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Non-rigid MR-CT Image Registration

Atsushi Yamada, Dominik S. Meier and Nobuhiko Hata

Brigham and Women's Hospital

ayamada@bwh.harvard.edu

617-963-4336

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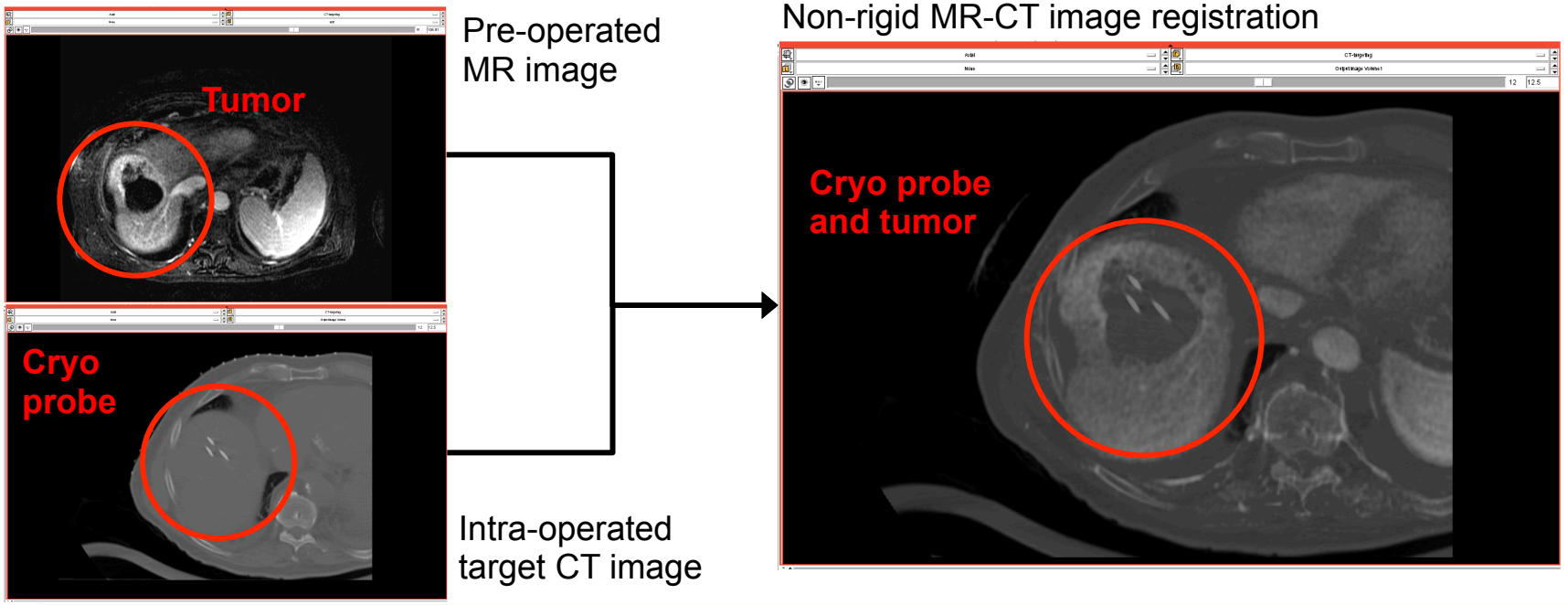
Learning Objective

- This tutorial demonstrates how to perform MR-CT and CT-CT non rigid registrations.
- The case study is CT-guided liver tumor cryoablation

As shown in this figure, non-rigid registration can enhance visualization of tumor margin and location.



Material

This tutorial requires the installation of the **Slicer3.6 release** from source files. It is available at the following locations:

Slicer3.6 Build Instruction page

http://www.slicer.org/slicerWiki/index.php/Slicer3:Build_Instructions

1. After building Slicer3.6, command “make edit_cache” at “[install folder]/Slicer3.6-build/Modules”.
2. Select “ON” of “BUILD BrainsFitIGT” on ccmake screen editor.

3. Press “c” then press “g” to generate new CMakeLists.txt.
4. After command “make”, you can use BrainsFitIGT module.

Material

This tutorial website is at:

http://wiki.na-mic.org/Wiki/index.php/Non-rigid_MR-CT_Image_Registration

This tutorial dataset is available at:

http://www.na-mic.org/Wiki/images/4/47/Non-rigid_MR_CT_Image_RegistrationTutorialData_TutorialContestSummer2011.tar.gz

Platform

- This tutorial was developed and tested on an Intel MacBook Pro (2.3 GHz Core i7, 4GB).

Overview

- Registration in CT-guided liver tumor cryoablation: clinical signification
- Strategy Overview
- MR-CT non-rigid registration
- CT-CT non-rigid registration
- MR-CT registration by using given Bspline transformation matrix

Clinical Signification

CT imaging can be used to plan the interventional approach to facilitate the safe placement of **the ablation applicators** in the tumor. **However, tumor is invisible or poor visible**

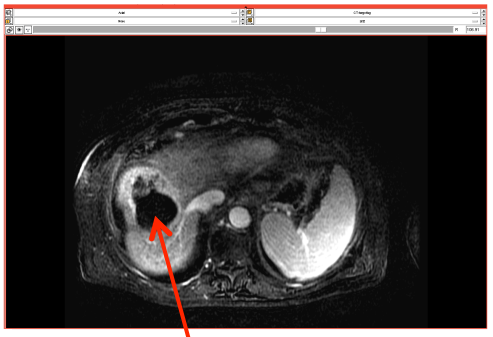
CT

Cryoprobe

Contrast enhanced CT or MRI

Tumor margins and surround structure can be depicted

Liver position, shape and structures may be differ significantly between two exams.

