nii.gz 图像是 FEAT 在 reg 文件夹中根据我们指定的 T1 结构图像创建的。

Using the FSLeyes GUI, add the `example_func2highres.nii.gz` (`example_func` is a distortion-corrected example volume from the EPI/functional data, and `example_func2highres` is the `example_func` image transformed into structural space), and the `example_func2highres_fast_wmedge.nii.gz` (this image shows the location of the white matter edges, as defined by the highres image). Change the colour map of this `wmedge` image, by selecting in the image list at the bottom left, and then selecting Red in the colour map drop down list at the top of the FSLeyes window.

使用 FSLeyes 面板添加 example_func2highres.nii.gz 图像(example_func 是来自 EPI/功能数据的变形校正后的示例体积，而 example_func2highres 是变换到结构空间后的 example_func 图像)和 example_func2highres_fast_wmedge.nii.gz 图像(该图像显示了由 highres 图像定义的白质边界的位置)。在左下方的图像列表里选择这张 wmedge 图像，然后在 FSLeyes 窗口顶部的色谱下拉菜单里选择 Red 来改变这张图的色谱。

Click around the image to see where the registration is particularly good (as the red edges derived from the structural should align with the changes the in greyscale intensities of the functional image). Toggle the visibility of the `example_func2highres` image on and off (the button), or adjust its transparency (the *Opacity* slider in the display toolbar at the top of the FSLeyes GUI) to judge its alignment to the `highres` image.

点击图像周围查看配准质量（来自结构图像的红色边界线应该与功能图像里的灰度强度变化对齐）。切换 example_func2highres 图像的可见性（通过按钮），或调整其透明度（FSLeyes 面板顶部显示工具栏中的“Opacity”滑块）来判断它是否与 highres 图像对齐。

Feel free to look at other images in this `reg` subdirectory or in the unwarp subdirectory inside this. For example, the uncorrected registration result is in the file `unwarp/example_func_distorted2highres.nii.gz` and can be viewed separately or added to the FSLeyes session above.

自由查看 reg 目录下和子目录 unwarp 下的其他图像。例如，可单独查看文件 unwarp/example_func_distorted2highres.nii.gz 里的未校正配准结果，或将其添加到上面的 FSLeyes 查看中比较结果。

Now open another FSLeyes session (without closing the old one) from the terminal to view the second registration step (structural to standard):

现在从终端里再打开一个 FSLeyes 窗口（不要关闭之前的）来查看第二步配准（结构空间到标准空间）的结果：

```
fsleyes standard.nii.gz &
```

Add the `highres2standard.nii.gz` image, which is the structural image transformed into standard space. In this case non-linear registration (FNIRT) was used after affine linear transformation (FLIRT) for maximum accuracy. Use the same FSLeyes tools to check the registration of the structural image to the standard image.

添加 highres2standard.nii.gz 图像，这是变换到标准空间后的结构图像。在这里，我们在仿射线性变换（FLIRT）完成后再进行了非线性配准（FNIRT），已获得最精确的结果。使用同样的 FSLeyes 工具来检查结构图像到标准图像的配准结果。

Leave both of these FSLeyes sessions open for the moment, as we are now going to compare the registrations you just ran to these given examples.

暂时不要关闭这两个 FSLeyes 窗口，因为我们将要对你刚才运行的配准结果与这些示例结果进行比较。

Once the FEAT job is finished

Firstly, look at your webpage reports for the registrations you ran. Can you spot any noticable differences compared to the example registration webpage report? We will now compare these registrations carefully using FSLeyes.

Go back to the FSLeyes window where you were looking at the first registration step (functional to structural). Now add the `example_func2highres.nii.gz` image from the registration you ran with fieldmap correction (`~/fsl_course_data/registration/test_reg.feat/reg/example_func2highres.nii.gz`). How does this registration compare to the original? It should be identical, or at least very, very similar.

当 FEAT 运行完成

首先，查看你刚才运行的配准的网页报告。与示例配准的网页报告相比，你此处能够发现任何明显的差异吗？我们将使用 FSLeyes 仔细地对比这些配准结果。

回到你查看第一步配准（功能空间到结构空间）结果的 FSLeyes 窗口。添加你刚才使用场图校正处理出来的 example_func2highres.nii.gz 图像 (~/fsl_course_data/registration/test_reg.feat/reg/example_func2highres.nii.gz)。这张配准结果与原始图像相比有何不同？它们应该是一样的，或者至少非常相似。

Now add the registration you ran **WITHOUT** fieldmaps (`~/fsl_course_data/registration/test_reg_no_fmap.feat/reg/example_func2highres.nii.gz`). You may wish to rename this image within FSLeyes to something like `example_func2highres_no_fmap.nii.gz` to avoid confusion (as FSLeyes will initially give both images the same name). Use the FSLeyes tools you practised earlier to compare the registrations with and without fieldmaps

现在添加你没有使用场图的配准结果(~/fsl_course_data/registration/test_reg_no_fmap.feat/reg/example_func2highres.nii.gz)。你可能会希望在 FSLeyes 里将该图片重命名为 example_func2highres_no_fmap.nii.gz 以防止混淆（因为 FSLeyes 会给予这两张图像相同的名字）。使用你先前实践过的 FSLeyes 工具来比较使用场图与不使用场图的配准结果。

Which areas likely benefit the most from fieldmap distortion correction?

