1. *Preprocessing*
2. *Realigning*
3. *Unwarping*
4. *SPM*

Realigning and Unwarping MRI data

Shuge Guan
Camille Lasbareilles

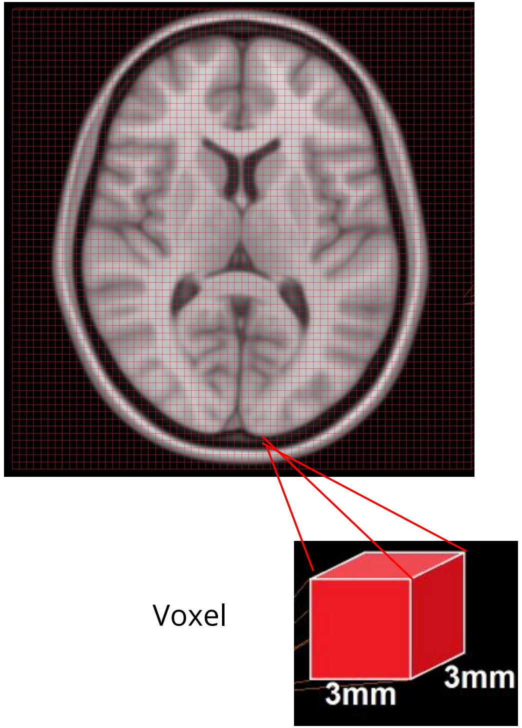
fMRI data

fMRI data: four-dimensional (3 x space and 1 x time)

- 3D array of **voxels** repeatedly sampled slice over slice to measure the whole volume of the brain.
- Each voxel has an associated **time-series** of as many time-points as volumes acquired per session.

Assumptions

1) The voxels at certain position present the same part of the brain over time.
2) All voxels that present a single time point must be acquired simultaneously.



Adapted from Nipype Beginner's Guide

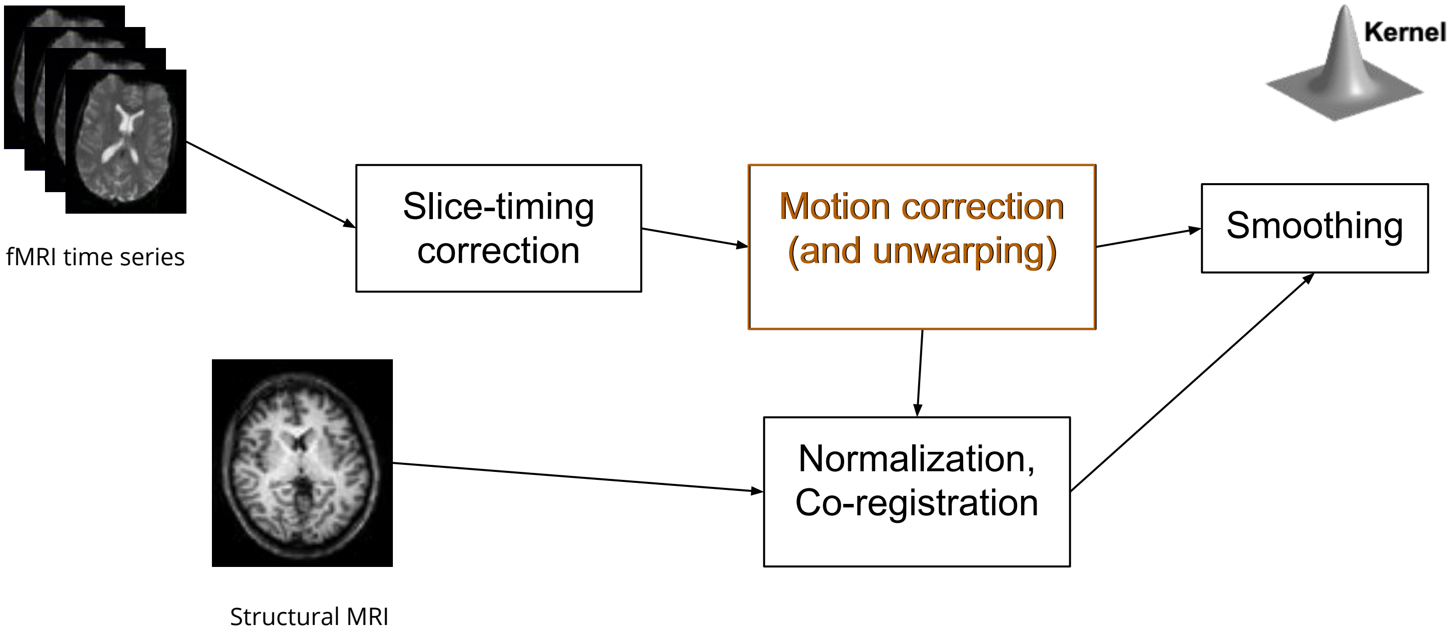
fMRI data pre-processing

→ **Correct or adjust our data and prepare it for statistical analysis**

Including:

- Take account of **time differences** between acquiring each image slice
- Correct for **head movement** during scanning
- Detect **anomalous measurements** that should be excluded from subsequent analysis
- Align the **functional** images with the reference **structural** image
- Normalize the data into a **standard space** so that data can be compared among several subjects
- Apply filtering to the image to increase the **signal-to-noise ratio**

Preprocessing pipeline



Adapted from Dr. Karl Friston May 2011 SPM workshop presentation

Motion on fMRI

- **Physiological**: heart beat, respiration, blinking
- **Actual movement** of the head
- **Task-related**: moving to press buttons

One volex: 3mm✕ 3mm ✕ 3mm
→ even small head movements lead to unwanted variation in voxels and reduce the quality of data.

