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Slicer3 Tutorial / Registration Library: Case 03 - DTI

aligning low-resolution diffusion MRI

Dominik Meier, Ron Kikinis Sept. 2010



Introduction / Scenario

- We have a low resolution DWI scan we seek to align with the structural reference T2 scan
- The DWI scan has a strong rotational misalignment and also strong voxel anisotropy. Both cause problems downstream for obtaining an accurate registered DTI and hence have to be corrected beforehand.









DTI tensor

T2 reference

DTI baseline

0.9375 x 0.9375 x 3 mm

0.4 x 0.4 x 1.5 mm



• To accomplish this task we will use the following modules:

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- Volumes Module
- Diffusion Tensor Estimation Module
- BrainsFit Registration Module
- Data Module
- Resample DTI Module

le	Moo	lules:	Diffusio	n Tensor	Estimati	on 😑
Mod	lules:		BRAINS	Fit	-	
Å						
Mod	ules:	Resa	ample DTI	Volume	=	



- Slicer version 3.6.1 or later
- Example Dataset: download and extract the dataset for this tutorial: RegLib_C29_DATA.zip, which should contain this tutorial, all original and some intermediate solution data files.
- The extension set RegLib_C29_DATA_DWI.zip contains the original DWI image and the resampled DTI image (omitted from main set to maintain moderate dowload sizes).
- Tutorials to complete first (optional):
 - Slicer3Minute Tutorial
 - Loading and Viewing Data
 - DTI tutorial



Pipeline

	Step	Module	Result	Slides
1	Resample T2 to isotropic voxel size 1x1x1	Resample Scalar Volume	T2.nrrd	7
2	Manually align DWI with T2	Transforms	Rigid transform node: Xf1_ManualInit.tfm	8
3	Resample DWI to T2 space and isotropic voxel size	Resample Scalar/Vector/DWI Volume	resampled DWI volume	8
4	Obtain DTI Estimation	Diffusion Tensor Estimation	DTI.nrrd	9-10
6	Register Baseline DTI to resampled T2	Registration / BrainsFit	nonrigid Bspline transform: Xf2_DTI-T2_unmasked, Xf3_DTI-T2_masked	11-15
7	Resample DTI	Diffusion / Utilities / Resample DTI Volume	Resampled DTI in space of T1: DTI_Xf3	16



- The original DWI image has two characteristics that cause problems downstream and hence should be corrected first:
- Resolution is 1 x 1 x 3 mm , which in combination with the strong rotation will cause strong "bleeding" of the zdirection when resampling
- 2. The volume has a strong rotation around the LR axis, which causes problems when creating the DTI tensor



If the original DWI is used to obtain a DTI, which in turn is registered to the T2, the strong anisotropy in the DWI image will cause interpolation artifact with a strong "blurring" of the directional (z (IS)) component, ultimately yielding the biased image above. To prevent this we make the DWI isotropic first and then also align it manually to the T2.

We address the misalignment via a rough manual alignment and the resampling to isotropic voxels at the same time when resampling the DWI with this transform



Preprocessing: Resample T2

- Go to the *Resample Scalar Volume* module: <u>Input Volume</u>: T2_raw <u>Resampling Parameters</u>: Spacing = 1, 1, 1 <u>Interpolation</u>: "hamming" <u>Ouput Volume</u>: "Create New Volume", rename to "T2"
- 2. Click "Apply"

Resample Scalar Volume
Parameter set Resample Scalar Volume 🥃
Status Idle
* Resampling Parameters
Spacing 1,1,1
Interpolation 🔲 linea 🔲 nearestNeighb 🗐 bsplir 🗈 hammir
cosir welch lancz blackm
▲ 10
Input Volume Tw 🖃 🛒
Output Volume T2 =
Default Cancel Apply

▲ Deservate Ossten Velu



Preprocessing: Manual Alignment

- 1. In the *Data* module, select the Scene node, and via rightmouse click, select "Insert Transform Node"
- 2. In the *MRML Node Inspector* below, rename to "Xf0_ManualInit"
- Move the DWI volume inside the "Xf0_ManualInit" node. Select DWI in the slice view to be visible along with the T2
- 4. Go to the *Transforms* module. Manually adjust LR rotation and IS translation etc. to roughly align the two volumes.
- Go to the Resample Scalar/Vector/DWI Volume module: <u>Input Volume:</u> DWI <u>Reference Volume:</u> T2 <u>Ouput Volume:</u> "Create New Diffusion Weighted Volume", rename to "DWI_ir" <u>Transform Node:</u> "Xf0_ManualInit".
- 6. Click "Apply"