- Visual cortex
- Prefrontal cortex

  Correct! The prefrontal cortex often suffers from large distortions (and drop-out, which cannot be corrected for using fieldmaps) due to its proximity to sinuses etc.
- Thalamus

下列哪个脑区最可能从场图变形校正中获益？

- 视觉皮层
- 前额叶皮层

  正确！由于前额叶皮层接近鼻窦等区域，因此常常会遭遇较大的变形（和脱落，这种情况无法通过场图进行校正）。
- 丘脑

Now go to the FSLeyes window where you were looking at the second registration step (structural to standard). Add the `highres2standard.nii.gz` image from the registration you ran (`~/fsl_course_data/registration/test_reg.feat/reg/highres2standard.nii.gz`). This registration step was done linearly (using FLIRT) rather than nonlinearly (using FNIRT). Compare the linear and linear+non-linear versions of this step.

现在来到你检查第二步配准（结构空间到标准空间）的 FSLeyes 窗口。添加你刚才处理出来的 highres2standard.nii.gz 图像 (~/fsl_course_data/registration/test_reg.feat/reg/highres2standard.nii.gz)。这一配准步骤是线性(使用 FLIRT)而不是非线性（使用 FNIRT）的。比较这一步的线性和线性+非线性配准的结果检查间差异。

Now add (to FSLeyes) the second brain example we have provided, using both linear and non-linear registration to the standard space:

现在将我们提供的第二个大脑例子添加到 FSLeyes 中，该实例同样分别使用了结构空间到标准空间的线性和非线性配准：

```
~/fsl_course_data/registration/EXAMPLE_REG/BRAIN_2/brain2_reg_linear2standard.nii.gz
~/fsl_course_data/registration/EXAMPLE_REG/BRAIN_2/brain2_reg_nonlinear2standard.nii.gz
```

Which brain (original or brain2) registered more successfully to the standard brain using linear only registration? Can you think why this might have been the case?

- Original brain

  Correct! This brain registered pretty well using linear only registration, although it was slightly improved with non-linear registration. This brain was from a young adult, whose brain was a much closer match to the MNI template it was registered to.

- Brain 2

哪一个大脑（原始或大脑 2）的仅线性配准效果更好？你能想到为什么会这样吗？

- 原始大脑

  正确！这个大脑的仅线性配准效果非常好，尽管使用非线性配准的结果会稍微更好一些。这一大脑来自一位年轻的成年被试，它与配准的 MNI 模板匹配程度更高。

- 大脑 2

Finally, de-select (or remove) the `highres2standard` images within the FSLeyes session. Add the combined registration images from the supplied example using both fieldmaps and non-linear registration (`~/fsl_course_data/registration/EXAMPLE_REG/example_reg.feat/reg/example_func2standard.nii.gz`) and the registration you ran without fieldmaps or non-linear registration (`~/fsl_course_data/registration/test_reg_no_fmaps.feat/reg/example_func2standard.nii.gz`). You may need to rename these within FSLeyes to avoid confusion. The registration without fieldmap correction or non-linear registration will be markedly worse than the original registration, as both sub-optimal registration steps have now been concatenated into one step.

最后，取消选择（或去除）FSLeyes 中的 highres2standard 图像。添加示例数据里使用场图和非线性配准处理的整合配准图像(~/fsl_course_data/registration/EXAMPLE_REG/example_reg.feat/reg/example_func2standard.nii.gz)和你运行的没有使用场图或非线性配准的结果图像(~/fsl_course_data/registration/test_reg_no_fmaps.feat/reg/example_func2standard.nii.gz)。你可能需要在 FSLeyes 里重命名这些图像以避免混淆。没有使用场图校正或非线性配准的结果将明显比原始配准要差，因为两个次优配准步骤现在都已合并为一个步骤。

How many times do we resample the image when we register from functional to standard space, and why?

- Twice - we want to make sure the brain is accurately aligned to the structural image and then to the standard template, so each registration and resampling must be performed independently.
- Never - we do all of our analysis in native space, and registration is just for display purposes.
- Once - we want to resample only into the standard space to minimize image degradation.

  Correct! The individual registration steps are concatenated to move from functional to structural to standard space all in one go, with resampling only happening at the very end into the standard space.