Possible Solutions:

- Make volunteer comfortable
- Schedule short scanning sessions
- Provide instructions not to move head
- Constrain volunteers’ movement

From previous presentation

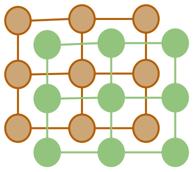
Most variance still remains! →Motion correction

Motion Correction: Realigning

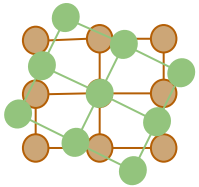
- Minimize the influence of movement on the data by aligning the **input image** to a **target image.**

- The target image can be the mean image of all timepoints, the first, or some other time point.

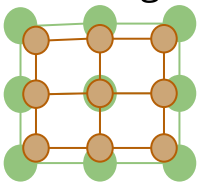
Translation



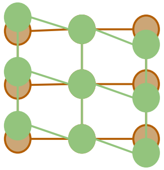
Rotation



Scaling



Shearing



Types of transformations

Only use linear transformations

- **Rigid body transformation**
  - Principle: assume that all movements are those of a rigid body (the shape of the brain does not change)
  - Translation and rotation
- **Similarity transformation**
  - Translation, rotation and a single global scaling
- **Affine transformation**
  - Translation, rotation, scaling and shearing

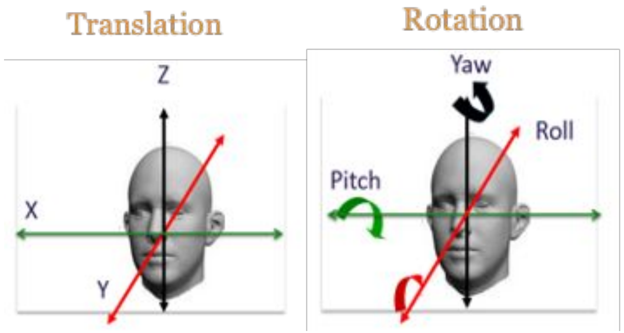
□Two steps:

1.Registration (estimate)

2.Re-slicing (resample)

Realigning-Registration

➔ Determining the 6 parameters that describe the **rigid body transformation** between each image and a reference image



Rigid body transformations parameterised by:

Translations × Pitch × Roll × Yaw

$$\begin{pmatrix} 1 & 0 & 0 & X_{trans} \\ 0 & 1 & 0 & Y_{trans} \\ 0 & 0 & 1 & Z_{trans} \\ 0 & 0 & 0 & 1 \end{pmatrix} \times \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(\Phi) & \sin(\Phi) & 0 \\ 0 & -\sin(\Phi) & \cos(\Phi) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \times \begin{pmatrix} \cos(\Theta) & 0 & \sin(\Theta) & 0 \\ 0 & 1 & 0 & 0 \\ -\sin(\Theta) & 0 & \cos(\Theta) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \times \begin{pmatrix} \cos(\Omega) & \sin(\Omega) & 0 & 0 \\ -\sin(\Omega) & \cos(\Omega) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

➔ The goal is to find the set of parameters which minimizes some cost function.

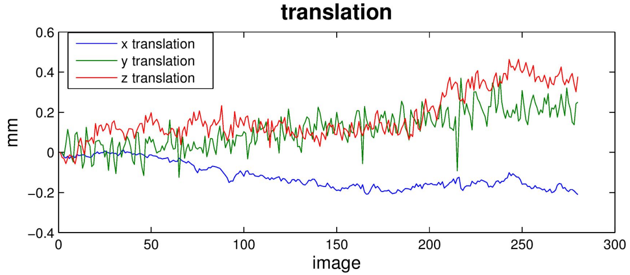
➔ Cost function = sum of squared difference between consecutive images

