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## Slicer3 Tutorial: Registration Library Case 08

## **Serial PET-CT**

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## Introduction / Scenario

- We have two sets of PET-CT scans, a baseline and follow-up scan.
- Both exams were obtained on a combined PET-CT scanner, hence the PET and CT within each exam are aligned already
- We want to align the follow-up exam with the baseline.
- Because we have two pairs of images, we have two sets of separate registrations we can perform and choose the better one: we can register CT-CT or PET-PET. Aligning CT of one exam with the PET of the other exam is unlikely to produce a better result than any of the first two.
- The images represent the same subject, hence we expect good alignment. However these are full body scans, hence unlike a brain scan there are many opportunities for relative motion within the image that are very difficult for a global registration to correct.



follow-up CT follow-up PET combined view



### **Modules Used**

- To accomplish this task we will use the following modules:
  - Register Images
  - Deformable Bspline Registration
  - Resample Scalar/Vector/DWI Volume
  - Extract Subvolume ROI
  - Data Module
  - Volume Module



- Slicer version 3.5 or later
- Example Dataset: download and extract the dataset for this tutorial: RegLib\_C08\_PET-CT.zip, which should contain this tutorial and all original and intermediate solution data files.
- Tutorials to complete first:
  - Extract Subvolume ROI
  - Slicer3Minute Tutorial
  - Loading and Viewing Data



## **1. Loading Example Dataset**

To get the Example Dataset loaded into Slicer:

- 1. File Menu: File: Load Scene...
  - Select the Slicer Scene file that comes with the downloaded example dataset, called: RegLib\_...\_SlicerScene.mrml
  - This will load all the necessary images. If this fails, use the "Add Data..." menu to load the files in the data directory.
- 2. Select Layout: From the icon bar, click on the -Layout menu and select "Conventional Layout".
- 3. Link Views: Click on the Ring Icon in any of the slice views to link all the views together. This will save you the work of making selections for each slice window separately.
- 4. (Choose Foreground: S1\_PET 5. (Choose Background: S1\_CT



File Edit Load Scene Import Scene

Add Volume

Add Transform Save

Close Scene

Exit

Ctrl-/

Ctrl-S

Ctrl-W







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### **Adjust Views**

- 1. Click on the little upward-facing triangle to collapse the 3D view.
  - 2. If the images do not appear as shown on the right, adjust the window&level:
  - Go to the "Volumes" module and select s1\_CT. Expand the "Display" tab.
  - 4. For the CT scan images, click on the "CT-abdomen" button.
  - 5. For the PET images, click on the "PET" icon.
  - 6. This will adjust the dynamic range and colormaps.





## **Initial Alignment**

- 1. The two exams are far apart initially, due to different coordinate origin settings in acquisition. We perform an initial alignment, for which we use CT-CT:
- 2. Go to the "Register Images Module", and select the following parameters: fixed image: s1\_CT moving image: s2\_CT
  - Save transform: "Create New Transform", then select rename and change to "Xform\_Aff0\_Init" Initialization: Centers of Mass Registration: Pipeline Affine Metric: MattesMI Expected offset magnitude: 50 Expected rotation,scale,skew magnitude: leave at default (see right) Expected offset magnitude: 50 Expected offset magnitude: 50 "Advanced Affine Registration Parameters" Tab:



3. Click "Apply"

Affine Max Iterations: 10

Affine sampling ratio: 0.02



# **Initial Alignment (2)**

- Algorithm should return within ~ 1 minute. To see the result we apply the result transform to the volume:Go to the data module.
- 5. Drag the node for "s2\_CT" on top of
  the transform node
  "Xform\_Aff0\_init". You should see the tree update as shown.
- Adjust the slice views to show the two CT scans: background: s1\_CT foreground: s2\_CT
- You should see the two images aligned as shown on the right. To see the effect use the toggle switch.





animated gif, view in presentation mode





## Non-rigid alignment

- 1. As apparent from the sagittal view, there are differences from posture and breathing that a global alignment cannot correct. We proceed to a non-rigid alignment to compensate for this: Go to the "Deformable Bspline registration" module
- 2. Select the following parameters: (if you loaded the scene file, you can also choose the parameter preset loaded that will set them for you):

Iterations: 20 Grid Size: 5 Histogram Bins: 50 Spatial Samples: 50000 Initial Transform: Xform\_Aff0\_Init Fixed Image: s1\_CT Moving Image: s2\_CT Output transform: create new, rename to "Xform\_BSpl1" Output Volume: create new, rename to "s2\_CT\_BSpl1"

 Click "Apply". Registration should take ~ 2 minutes





# Non-rigid alignment (2)

- 4. The result and deformation applied can be seen on the right. The differences in the chest region were reduced, however head position remains different. Because we care about the abdominal region, we proceed with further refinement by cropping the region of interest:
- 5. Go to the "Extract Subvolume ROI" module. We clip both s1\_CT and s2\_CT between the 5th lumbar and the 5th thoracic vertebrae.
  For a separate tutorial on how to use the Subvolume module, see the slicer training compendium:

To skip this step, load the ready-made cropped volumes from your example directory:

s1\_CT\_crop , s2\_CT\_crop. Once loaded set the proper display in the Volumes module as described before on slide #x



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# Non-rigid alignment (3)