当我们将图像从功能空间配准到标准空间时，我们对图像进行了几次重采样，原因是什么？

- 两次-我们想要确保大脑被准确地对齐到结构图像，然后到标准模板，所以每一次配准和重采样都要单独地执行。
- 从不-我们在原始空间上进行所有的分析，配准只是为了展示结果而已
- 一次-我们想要通过仅将图像重采样到标准空间来最小化图像质量的下降。

  正确！每个单独的配准步骤连接在一起便可一次功能图像配准到结构图像再到标准图像，而重采样仅发生在最后配准到标准图像上时。

Applying and Inverting Transformations

The objective of this section of the practical is to become familiar with applying transformations, as well as their inverses, to move masks (or images) between different spaces. This is very useful as although FEAT, Featquery and FDT do a lot of this "behind the scenes" for you, there will be many cases when you want to do something beyond the standard options and then you'll need to be able to do this for yourself.

应用和逆转变换

本部分实操课程的目的是让你熟悉如何应用和逆转变换来在不同空间之间移动掩板（或图像）。这部分课程内容十分有用，因为尽管 FEAT, Featquery 和 FDT 在“幕后”为你做了很多这样的工作，但在很多时候你会想要做一些标准选项以外的事情，这时你就需要有足够的能力来自行完成操作。

We will be working with the files from the Feat analysis in the previous part of the practical, however what we are doing is not restricted to functional analysis. FDT outputs similar files when analysing diffusion datasets, and the same files (affine transformation matrices and warp fields) are output by the fundamental tools, FLIRT and FNIRT, when doing any structural analyses.

我们将会使用上一部分实操中进行的 Feat 分析的结果文件，但我们所做的并不限于功能分析。FDT 在进行弥散数据分析时会输出相似的文件。而在进行任何结构分析时，基本工具 FLIRT 和 FNIRT 会输出一样的文件（仿射变换矩阵和变形场）。

Transformation files

If you look in the example registration directory you will see many different files:

变换文件

如果你查看示例配准目录，你将会看到许多不同的文件：

```
cd
~/fsl_course_data/registration/EXAMPLE_REG/example_reg.feat/reg/
ls
```

The crucial ones for registration purposes are the transformation files that come in two different varieties: affine matrices (ending with `.mat`) and warp fields (ending with `_warp.nii.gz`). For now we will not look at the contents of these files (see the exercises below for more about this) but instead we will explain what each of them means.

用于配准的关键文件是变换文件，它有两种不同的形式：仿射矩阵（以.mat 结尾）和变形场（以_warp.nii.gz 结尾）。现在我们先不浏览这些文章的内容（更多相关信息，请参见下方的练习），取而代之地，我们会解释这些文件的含义。

The naming convention is always from the input space to the reference space (or source to destination if you prefer). For example, the file `highres2standard.mat` is an affine transformation going from the highres (structural) space to the standard (MNI) space. There is also the file `highres2standard_warp.nii.gz` that represents a non-linear warp from highres space to standard space. We have both of these because it is necessary to initialise all non-linear registrations with an affine registration (that gets the head in roughly the right position and scaling to allow the non-linear registration to work well). When you want to use a transformation between these spaces, you would generally go for the warp field (when it exists) and ignore the initial affine registration. Note that the warp fields include the affine transformation as part of them, so you don't need to use both.

传统的命名方式始终是从输入空间到参考空间（或从起源空间到目的空间，如果您愿意的话）。例如，文件 highres2standard.mat 是从 highres（结构）空间到标准（MNI）空间的仿射变换。还有文件 highres2standard_warp.nii.gz 表示从高分辨率空间到标准空间的非线性变形。我们之所以要生成这两个文件，是因为有必要使用仿射配准来初始化所有非线性配准（这能使头部大致位于正确的位置，并通过对它进行缩放来使非线性配准正常运行）。 当您要在这些空间之间使用转换时，通常会使用变形场（如果存在），而忽略初始仿射配准。 注意，变形场包括了仿射变换，因此您无需同时使用两者。

There are three main spaces in a FEAT analysis: functional (represented by `example_func`); structural (represented by `highres`); and MNI (represented by `standard`). Various combinations of transformations exist in this directory (e.g. `example_func2highres`,`example_func2standard`, `highres2standard`) but not all (e.g. `standard2highres`). Note that in a diffusion analysis, run via FDT, the three spaces are called `diff`, `str` and `standard`, and all combinations of transformations are provided.

One thing that might confuse you is why there exists `example_func2highres_warp.nii.gz` when BBR (which performs *linear* registration) was run to do the registration of functional to structural images. This is because of the fieldmap-based distortion correction, which is not just a linear (affine) registration and so must be represented as a warp field.

Creating an example mask

Now let's make a mask in the standard (MNI) space so that we can transform it into the other spaces and use it to calculate some ROI quantities. We will do this using FSLeyes - type in `fsleyes -std &` to get started.