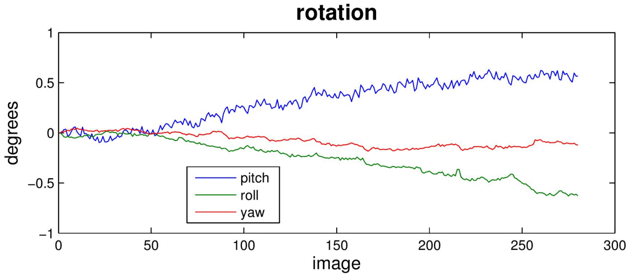
Realigning-Transformation

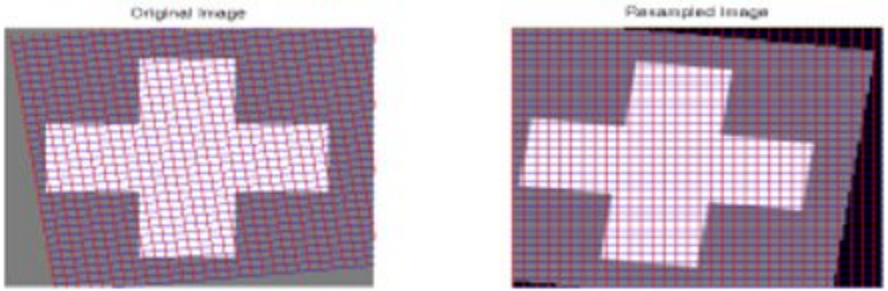
"Reslice", i.e. resample the images→ apply the transformation parameters

- Need to fill in the gaps
- Determine values of the new voxels

➔ **Interpolation**

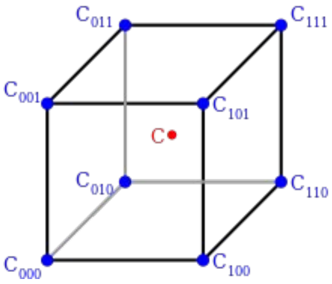


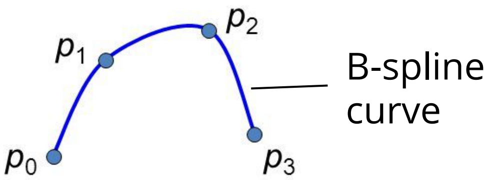




Interpolation

- Interpolation involves **constructing new data points** based on known data
- Interpolation can be
  - **Nearest neighbour (0- order)**: take the intensity of the closest voxel
  - **Tri-linear** (1st-order): take the average of the neighbouring voxels
  - **"B-splines"** used in **SPM**: Approximate all control points, Polynomials of any degree d





p_1 and p_2 are interpolated

Part 2: Unwarping

After realignment

- There is still a lot of variance that is explained by movement
- **Movement-related-variance**
- This variance is typically **large** compared to experimentally-induced variance.
- Up to 90% of the variance in fMRI time series after realignment = movement
    - Loss of sensitivity (missing true activations)
    - Loss of specificity (mistake movement-induced variance for true activation)

Why is there still residual variance after realignment?

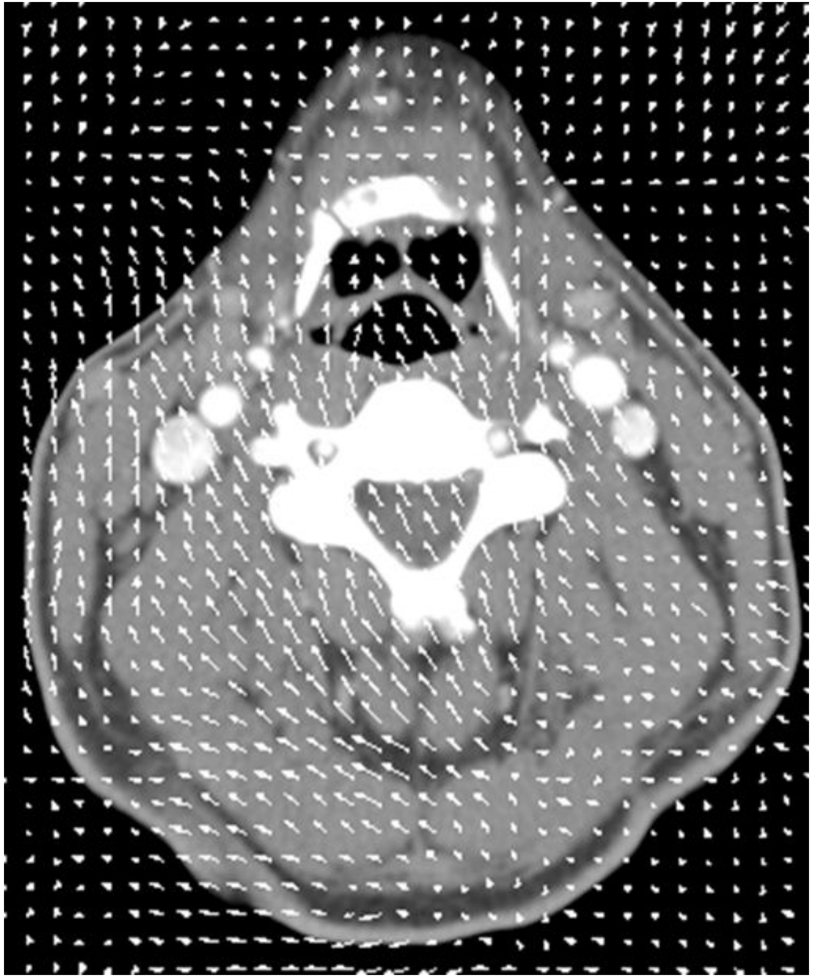
- Realignment **only** addresses rigid/linear transformations that preserve shape (e.g. shape of the brain)

However…

- There are also non-rigid/non-linear transformations that modifies the shape of the image