MRML Tree
⊟ Scene
Default Scene Camera
DTI
DTI_base

$_{\Gamma}$ MRML Node	MRML Node Inspector		
ID:	vtkMRMLLinearTransformNode4		
Name:	Xf0_ManualInit		
MRML	Node Name		



DWI -> DTI conversion

We're now ready to convert the new isotropic DWI into a DTI. This conversion will produce 3 new volumes:



DTI_base: used as moving image to compute the registration with a T2 reference

DTI: final registration transform will be applied to the tensor to resample it in the new reference space (T2).

DTI_mask: the mask will be used to guide the automated intensity-based registration of the DTI_baseline. Particularly the nonrigid aspects of the registration to correct for the DTI distortions benefit from the ROI provided by the mask.



Convert DWI -> DTI

- 1. We next convert the DWI volume into a DTI tensor image that can be used for fiber tracking and other forms of quantifying diffusion.
- 2. The DTI Estimation module in the Diffusion / Utilities section will perform this task in a single automated step:
 - 1. Select the DWI image
 - 2. Create new DTI output image
 - 3. Create new output baseline volume
 - 4. Create new Otsu mask volume
 - 5. Leave Estimation Parameters at defaults
 - 6. Click Apply
 - The DTI_baseline output will serve as moving image for the registration
 - The Otsu mask image may be useful as mask to focus registration

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Help & Acknowledgement
 Diffusion Tensor Estimation

 Parameter set Diffusion Tensor Estimation =
 Status Idle

 IO

 Input DWI Volume =
 Output DTI Volume DTI =

Output Baseline Volume DTI_Baseline 🖃 🖨

Otsu Threshold Mask 🛛 Otsu Threshold Mask 🖃 🚔

Estimation Parameters

Estimation Parameters 🔳 LS 🔲 WLS 🔲 NL

Shift Negative Eigenvalues 🗉

Otsu Omega Threshold Parameter 0.5

Cancel

Remove Islands in Threshold Mask

Apply Mask to Tensor Image 🗷

Default

Apply

ы



- 1. Go to the "BrainsFit" module
- 2. Input: Fixed Image: T2 Moving Image: DTI_baseline

3. Output:

"Slicer Bspline Tansform": create new, rename to "Xf1_DTI-T2_unmasked" Check boxes for: "rigid", "affine" + "Bspline" registration

Registration Parameters as shown below: Changes to defaults

highlighted • Registration Parameters

	negisu aliun narameters
	Transform Type
	Number Of Iterations 1500
	Number Of Samples 20000D
	Minimum Step Size 0.005
	Transform Scale 1000
	Reproportion Scale 1
	Skew Scale 1
<	Number Of Grid Subdivisions 5,5,3
	Maximum B-Spline Displacement 0

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🚹 🎦 Modules:	BRAINSFit =
3DSlicer	
* Help & Acknowled	gement
↑ BRAINSFit	
	Parameter set BRAINSFit 🖃 💂
	Status Idle
Input Parameters	
	Fixed Image Volume T2
M	oving Image Volume DTe =
Registration Phase	es To Use
Initialize with previo	ously generated transform e 🖃
Initialize with N	/lomentsAlign registration phase 🔲
Initialize with Geom	etryCenterAlign registration phase
Initialize with Cente	rOfHeadAlign registration phase 🗏
	Include Rigid registration phase 🗹
Include Se	caleVersor3D registration phase 🔲
Include ScaleS	kew∨ersor3D registration phase 🔲
	nclude Affine registration phase 🗹
	clude BSpline registration phase 🗷
↑ itput Settings (At	Least One Output Must Be Specifie
Slie	cer BSpline Transform Xm 🗕 🛋



Registration: Masking

- For this scenario a mask of the brain parenchyma is useful and improves registration quality.
- The DTI estimation process produced a mask for the DTI_base image, but we still need a second mask for the T2.
- BRAINSfit requires masks for both the fixed and moving image. To obtain a mask for the fixed image we first perform the same (Affine + Bspline) registration without a mask and use the result transform to resample the DTI_mask volume into the T1 space.
- We can either perform a separate segmentation for the T2 or reuse the DTI_mask by first performing another registration. We'll do the latter here.