FEAT 分析中有三个主要空间：功能空间（由 example_func 表示）；结构空间（由 highres 表示）；和 MNI 空间（由 standard 表示）。 此目录中存在各种变换组合（例如 example_func2highres, example_func2standard, highres2standard），但不是全部的组合都在这里（例如 standard2highres）。 请注意，在通过 FDT 进行的弥散分析中，这三个空间分别称为 diff，str 和 standard，并提供了变换的所有组合。

可能使您感到困惑的一件事是，当运行 BBR（执行线性配准）将功能图像配准到结构图像时，为什么存在 example_func2highres_warp.nii.gz。 这是因为基于场图的失真校正不仅是线性（仿射）配准，所以还必须表示为变形场。

创建一个示例掩板

现在，让我们在标准（MNI）空间中创建一个掩板，以便我们可以将其变换到其他空间，并使用它来计算一些 ROI 数量。我们将使用 FSLeyes 来完成这项工作-输入 `fsleyes -std &` 开始。

Once FSLeyes is open, select the *Settings > Ortho View 1 > Atlas panel* menu option. This will open up a new panel along the bottom of the FSLeyes GUI that allows you to look at anatomical information from the atlases included with FSL. We can use these atlases to create a mask image (we will choose the left hippocampus from the Harvard-Oxford subcortical atlas, but there are lots of possibilities).

打开 FSLeyes 后，选择 Settings > Ortho View 1> Atlas 面板菜单选项。 这将在 FSLeyes GUI 的底部打开一个新面板，使您可以查看 FSL 附带图册的解剖信息。我们可以使用这些图集来创建掩板图像（我们将从 Harvard-Oxford subcortical atlas 中选择左海马）。

Click the *Atlas search* tab. Type `hip` into the search box at the top of the right section - note that as you type, all atlases, in the atlas list to the left, which contain a structure that matches the search term, are highlighted. Click the checkbox next to the *Harvard-Oxford Subcortical Structural Atlas* to add it as an overlay. Then, in the structure list on the right, click the "+" button by the Left Hippocampus entry, to move the cursor location to this structure.

点击 Atlas search 选项卡。在右侧部分顶部的搜索框中键入 hip-请注意，在键入时，左侧图集列表中包含与搜索词匹配的结构的所有地图集都将突出显示。单击 Harvard-Oxford Subcortical Structural Atlas 旁边的选择框，将其添加为叠加图。然后，在右侧的结构列表中，单击 Left Hippocampus 条目旁边的“+”按钮，以将光标位置移至该结构。

Now we are going to select the voxels in the left hippocampus. An alternative method to create a mask will be discussed in the first FEAT practical.

现在我们要选择左海马里的所有体素。另一个创建掩板的替代方法将会在第一个 FEAT 实操课程中提及。

1、 Turn on edit mode (*Tools > Edit mode*). Two new toolbars will be added to the FSLeyes window.

1、 打开编辑模式(Tools > Edit mode)。FSLeyes 窗口中会出现两个新的工具栏。

2、 On the toolbar along the top:

- Click the selection mode button ( )
- Click the select-by-intensity button ( ).
- Enable 3D selection (3D).

Now we are able to select regions of voxels according to their intensity.

3、 Click anywhere in the left hippocampus structure to select all of the voxels within it.

4、 On the toolbar running down the left hand side, click the *Create mask* button ( ), to copy this selection to a new mask image.

A new image will be added to FSLeyes, with ones in the left hippocampus, and zeros everywhere else. Exit edit mode (*Tools* > *Edit mode*), and toggle the visibility of the Harvard Oxford subcortical atlas (the button in the overlay list) so you can see your new mask image better.

*Aside: This mask can also be created directly at the command line using fslroi and fslmaths with the images in $FSLDIR/data/atlases and finding the appropriate values from the xml files (but be warned that the numbers in the xml files differ by one from the numbers needed in fslroi - see the FSL wiki for more details).

2、在顶部的工具栏上：

- 点击选择模式按钮( )
- 点击按强度选择按钮( )
- 启用 3D 选择(3D).

现在我们可以根据体素的强度选择该区域的体素。

3、 点击左海马结构中的任意部位来选择该区域的全部体素。

4、 在左侧的工具栏里点击创建掩板按钮( )，将所选内容复制到一个新的掩板图像上。

一张新的图像会被添加到FSLeyes，该图像中只有左海马的值为1，其余地方的值都为0。退出编辑模式(Tools > Edit mode)，并切换 Harvard Oxford subcortical atlas 的可见性（叠加列表中的按钮），一边更好地查看新的掩板图像。

*备注：也可以使用 fslroi 和 fslmaths，和 $FSLDIR/data/atlases 中的图像直接在命令行中创建此掩码，并从 xml 文件中找到适当的值（但请注意，xml 文件中的数字与 fslroi 中需要的数字不同-有关更多详细信息，请参见 FSL Wiki）。

We will now save this mask image out to a file in the directory ~/fsl_course_data/registration/EXAMPLE_REG/example_reg.feat/reg. Click on the save button (💾) alongside the mask image in the overlay list, and choose an appropriate name (e.g. LeftHippMask). To make life a lot easier later on make sure you remove all spaces from the filename. This is a general rule to stick with, as spaces within filenames will almost always cause problems and are easily avoided.