Non-linear transformations : Inhomogeneities in the magnetic field

- Different tissue types: white matter, grey matter, CSF, blood, air-tissue interfaces
- Different tissue types = different magnetic susceptibilities
- The differences in tissue susceptibility = field inhomogeneity between tissue boundaries because spin dephase faster (= signal loss)
- Areas with air-tissue boundaries are "problem areas"
  - *Orbitofrontal cortex*
  - *Medial temporal lobe*
  - *Frontal pole*



This is what happens in EPI data

- EPI images are not faithful representations of the object (brain) being scanned
- Observed image = warped version of reality
- Funfair mirrors
- An image collected for a given subject position is not identical to that collected at another
- **Susceptibility-by-movement** interaction accounts for a large amount of residual movement-related variance

To summarise…

Image distortion

The image obtained in the scanner is distorted (EPI is not an exact replica)

Image distortion

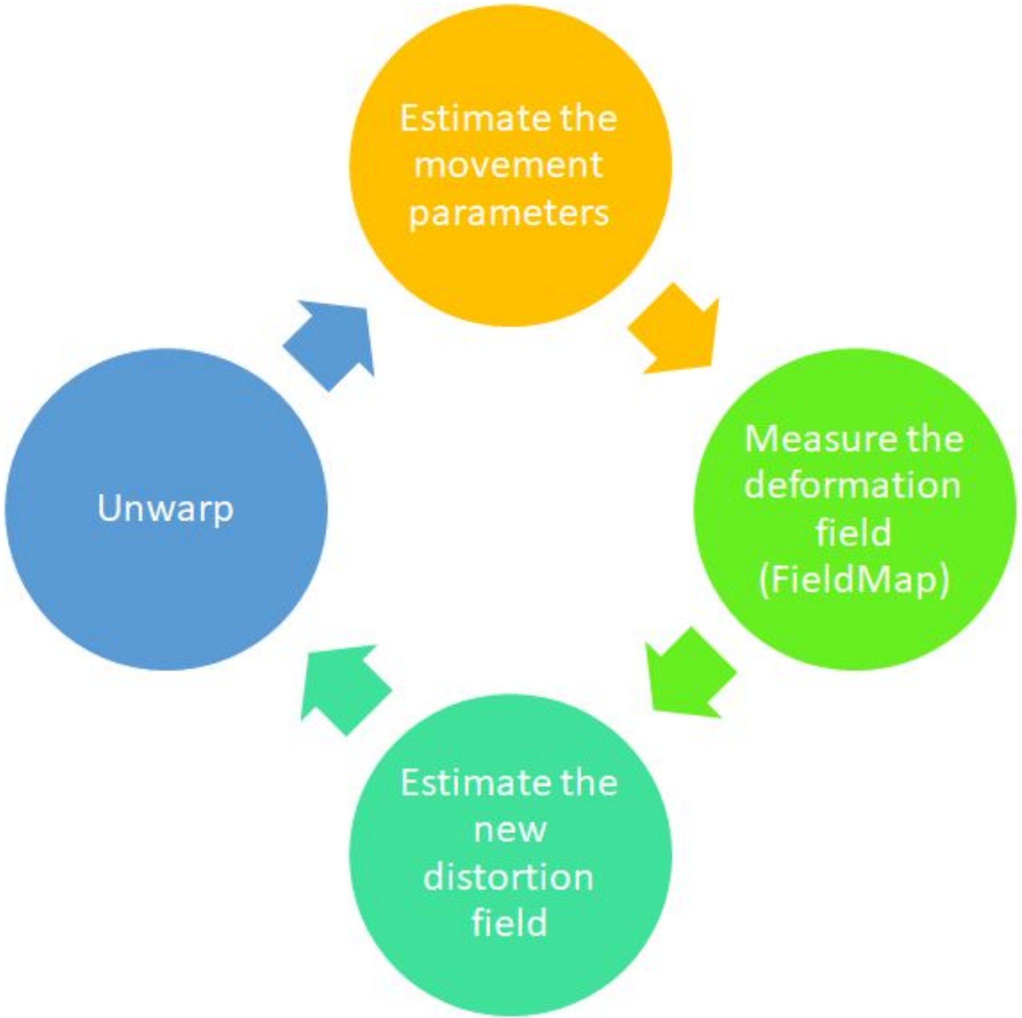
AND

Participant movement

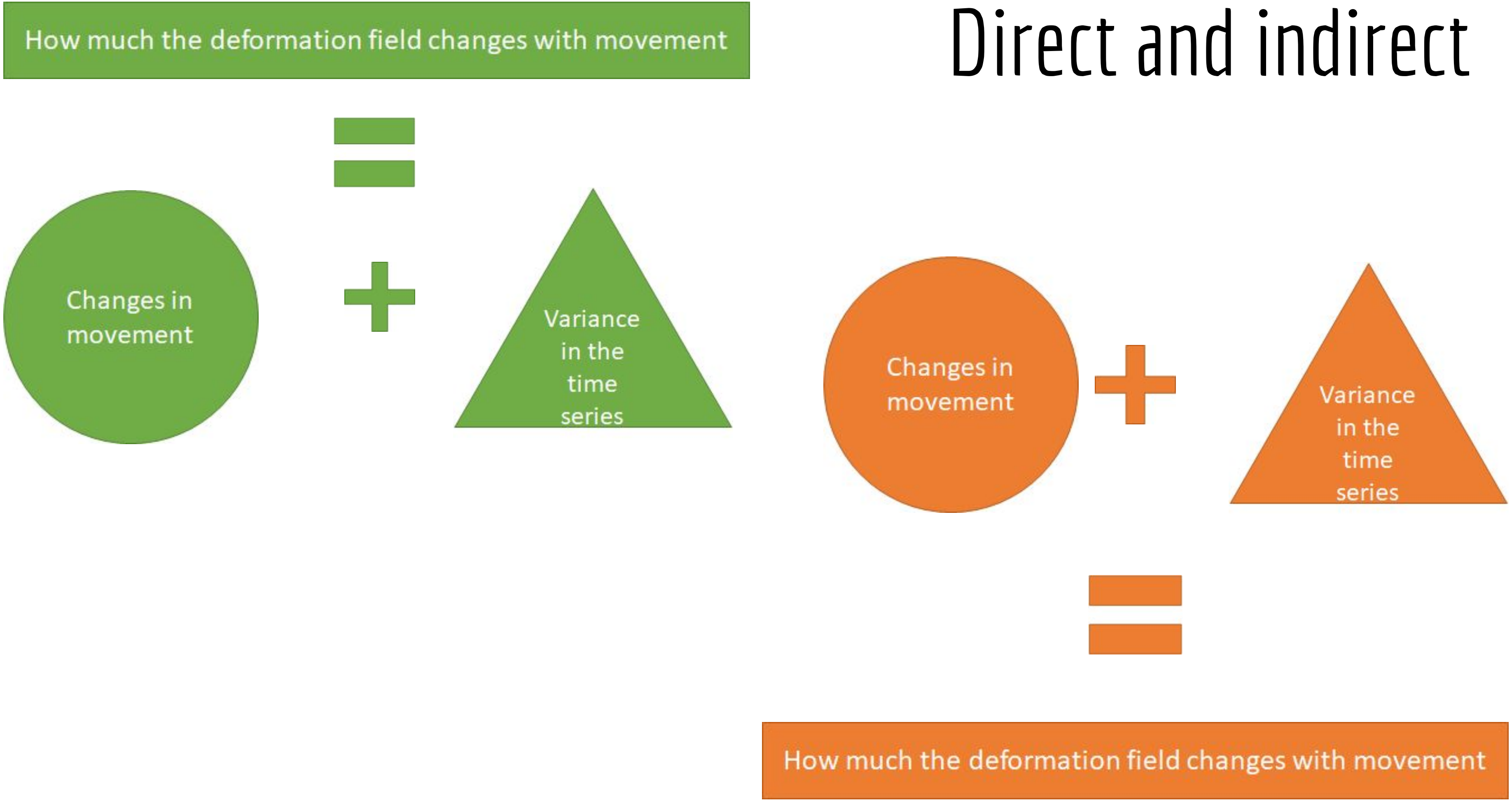
Participant movement **interacts** with the image distortions.

So what can I do?

- UNWARP
- UNWARP estimates the changes in distortion caused by movement by:
  - Measuring the distortion field with FieldMap
  - Observing the subject motion parameters (obtained during realignment)
  - Changing the deformation field with subject movement
  - Giving an estimate of the distortion at each time point