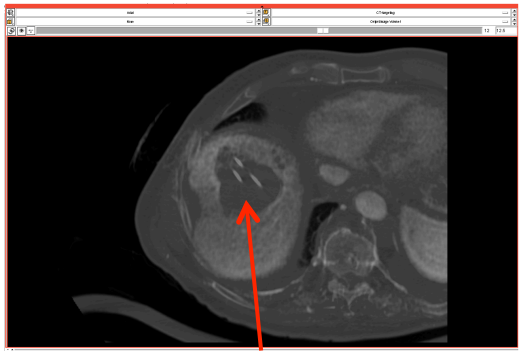


MRI

tumor

Non-rigid registration is desirable to compensate for liver deformation caused by patient positioning, respiratory motion and interventional manipulation.

Non-rigid registration

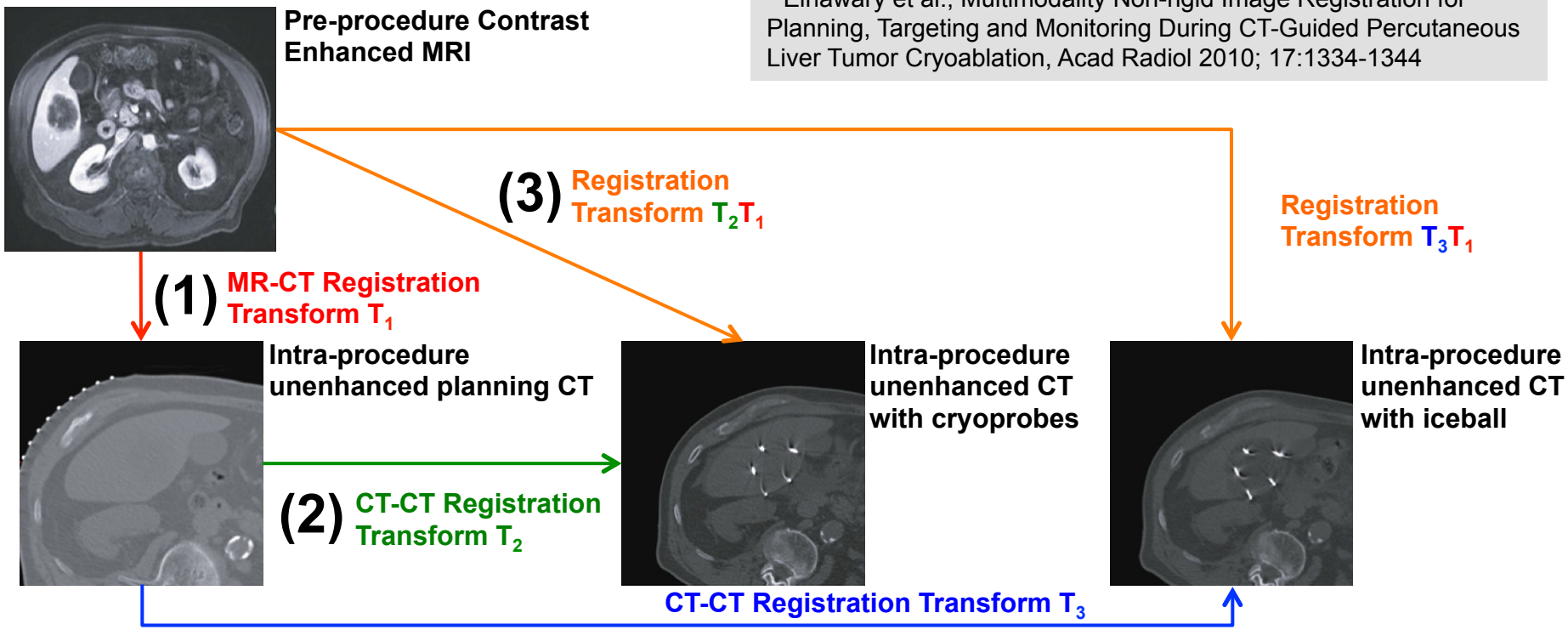


Tumor and Cryoprobe

Registration Between MR and CT Images

In CT-guided cryoablation, there are three different registration tasks as follows. These three tasks will be performed in this tutorial.

* Elhawary et al., Multimodality Non-rigid Image Registration for Planning, Targeting and Monitoring During CT-Guided Percutaneous Liver Tumor Cryoablation, Acad Radiol 2010; 17:1334-1344



Strategy Overview

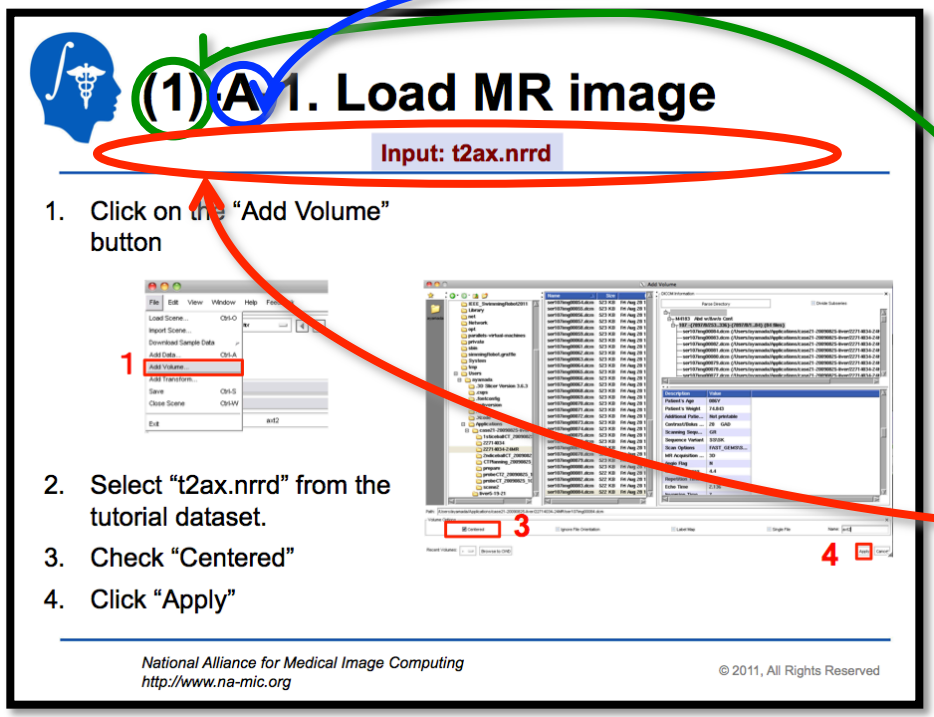
- To accomplish each task, the plan will be as