6. Now we repeat the Bspline registration process with the cropped volumes:

Iterations: 120 Grid Size: 9 Histogram Bins: 50 Spatial Samples: 150000 Initial Transform: Xform\_Aff0\_Init Fixed Image: s1\_CT\_crop Moving Image: s2\_CT\_crop Output transform: create new, rename to "Xform BSpl2"



animated gif, view in presentation mode

Leformable BSpline Registration         Parameter set         Presets_BSpl2         Status Completed         Registration Parameters         Iterations         Iterations         Grid Size         Histogram Bins         Spatial Samples         Spatial Samples         Maximum Deformation         Maximum Deformation         Default Pixel Value         Default Pixel Value         Fixed Image         s1_CT_crop         Moving Image         s2_CT-crop         Output Volume         s2_CT_crop_BSpl2         Default         Cancel         Apply						
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- 7. Click "Apply". This will take ~ 1-2 min
- 8. Resulting alignment should look like shown on the right. Small residual misalignment remains in some areas, but the liver is mostly aligned

Output Volume: create new, rename to "s2 CT BSpl2"

9. We now proceed to send the full CT and PET images through the same transforms. The sequence goes first through Xform\_Aff0\_Init and then through Xform\_BSpl2. However, since we gave Xform\_Aff0\_Init as starting point for the Bspline, its transform already includes the affine portion. So we have to apply only 1 step for the resampling.



#### Resample

Modules: sample Scalar/Vector/DWI Voluma

- Go to the "Resample Scalar/Vector/DWI Volume" module.
   Select the following:
  - Select the following: Input Volume: s2\_CT Reference Volume: s1\_CT Output Volume: create new, rename to s2\_CT\_BSpl2 Transform Node: XForm\_BSpl2 **Transform order: output-to-input** Interpolation Type: ws (windowed sync) Interpolation window function: h (Hanning)
- **≝**<sup>∎</sup> 3.

Volumes

Modules:

- Click "Apply"
- 4. Repeat the steps 2-3 above for: s2\_PET as Input, s1\_PET as reference volume, and s2\_PET\_BSpl2 as output.
- 5. Go to the Volumes module; in the "Display" tab select "CT\_Abdomen" and "PET" as the display parameters for the 2 newly created volumes s2\_CT\_BSpl2 and s2\_PET\_BSpl2

	* Resample Scalar/Vector/DWI Volume				
	Parameter set esample Scalaor/DWI Volume-				
	Status Id				
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	Input Volume s2_CT =				
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	Output Volume s2_CT_BSpl2 -				
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Modules:	Volumes 😑				

* Display					
Lookup Table:	Grey				
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Window Level E	ditor Presets:				
	CT-abdomen CT-brain CT-lung				
Volume Window	/ Level Presets:				



#### **View Results**

We can now compare the aligned PET images:

- 🖳 1. Choose Foreground: S2\_PET
- 🖳 2. Choose Background: S1\_PET
  - 3. Using the view toggle button switch back and forth between FG and BG to see the alignment. You should see something similar to the animation below.





animated gif, view in presentation mode

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- 1. We now have all 4 images in the same aligned space.
- 2. From the File menu, select "Save"
- 3. In the dialog box, check the boxes for: XForm\_BSpl2

s2\_CT\_BSpl2 s2\_PET\_BSpl2

- 4. Choose desired output directory
- 5. Click on "Save Selected".

Save Scene & Data Options								
Change Destination for All Selected: //workspace								
Select	Node Name	Node Type	Node Status	File Format	File Name	Data Directory		
	(Scene Description)	(SCENE)	Modified	MRML (.mrml) 🚽	SlicerScene1.mml	/workspace/		
	s2_PET	Volume	Not Modified	NRRD (.nrrd)	RegLib_C08_PETCT	/workspace/		
	s1_CT	Volume	Not Modified	NRRD (.nrrd)	RegLib_C08_PETCT	/workspace/		
	s2_CT	Volume	Not Modified	NRRD (.nrrd)	RegLib_C08_PETCT	/workspace/		
	s1_PET	Volume	Not Modified	NRRD (.nrrd)	RegLib_C08_PETCT	/workspace/		
	Xform_Aff0_init	LinearTrans	Not Modified	Transform (.tfm)	Xform_Aff0_init.tfm	/workspace/		
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	s2_PET_BSpl2	Volume	Not Modified	NRRD (.nrrd)	s2_PET_BSpl2.nmd	/workspace/		
	s2_CT_BSpl2	Volume	Not Modified	NRRD (.nrrd)	s2_CT_BSpl2.nmd	workspace/		

Save Selected Cancel

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- Try the Manual Registration Tutorial or one of the tutorials from the Registration Case Library.
  - <u>http://www.slicer.org/slicerWiki/index.php/Slicer3.4:Training</u>
  - <u>http://na-</u> <u>mic.org/Wiki/index.php/Projects:RegistrationDocumentation:UseCaseI</u> <u>nventory</u>
  - <u>http://www.slicer.org/slicerWiki/index.php/Slicer3:Registration#Registration\_in\_3D\_Slicer|Main</u>
- Feedback: anything amiss? If you have suggestions on how we can improve this and other documentation, please let us know: visit:
  - <u>http://na-mic.org/Wiki/index.php/Projects:RegistrationDocumentation</u>



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