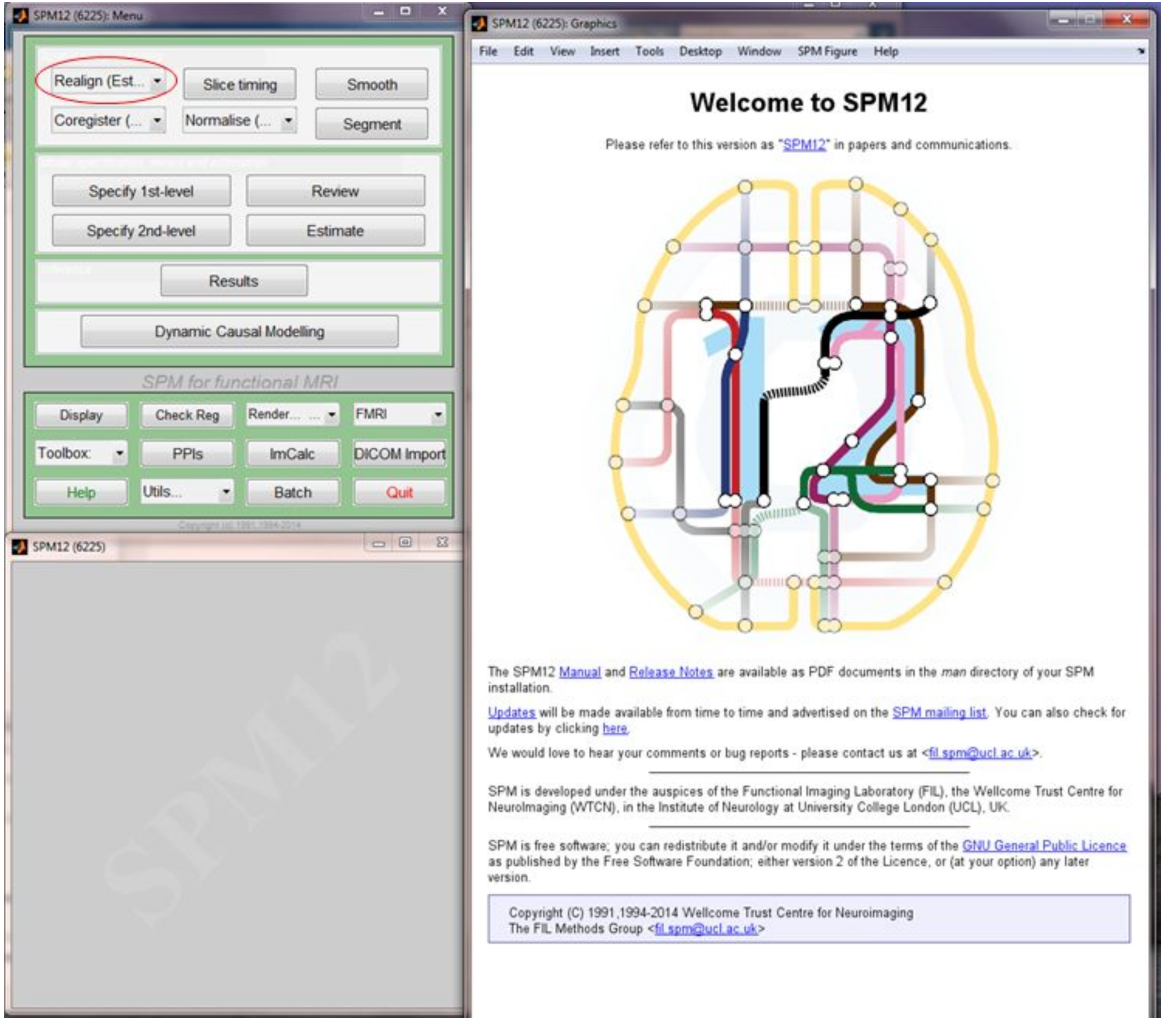

Estimate the movement parameters
Measure the deformation field (FieldMap)
Estimate the new distortion field
Unwarp