STEP:		A	B	C	D
Process:		Masking	Contrast Enhancement	Non-rigid Registration	Bspline Waping
Modules:		Edit	N4ITK MR Bias Correction	BRAINSFitIGT	BRAINS Resample
Task (1)	Input:	t2ax.nrrd	t2ax.nrrd t2ax-label.nrrd	t2ax-N4.nrrd t2ax-label.nrrd CT-plan.nrrd CT-plan-label.nrrd	
	Output:	t2ax-label.nrrd	t2ax-N4.nrrd	t2ax-REG.nrrd T1.tfm	
Task (2)	Input:	CT-plan.nrrd		CT-plan.nrrd CT-plan-label.nrrd CT-intra.nrrd CT-intra-label.nrrd	
	Output:	CT-plan-label.nrrd		CT-plan-REG.nrrd T2.tfm	
Task (3)	Input:	CT-intra.nrrd			t2ax-REG.nrrd T2.tfm CT-intra.nrrd
	Output:	CT-intra-label.nrrd			MR-CT-intra.nrrd

* Tutorial dataset * Mask data
* Contrast enhanced image
* Deformed image
* Bspline transformation matrix

Tutorial Format

Each slide has some information, that is, **task number**, **step**, **input and output** as follows.



STEP:	A	B
Process:	Masking	Contrast Enhancement
Modules:	Edit	N4ITK MR Bia Correction
Task (1) Input:	t2ax.nrrd	t2ax.nrrd t2ax-label.nrrd
Task (1) Output:	t2ax-label.nrrd	t2ax-N4.nrrd
Task (2) Input:	CT-plan.nrrd	
Task (2) Output:	CT-plan-label.nrrd	

Figure of the previous Page

(1) STEP:A
Mask of MR Image

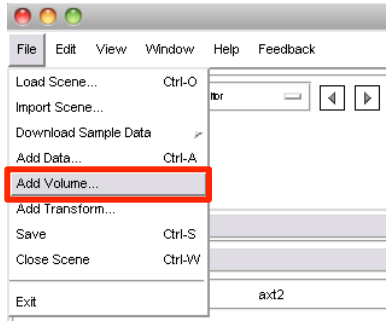
Objective:

To make a mask file (t2ax-label.nrrd) which decides a region of non-rigid registration