现在，我们将该掩板图像保存到 ~/fsl_course_data/registration/EXAMPLE_REG/example_reg.feat/reg 目录中。 单击叠加列表中掩板图像旁边的保存按钮（💾)），然后选择适当的名称（例如 LeftHippMask）。为了使以后的工作更加轻松，请确保从文件名中删除所有空格。这是必须遵守的一般规则，因为文件名中的空格几乎总是会引起问题，并且很容易避免。

Inverting a transform

We want to transform the mask we just made into the functional space in order to calculate an ROI value (e.g. of a statistical image, or an average timecourse, etc.). To go from the standard space to the functional space we would need to have the transformation standard2example_func_warp.nii.gz (or something named like this). In FEAT this does not exist, but in FDT the equivalent is generated automatically, and called standard2diff_warp.nii.gz.

逆转变换

我们想要将刚刚制作的掩板变换到功能空间以计算 ROI 值（例如统计图像或平均时程等）。要从标准空间转到功能空间，我们需要使用相关变换信息 standard2example_func_warp.nii.gz（或类似这样的名称）。在 FEAT 中不存在此文件，但在 FDT 中会自动生成等效项，并称为 standard2diff_warp.nii.gz。

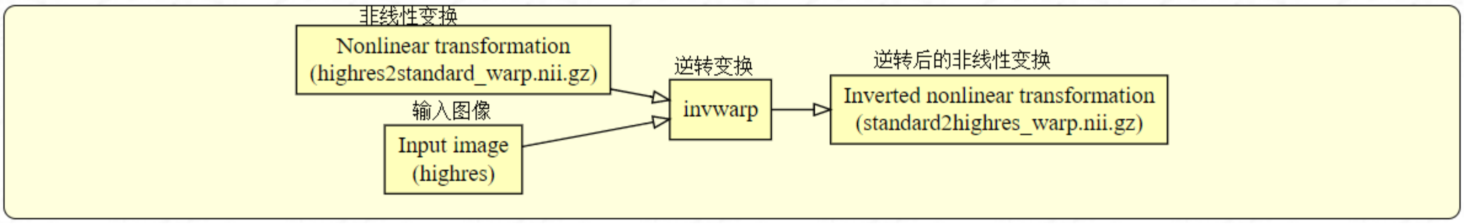
As FEAT does not create the required warp field, we need to create it ourselves from the transformations that it does provide. In this case we do not want to undo the distortion correction (i.e. we want a mask in distortion-corrected functional space). For the structural-to-functional transform we therefore only need `highres2example_func.mat` which was already created by FEAT. We do need to calculate the nonlinear standard-to-structural transform, which can easily be done using the invwarp command, as follows:

由于 FEAT 无法创建所需的变形场，因此我们需要根据它提供的变换自行创建变形场。在这种情况下，我们不想撤消变形校正（即我们想在变形校正后的功能空间中使用掩板）。因此，对于从结构到功能的变换信息，我们仅需要由 FEAT 创建的 highres2example_func.mat 文件。我们确实需要计算标准到结构的非线性变换，这可以使用 invwarp 命令轻松完成，如下所示：

```
invwarp -w highres2standard_warp -o standard2highres_warp -r highres
```

where the final part (the reference) controls the size (FOV) and resolution of the warp and should generally be the destination space of the new transform. As this warp transforms from standard space to structural (we will stick on the final transformation to functional space below), we specify highres.

最终部分（参考）控制变形的大小（视角 FOV）和分辨率，且通常应该是新变换的目标空间。当这种变形从标准空间变换到结构空间时（我们将在下面继续将其最终变换到功能空间），我们指定了 highres。



Applying a transformation

Now that we have the transformation that we need, we can apply it using the applywarp command, by specifying a warp (`-w`). The command you need is (with your own filenames):