Direct and indirect



When to use UNWARP

- UNWARP is intended to correct data afflicted by a particular set of problems:
  - Lots of movement in the data (i.e. ›1mm or ›1 degree)
  - Task-related movements (button press)
  - Studying the “problem areas”
  - Minimises total (across the image volume) variance in the dataset
  - Removes unwanted variance whilst preserving “true” activation
- UNWARP is computationally intense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Render...
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Toolbox:
PPIs
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DICOM Import
Help
Utils...
Batch
Quit
SPM12 (6225)
SPM12 (6225): Graphics
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Welcome to SPM12
Please refer to this version as "SPM12" in papers and communications.
The SPM12 Manual and Release Notes are available as PDF documents in the man directory of your SPM installation.
Updates will be made available from time to time and advertised on the SPM mailing list. You can also check for updates by clicking here.
We would love to hear your comments or bug reports - please contact us at <fil.spm@ucl.ac.uk>.
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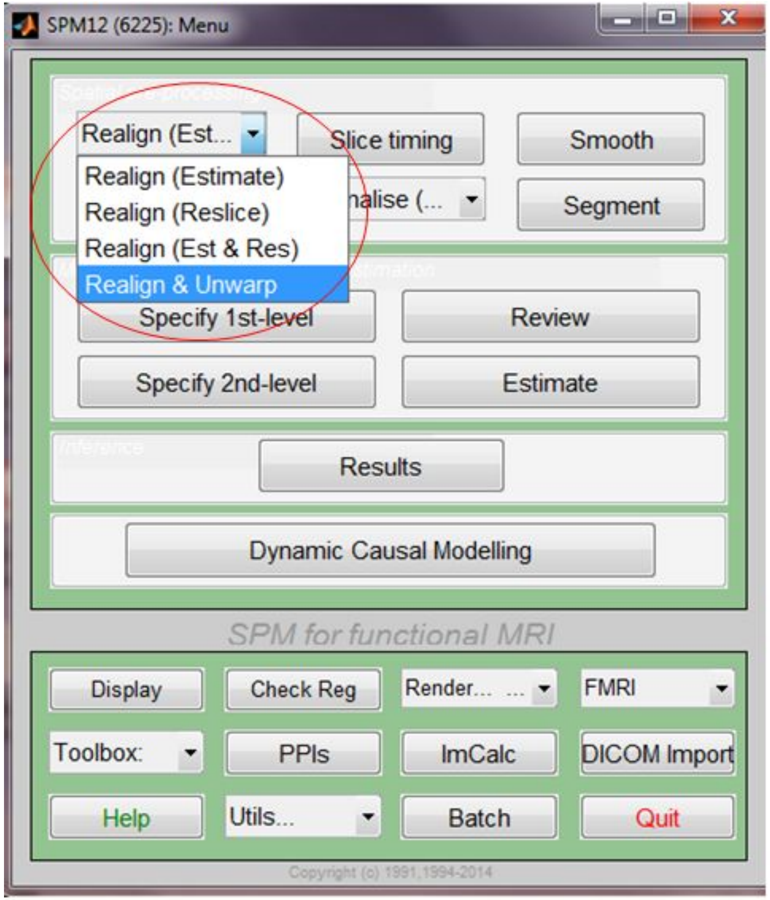
The FIL Methods Group <fil.spm@ucl.ac.uk>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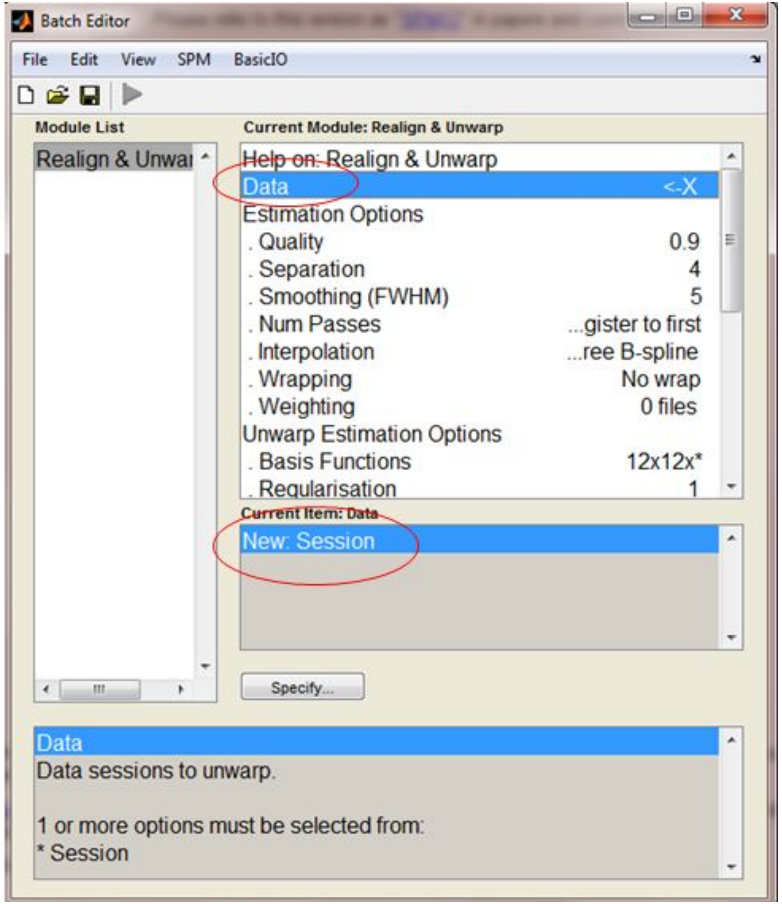
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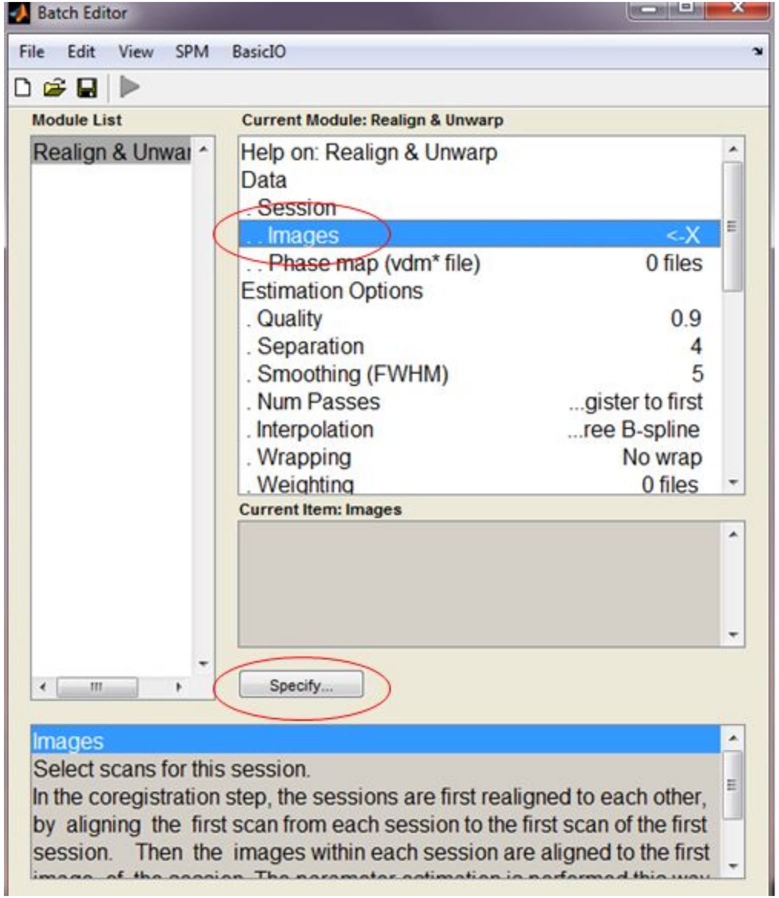
* Session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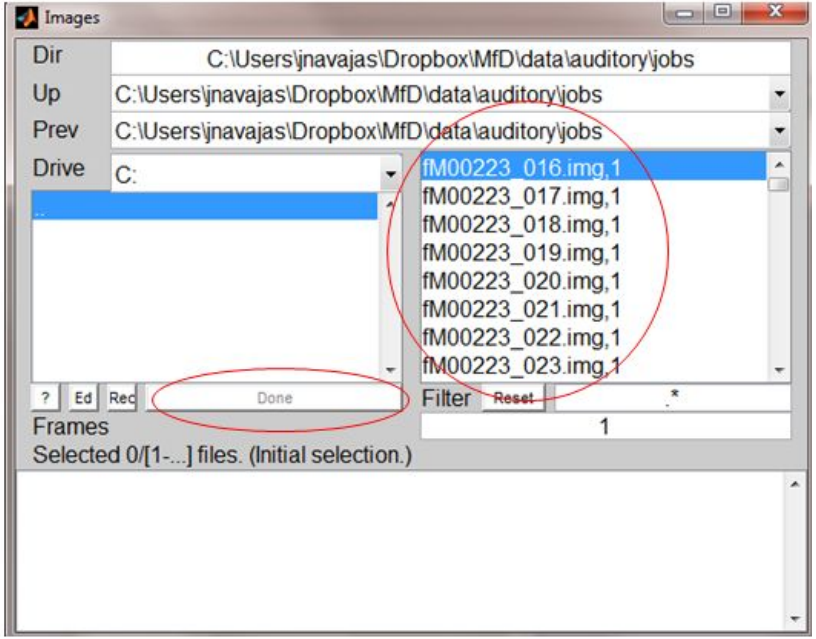
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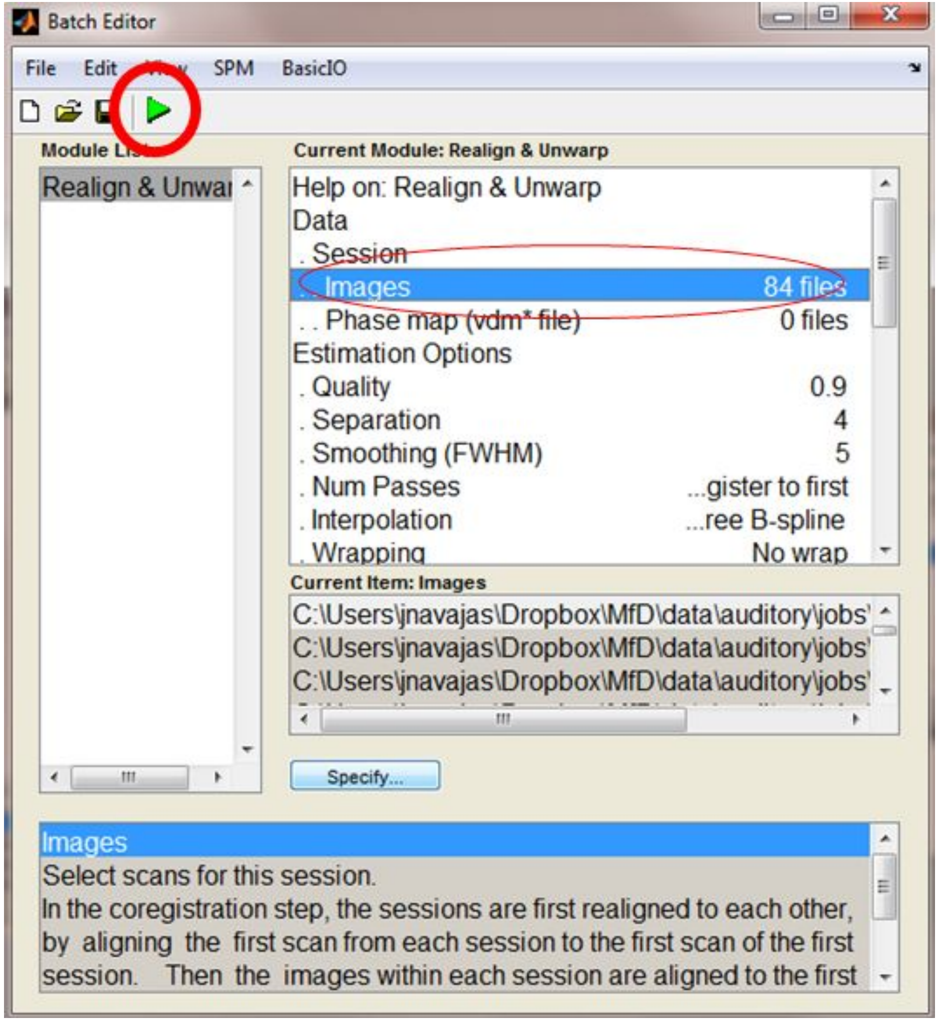
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References

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