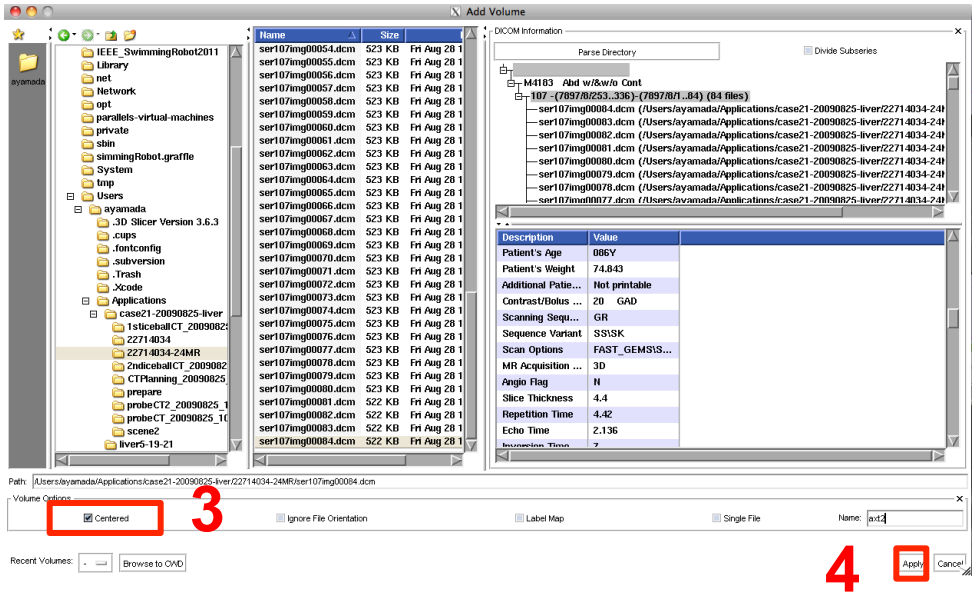
(1)-A-1. Load MR image

Input: t2ax.nrrd

1. Click on the “Add Volume” button

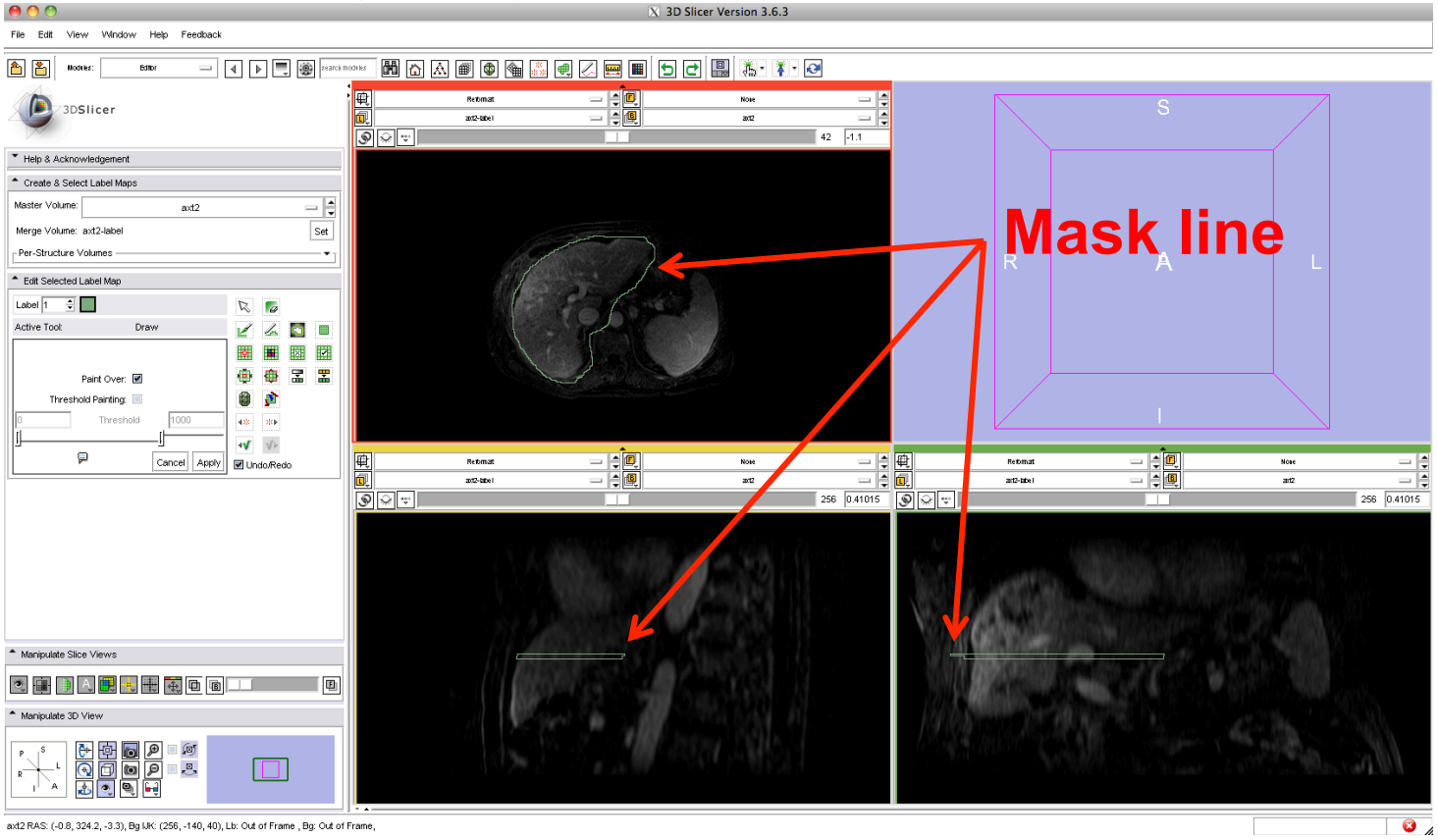


2. Select “t2ax.nrrd” from the tutorial dataset.
3. Check “Centered”
4. Click “Apply”



(1)-A-2. Segmentation of Liver

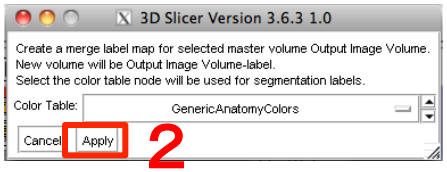
To decide a non-rigid registration area, the liver will be masked



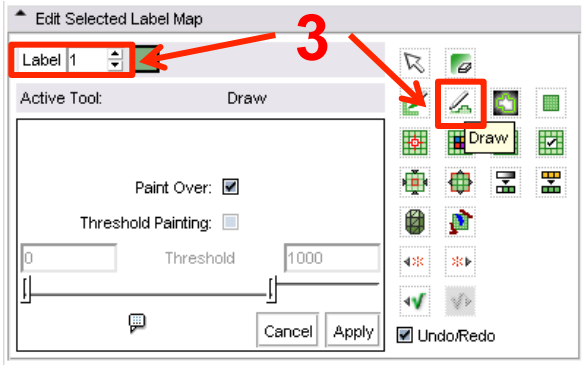
(1)-A-3. Preparation

Output: t2ax-label.nrrd (made automatically when Editor workes)

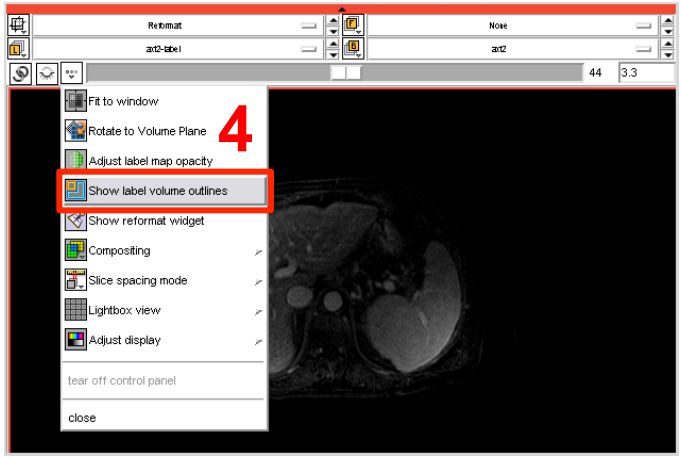
1. Go to the “Editor” module
2. Click “Apply” on the small window about Color table



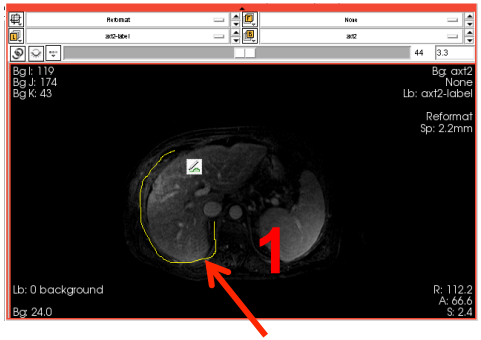
3. Select “Draw” button of the module pane to segment liver with label 1