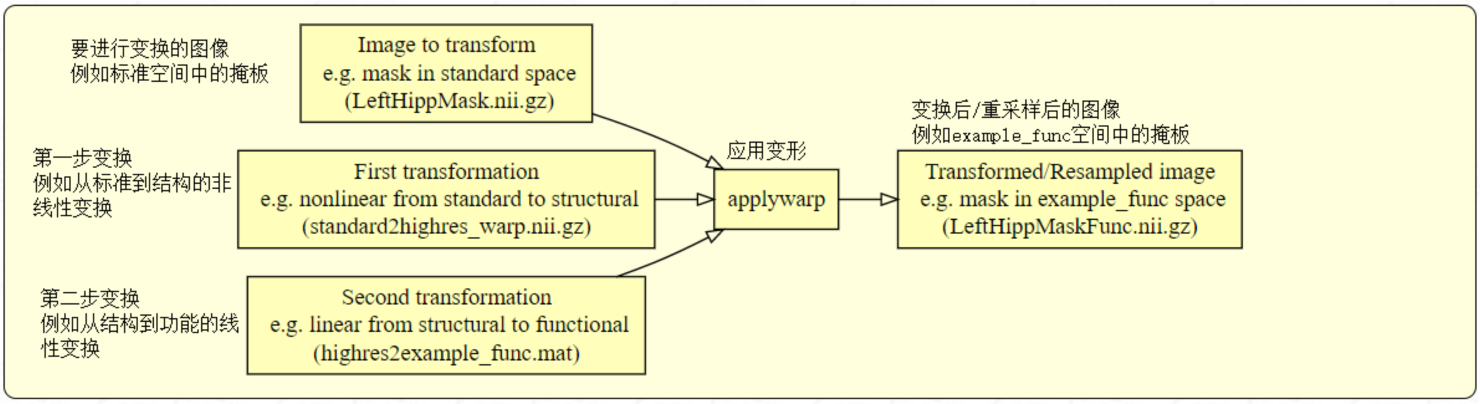
应用变换

现在我们有了所需的变换，我们可以使用 applywarp 命令指定变形（-w）来应用它。您需要的命令是（使用您自己的文件名）:

```
applywarp -i LeftHippMask -r example_func -o LeftHippMaskFunc \
  -w standard2highres_warp --
postmat=highres2example_func.mat
```

which goes from the `standard` space via the `highres` space to the `example_func` space (the last part only needing a rigid-body transformation matrix, as we want to end up in the distortion-corrected functional space, rather than the original distorted one).

通过 highre 空间从标准空间变换到 example_func 空间（最后一部分只需要一个刚体转换矩阵，因为我们的目标空间是变形校正后的功能空间，而不是原始的变形空间）。



Visual Check

Use the command 使用命令:

视觉检查

使用命令:

```
fsleyes example_func LeftHippMaskFunc &
```

to see the mask on the functional image. Note that the values at the edge of the mask lie between 0 and 1.

来查看功能图像上的掩板。注意掩板边界的值在 0 到 1 之间。

Thresholding the Mask

In order to obtain a binary mask (where each voxel has a value of either 0 or 1) we need to threshold and binarise the transformed mask. This is easily done with fslmaths but the threshold used is arbitrary. If a high threshold is chosen (e.g. 0.9) then most edge voxels will be excluded and the mask will be tighter and less likely to include neighbouring structures. This is often desirable when trying to make sure that only the structure of interest is included, but it might end up with the mask being quite small. So sometimes a threshold near 0.5 is preferable, to make a mask of similar size/volume. Or sometimes a mask is needed that does not leave out any of the structure, in which case a low threshold (e.g. 0.1) can be better. We also binarise the mask with the -bin command in fslmaths, to make all voxels within the mask have a value of 1. In this case we will choose a high threshold in order to get a mask where we are very confident that each voxel in the mask is within the hippocampus. This can be done with:

设定掩板阈值

为了获得二进制掩板（每个体素的值为 0 或 1），我们需要对转换后的掩板重新设定二进制阈值。使用 fslmaths 可以轻松完成此操作，但是所使用的阈值是任意的。如果选择高阈值（例如 0.9），则将排除大多数边缘体素，并且掩板会变小且不太可能包括相邻结构。当你试图确保仅包含感兴趣的结构时，这通常是合乎需要的，但最终可能会导致掩板非常小。因此，有时最好使阈值接近 0.5，以制作具有相似大小/体积的掩板。或者有时需要不遗漏任何结构的掩板，在这种情况下，低阈值（例如 0.1）会更好。我们还使用 fslmaths 中的-bin 命令对掩板进行二进制处理，以使掩板中的所有体素的值均为 1。在本次示例下，我们将选择一个较高的阈值来获得一个掩板，因为我们非常掩板的每一个体素都在海马内。这可以通过以下方式完成：

```
fslmaths LeftHippMaskFunc -thr 0.9 -bin LeftHippMaskFuncBin
```

Load the resulting image into FSLeyes and compare it to the original, pre-thresholded version in the functional space.

将生成的图像加载到 FSLeyes 中，并将其与功能空间中原始的重设阈值前的版本进行比较。

Using the Mask

There are many possible ways in which a mask can be used (e.g. getting average statistical values) but as an example will we calculate the average timecourse of the fMRI within this mask. This is done with the command:

使用掩板

可以有多种使用掩板的方式（例如获取平均统计值），但作为示例，我们将计算该掩板内的 fMRI 平均时程。这是通过以下命令完成的：

```
fslmeants -i ../filtered_func_data -m LeftHippMaskFuncBin
```

which will output a column of numbers, representing the timecourse of the average signal intensity (of the pre-processed fMRI data) within this mask. We won't do anything with this for now, but such calculations can be very useful in all sorts of situations.