Rsample Mask for T2

- We apply the obtained transform to the binary mask label file to obtain a new mask for the T2.
- 1. Go to the *Resample Scalar/Vector/DWI Volume* module:
- 2. Remember to select "Output-to-input" as the order of transform evaluation and nearest-neighbor (nn) as the interpolation method
- 3. Click Apply. You should now have a new mask label file to be used in BRAINSfit.

Resample Scalar/Vector/DWI Volume
Parameter set DTI_mask_Xf1 =
Status Completed
Input/Output
Input Volume DTI_mask =
Reference Volume (To Set Output Parameters) T2 =
Output Volume DTI_mask_Xf1 =
Deformation Field
* Resampling Parameters
 Transform Parameters
Transform Node Xf1_DTI-T2_unmasked 🖃 🗬
Transforms Order 🔲 input-to-output 🔳 output-to-input
Bulk Transform 🔳
 Manual Transform (Only Used If No Transform Node Set)
* Rigid/Affine Parameters
 Interpolation Type
Interpolation 🔲 linear 🔳 nn 问 ws 🔲 bs



This requires :

- 1. BRAINSfit registration (unmasked), output = Bspline Xform only
- 2. Resample Scalar/Vector/DWI volume, applied to DTI_mask; output = T2_mask



- We now have the masks to repeat the registration: We use the same settings except we add the two mask files: Go to the "BrainsFit" module
- 2. Input: Fixed Image: T2 Moving Image: DTI_baseline
- 3. Mask Processing Tab: Check box: Mask Processing Mode: ROI Fixed Mask: DTI_mask_Xf1 Moving Mask: DTI_mask
- 4. Output:

"Slicer Bspline Tansform": create new, rename to "Xf2_DTI-T1_masked" "Output Volume": create new, rename to "DTI_base_Xf2" Check boxes for: "rigid", "affine" + "Bspline" registration

Registration Parameters as shown below: Changes to defaults highlighted



Moving Image Volume DTI base -* Registration Phases To Use Initialize with previously generated transform - 1 Initialize with MomentsAlign registration phase Initialize with GeometryCenterAlign registration phase Initialize with CenterOfHeadAlign registration phase II Include Rigid registration phase Include ScaleVersor3D registration phase I Include ScaleSkewVersor3D registration phase Include Affine registration phase 🗹 Include BSpline registration phase 🗹 Output Settings (At Least One Output Must Be Specified.) Slicer BSpline Transform Xf2 DTI...masked Slicer Linear Transform - 14 Output Transform - | Output Image Volume DTI base Xf2 Output Image Pixel Type I float I short I ushort I int uint uchar * Registration Parameters Transform Type Number Of Iterations 1500 Number Of Samples 200000 ¢ Minimum Step Size 0.005 Transform Scale 1000 \$ Reproportion Scale 1 ٢ Skew Scale 1 \$ Number Of Grid Subdivisions 7,7,5 -Maximum B-Spline Displacement Advanced Output Settings Control Of Mask Processing Mask Processing Mode INOMASK IROLAUTO IROL Output Fixed Mask (ROIAUTO only)

Parameter set Xf2...ked 🗕 🚔

Fixed Image Volume T2 -

Input Parameters

Status Completed

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Resample DTI

Last step is to resample the DTI with the new transform (Xf3).

This is done with the *Resample DTI Volume* Module, found in the *Diffusion / Utilities* Set

- 1. Input image = DTI Output Volume = New DTI Volume Reference Volume = T2
- 2. Transform Parameters: Transform Node = Xf2_DTI-T2_masked Select/check the *output-to-input* box
- 3. Apply

🚹 🎦 Modules: Resample DTI Volume 📼 ┥
3DSlicer
* Help & Acknowledgement
Resample DTI Volume
Parameter set Resample DTI Volume 🗕 🚔
Status Idle
Input/Ouput
Input Volume DTI 🖃 🗬
Output Volume DTI_BSpl2 =
Reference Volume (To Set Output Parameters)
Deformation Field
* Resampling Parameters
Transform Parameters
Transform Node 🗙m =
Transforms Order 🔲 input-to-output 🔳 output-to-input
Bulk Transform 🔳



We have now the DTI in the same orientation and resolution as the T2 reference scan.

For verification: for the resampled DTI_BSpl2 select "Color Orientation" from the Display tab in the Volumes module, then set fore- and background to the T2 and DTI_Xf2 respectively and drag the fade slider to a halfway position.



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