4. Select “Show label volume outline” to confirm the segmented area easily

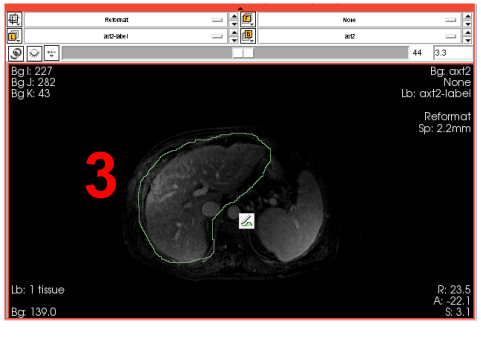


(1)-A-4. Segmentation of Liver



1. Draw the line by freehand with left click of mouse around the liver

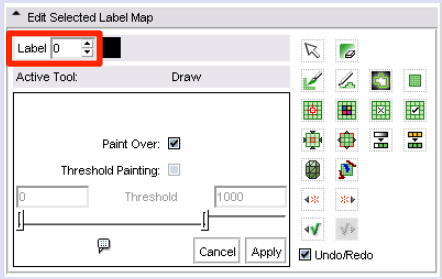
2. Draw the line continuously around the liver

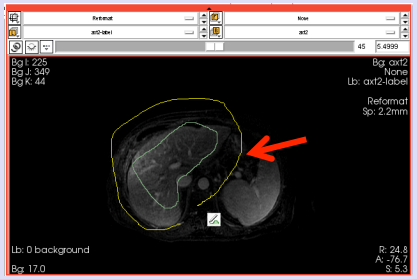


3. Double click the right button of the mouse near the start point for closing the line

Tips!

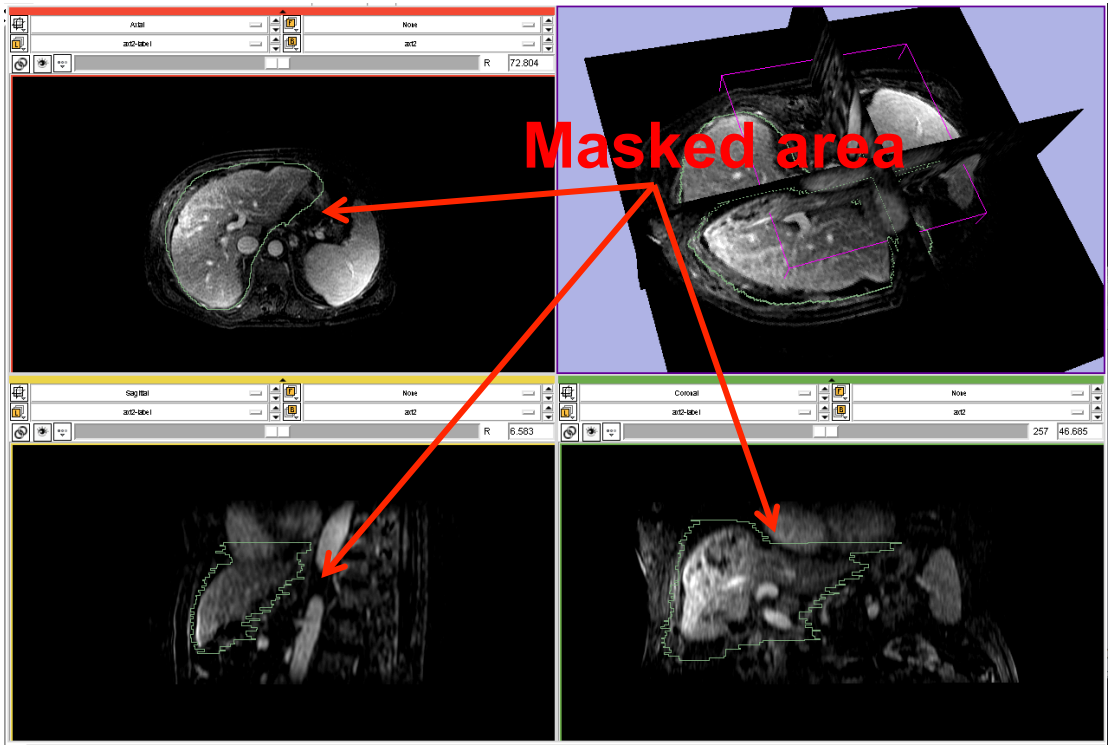
If the line is not good, delete the line by new line surrounding it with label 0





(1)-A-5. Segmentation of Liver

4. Make mask for each slice image which shows liver and check the mask by using other planes



(1) STEP:B
Make Contrast Enhanced MRI

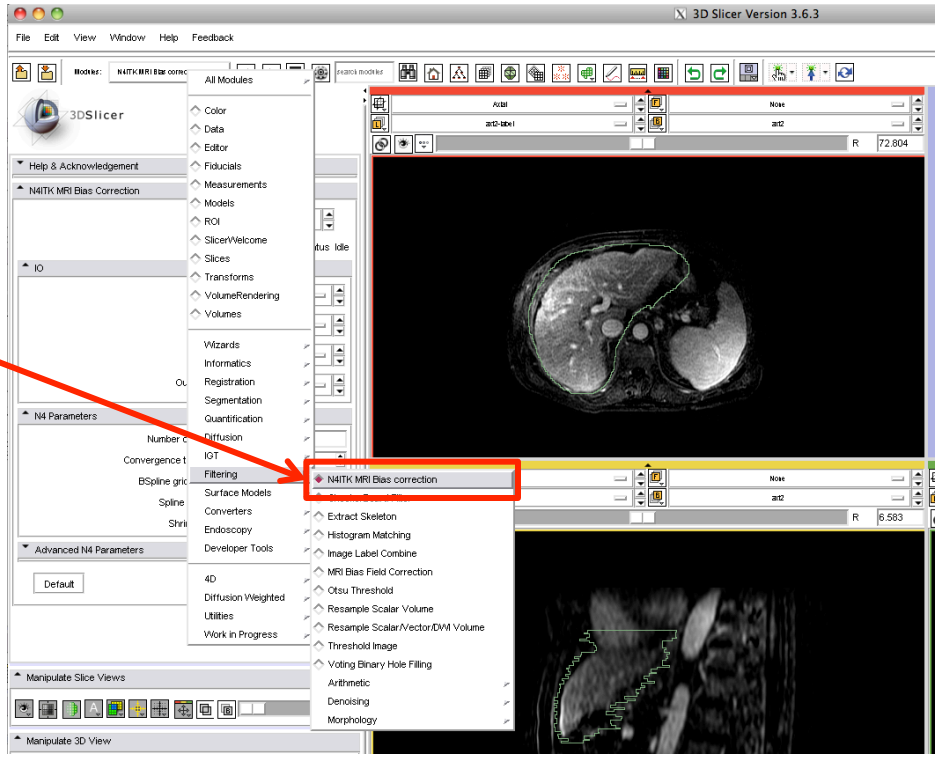
Objective:

To make a contrast enhanced MR image (t2ax-N4.nrrd) because MR image don't have an uniform contrast

(1)-B-1. MR Bias Correction

To obtain contrast enhanced MRI, “N4ITK MR Bias Correction” module is introduced.