它将输出一列数字，代表此掩板内（预处理过的 fMRI 数据的）平均信号强度的时程。我们暂时不会对此进行任何处理，但是这种计算在各种情况下都非常有用。

The main point of this exercise was to see how to transform your own masks (or images, as the only difference is skipping the thresholding and binarising steps) between spaces. For functional studies you can often do similar things with the tool Featquery but it is not as flexible and generally useful as being able to process things yourself.

本节练习的主要目的是了解如何在空间之间变换自己的掩板（或图像，因为它们唯一的区别是跳过阈值化和二进制化步骤）。对于功能研究，您通常可以使用 Featquery 工具执行类似的操作，但是它不如自己处理那样功能灵活且有用。

If we were interested in the functional signal in (for example) the amygdala within the fMRI data in a particular subject, which space would we transform a standard mask of the amygdala into for further processing?

- The structural space - we want to make sure we get the most accurate signal from the data, and this is when the image is in structural space
- The distortion-corrected functional space - we do our task analysis in functional space, once it has been corrected for distortions

  Correct!
- The native functional space - we do our task analysis in functional space, without any registrations applied

如果我们对特定受试者的fMRI数据中的（例如）杏仁核中的功能信号感兴趣，那么我们会将杏仁核的标准掩板变换到哪个空间以进行进一步处理？

- 结构空间-我们要确保从数据中获得最准确的信号，这就是图像在结构空间中的时候
- 变形校正后的功能空间-经过变形校正后，我们将在功能空间中进行任务分析正确！
- 原始功能空间-我们在功能空间中进行任务分析，而无需进行配准

Multiband data registration (Optional)

A new functional imaging technique that is becoming more popular is 'multiband imaging'. Multiband imaging allows people to acquire functional images more quickly, allowing more volumes in the functional 4D file for more statistical power, or shortening functional scanning times. Many of you might be using multiband data for your own imaging projects, so here we have an optional section to demonstrate how we can optimise registration of multiband scans.

多频段数据配准（可选课程）

一种越来越流行的新功能成像技术是“多频段成像”。多频段成像使人们可以更快地获取功能图像，从而可以在功能4D文件中获得更大的体积，进而获得更大的统计力度，或缩短功能扫描时间。你们中的许多人可能将多频段成像用于您自己的成像项目，因此这里有一个可选的课程来演示如何优化多频段扫描的配准。

Because multiband images are acquired very quickly, they can have low contrast between grey and white matter. Therefore, to aid registration we can add an additional high-contrast image to our registration between functional and standard spaces. This high-contrast image is usually one of the first few scans ('pre-saturation' scans) acquired in a multiband sequence, which are usually discarded before functional analysis. In every other way it matched the functional scans used in the analysis, so it is a perfect match to the FUNC.nii.gz image, just with greater contrast between tissues in the brain. Note that registration of multiband data does not require this step to run, but it is recommended to use this intermediate contrast image for improved registration of multiband images.

由于多波段图像的获取速度非常快，因此它们在灰色和白色物质之间的对比度可能很低。因此，为了帮助注册，我们可以在功能空间和标准空间之间的注册中添加一个附加的高对比度图像。 这种高对比度的图像通常是在多波段序列中获得的前几个扫描（“预饱和”扫描）之一，通常在功能分析之前将其丢弃。 它以其他方式与分析中使用的功能扫描相匹配，因此它与 FUNC.nii.gz 图像非常匹配，只是大脑各组织之间的对比度更高。 请注意，多波段数据的注册不需要执行此步骤，但是建议使用此中间对比度图像以改善多波段图像的注册。

Move into the multiband_data directory:

进入 multiband_data 目录：

```
cd ~/fsl_course_data/registration/multiband_data/
ls
```

This directory contains the following images:

1. A structural scan and the brain extracted version: STRUCT.nii.gz and STRUCT_brain.nii.gz
2. A functional scan: MULTIBAND_FUNC.nii.gz

该目录包含以下图像：

1. 一张结构扫描图像和提取大脑后的版本：STRUCT.nii.gz 和 STRUCT_brain.nii.gz
2. 一张功能扫描图像：MULTIBAND_FUNC.nii.gz

3. A high-contrast volume to help aid registration: CONTRAST_FUNC.nii.gz
4. A magnitude fieldmap image and its brain extracted counterpart: FMAP_MAG.nii.gz and FMAP_MAG_brain.nii.gz
5. A phase fieldmap image: FMAP_PHASE.nii.gz
6. A fieldmap image we have created for you: FMAP_RADS.nii.gz
7. A text file containing the fieldmap information: FMAPS.txt
8. An example registration: example_multiband_reg.feat