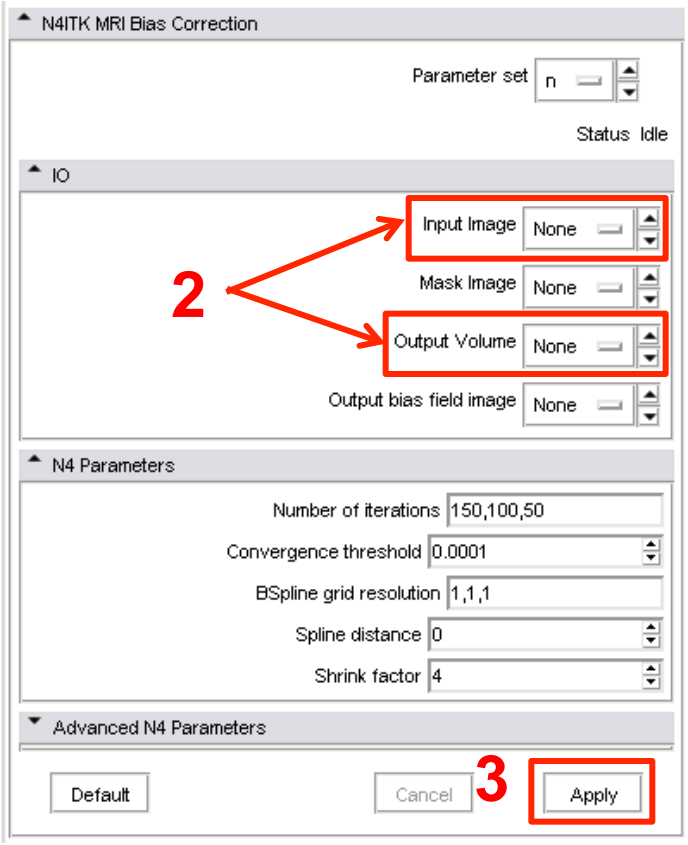
1. Go to the “N41ITK MR Bias Correction” module from “Filtering” category of module list



(1)-B-2. Contrast Enhancement

Input: t2ax.nrrd and t2ax-label.nrrd, Output: t2ax-N4.nrrd

2. Parameters: Input image = t2ax, Mask image = t2ax-label, Output volume = create new volume and name it “t2ax-N4”
3. Click “Apply”
4. Save the t2ax-N4.nrrd and t2ax-label.nrrd in the working directory
5. Close Slicer3



(2) STEP:A
Mask of Planning-CT Image

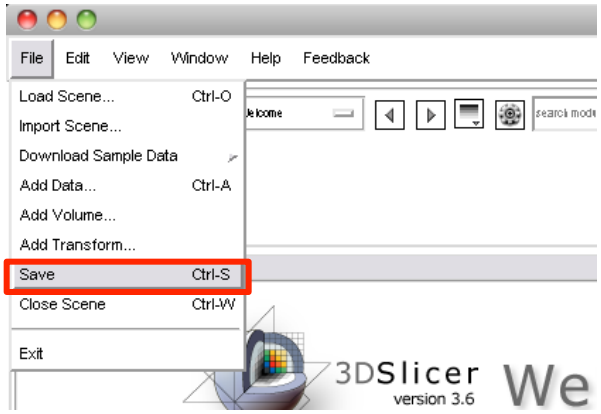
Objective:

To make a mask file (CT-plan-label.nrrd) which decides a region of non-rigid registration

(2)-A. Segmentation of Liver

Input: CT-plan.nrrd, Output: CT-plan-label.nrrd, CT-plan.mrml

1. Operate ***STEP: A*** for planning-CT image. Load "**CT-plan.nrrd**" from the dataset. The label data will be "**CT-plan-label**" automatically.
2. Save "CT-plan.nrrd", "CT-plan-label.nrrd" and Scene file as "CT-plan.mrml". Click on the "Save" button.



3. Close Slicer3

(1) STEP:C
Non-rigid Registration

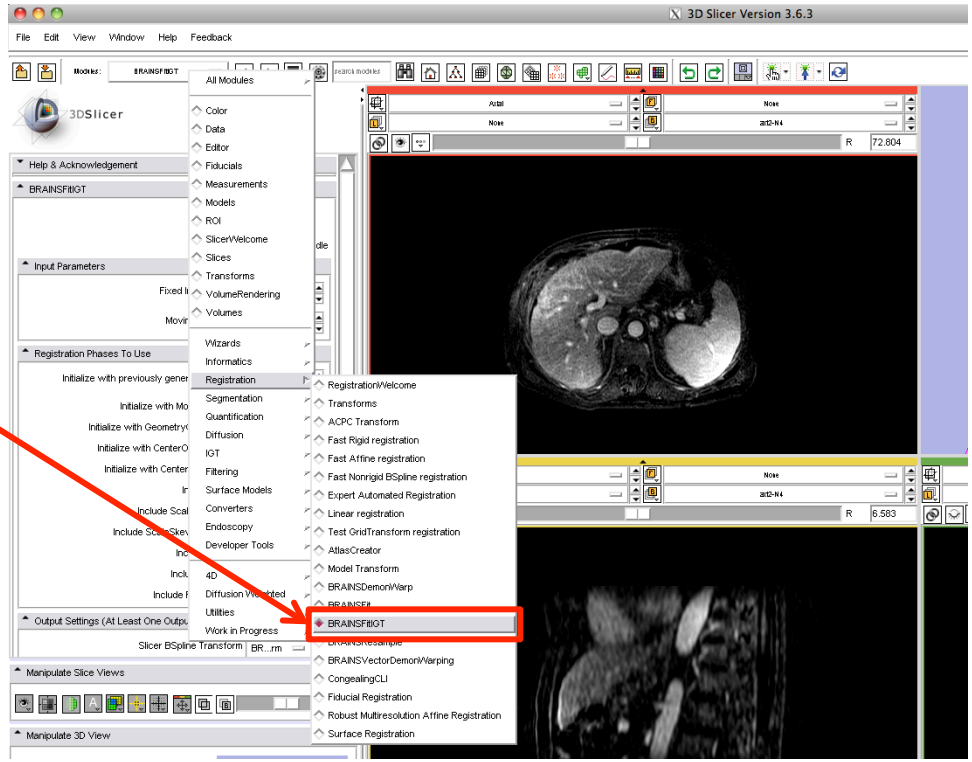
Objective:

To obtain a warped image (t2ax-REG.nrrd) and Bspline transform matrix (T1.tfm)

(1)-C-1. Non-rigid Registration

By using the image and label data obtained the process so far, non-rigid registration will be performed.

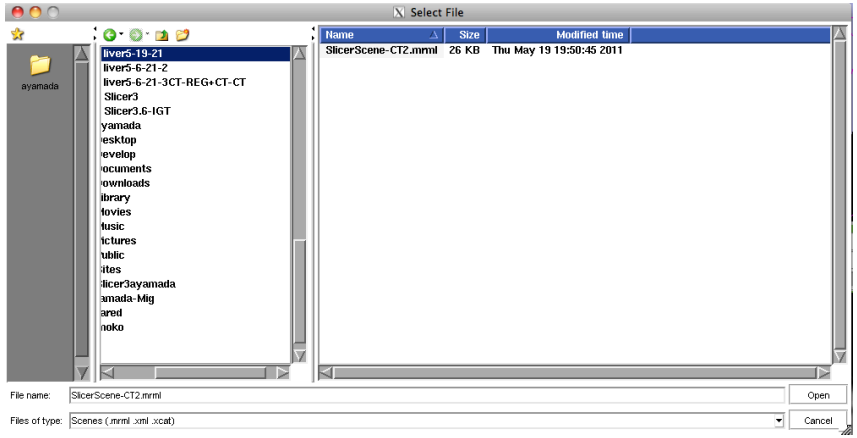
1. Go to the “BRAINSFitIGT” module from “Registration” category of module list

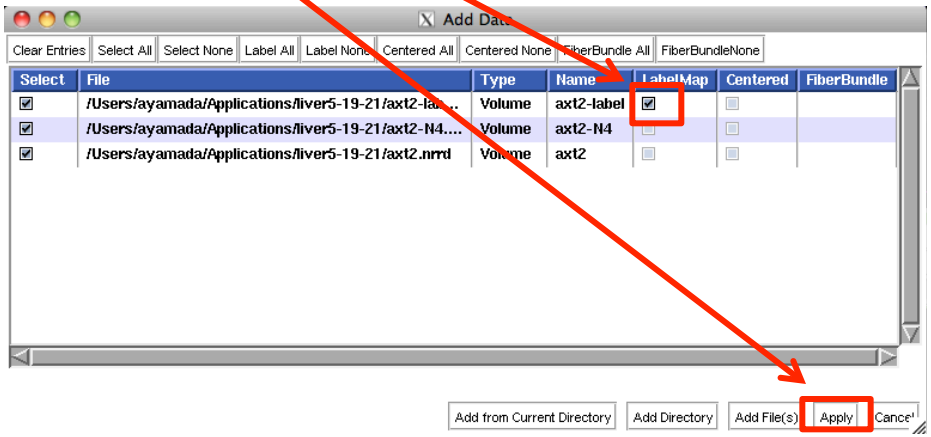


(1)-C-2. Preparation Step

Input: CT-plan.mrml, t2ax-N4.nrrd and t2ax-label.nrrd

2. Start Slicer3
3. Click on the “Load Scene” and load CT-plan.mrml
4. Click on the “Add Data” and select t2ax-N4.nrrd and t2ax-label.nrrd. For the t2ax-label.nrrd, check “LabelMap” check box and click on the “Apply”



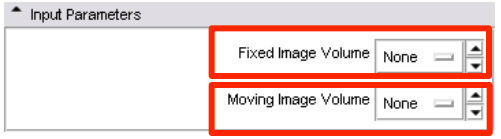


(1)-C-3. Registration Step

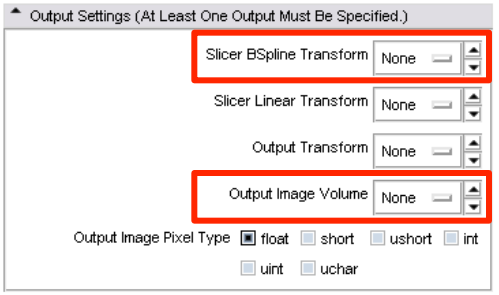
Input: CT-plan.nrrd, t2ax-N4.nrrd, CT-plan-label and t2ax-label

Set “BRAINSFitIGT” module parameters as follows

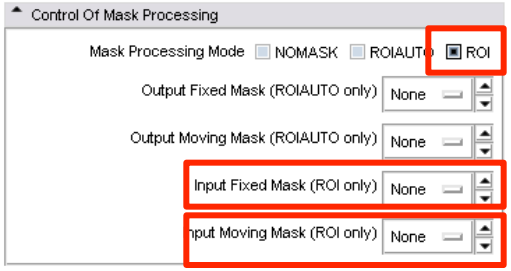
1. Set Fixed image volume = “CT-plan”, Moving image volume = “t2ax-N4”