3. 一张用于帮助配准的高对比体积图：CONTRAST_FUNC.nii.gz
4. 一张幅值场图及其提取大脑后的版本：FMAP_MAG.nii.gz 和 FMAP_MAG_brain.nii.gz
5. 一张相位场图：FMAP_PHASE.nii.gz
6. 一张我们已经为你准备好的场图：FMAP_RADS.nii.gz
7. 一个包含场图信息的文本文件：FMAPS.txt
8. 一个示例配准：example_multiband_reg.feat

If you are short on time you can open the example registration web report to have a look at this registration, and note how the intermediate step helps the functional to structural registration:

如果时间有限，你可以打开示例配准的网页报告来查看该配准，并注意中间步骤如何帮助实现功能像到结构像的配准：

```
firefox example_multiband_reg.feat/report_reg.html &
```

Note that the registration from example_func to highres is now split into two parts. The first transforms from example_func to the high-contrast volume (referred to as initial_highres). The second transforms from the high-constrast volume to highres.

请注意，从 example_func 到 highres 的配准现在分为两部分。第一部分从 example_func 转换为高对比体积（称为 initial_highres）。 第二部分从高对比体积变换为 highres。

If you want to try running this registration yourself, open a new FEAT GUI by typing Feat & in the terminal. Change the drop-down list to **Preprocessing** and enter the MULTIBAND_FUNC.nii.gz image in the **Select 4D data** input. Now go to the **Pre-stats** tab and click the **B0 unwarping** button. Fill in the information as follows (note that not all scan information is the same as before so follow the instructions carefully):

- **Fieldmap**: FMAP_RADS (select this using the file browser that the folder icon opens)
- **Fieldmap mag**: FMAP_MAG_brain
- **Effective EPI echo spacing**: 0.57ms (taken from the FMAPS.txt file here, remember to ask your operator and divide by the parallel-imaging acceleration factor (which is not the same as the multi-band acceleration factor).
- **EPI TE**: 33.4ms
- **Unwarp direction**: "-y" (again your operator can tell you whether the unwarp direction, or phase encode direction, is x, y or z, but whether it is + or - needs to be determined, currently, by trial and error, which has already been done here)
- **% Signal loss threshold**: Leave at the default value of 10%.

如果要尝试自己运行此配准，请在终端中键入 Feat &打开新的 FEAT GUI。将下拉列表更改为 Preprocessing，然后在 Select 4D data 中输入 MULTIBAND_FUNC.nii.gz 图像。现在转到 Pre-stats 选项卡，然后单击 B0 unwarping 按钮。填写以下信息（请注意，并非所有扫描信息都与前面的相同，因此请仔细按照说明进行操作）：

- **Fieldmap**: FMAP_RADS (使用文件夹图标打开的文件浏览器选择该文件)
- **Fieldmap mag**: FMAP_MAG_brain
- **Effective EPI echo spacing**: 0.57ms (此处可从文件 FMAPS.txt 中获得，记住询问你的扫描员并除去平行成像加速因子(它与多频段加速因子不是同一个).
- **EPI TE**: 33.4ms
- **Unwarp direction**: "-y" (同样地，你的扫描员可以告诉你去变形方向或相位编码方向是 x，y 或 z，但究竟是+或-目前需要通过反复试验来确定，在此处我们已经为你完成了试验。)
- **% Signal loss threshold**: 保留默认值 10%即可。

All other parts of this tab can be left with their default settings. In the **Registration** tab, now click on the **Expanded functional image** button. Open the file browser and select CONTRAST_FUNC.nii.gz, then change the degrees of freedom to 6. Note that registration does not require this step to run, but it is recommended to use this intermediate contrast image for registration of multiband data. Select STRUCT_brain.nii.gz as your **Main structural image**. Make sure you turn the **non linear** option **OFF** so that you save some time here. Go back to the **Data** tab, and rename your output (in the **Output directory** section) to something like "test_reg_multiband". Check all your options and press the **Go** button at the bottom again. This should start up a new web browser tab with the progress of your new FEAT run. Note how the extra registration step is now included in the report. Feel free to load any of the registration steps into FSLeyes to explore these in more detail.

此选项卡的所有其他部分都可以保留默认设置。现在，在 Registration 选项卡中，单击 Expanded functional image 按钮。 打开文件浏览器，选择 CONTRAST_FUNC.nii.gz，然后将自由度更改为 6。请注意，配准不要求执行此步骤，但是建议使用此中间对比图像配准多频段数据。选择 STRUCT_brain.nii.gz 作为您的 Main structural image。确保关闭 non linear 选项以节省一些时间。返回到 Data 选项卡，并将您的输出（在 Output directory 部分中）重命名为“test_reg_multiband”。检查所有选项，然后再次按底部的 Go 按钮。这将启动一个新的 Web 浏览器选项卡，其中包含新 FEAT 的运行进度。 请注意报告是如何将额外的配准步骤囊括其中的。你可以自由地将任何配准步骤加载到 FSLeyes 中，以更详细地探索这些步骤。

—— THE END ——