2. Set BSpline transform = create a new transform and name it “T1” and Output image volume = create a new volume and name it “t2ax-REG”



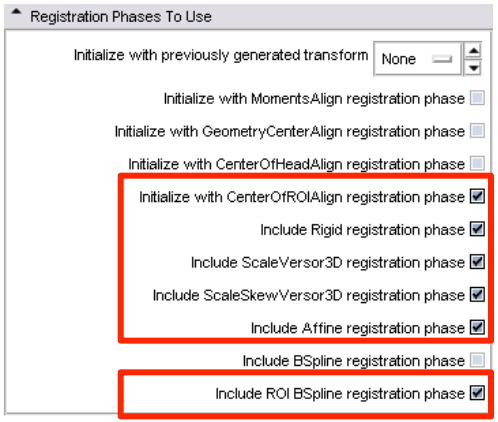
3. Set Input fixed mask = “CT-plan-label”, Input moving mask = “t2ax-label”. Check “ROI” of Mask Proceeding



(1)-C-4. Registration Step

Output: T1 and t2ax-REG

4. Check “Initialize with CenterOfROIAlign registration phase”, “Include Rigid registration phase”, “Include ScaleVersor3D registration phase”, “Include ScaleSkewVersor3D registration phase”, “Include Affine registration phase” and “Include ROI BSpline registration phase”

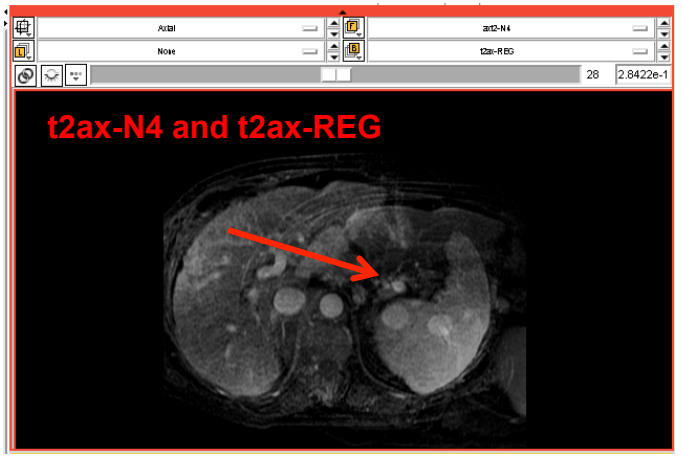


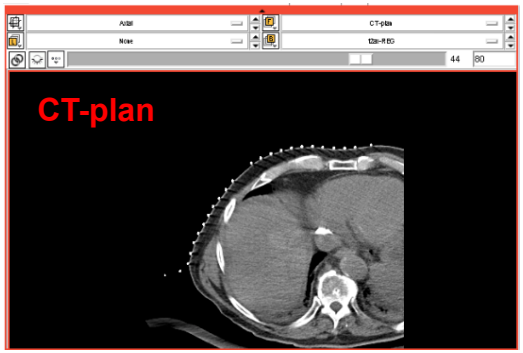
5. Click “Apply”

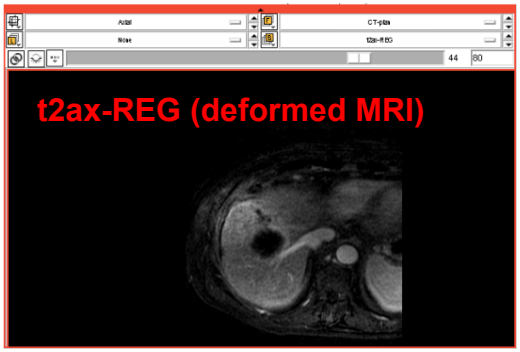
6. After about 39 sec (on the test environment), you can see the moved and deformed t2ax-N4 image as “t2ax-REG”.

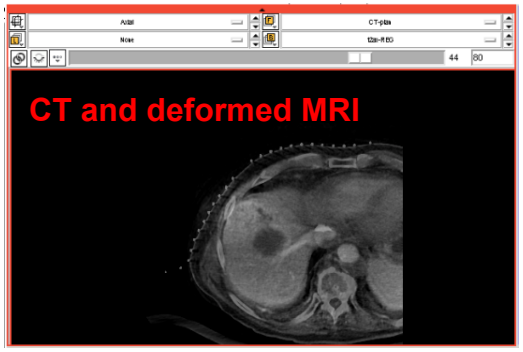
(1)-C-5. Result

1. Select “t2ax-REG” at Background layer and “t2ax-N4” at Foreground layer. The movement and deformation can be confirmed.
2. Select “CT-plan” at Foreground layer. You can see that the shape of the liver on MRI was deformed and fitted the liver on CT image.





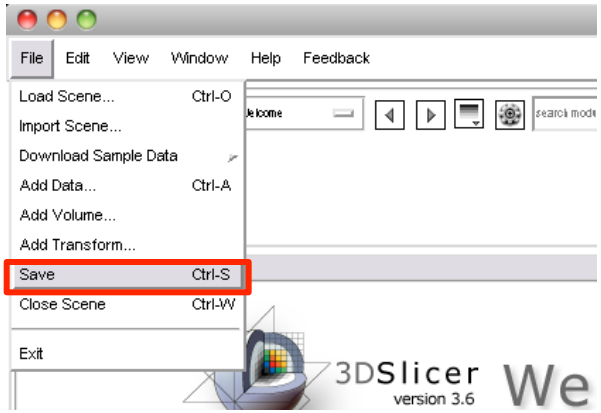




(1)-C-6. Save the scene

Output: T1.tfm, t2ax-REG.nrrd and t2ax-REG.mrml

1. Save “T1.tfm” and “t2ax-REG.nrrd” and this scene as “t2ax-REG.mrml”. Click on the “Save” button.



3. Close Slicer3

(3) STEP:A
Mask of Intra-CT Image

Objective:

To make a mask file (CT-intra-label.nrrd) which decides a region of non-rigid registration

(3)-A. Load intra-CT image

Input: CT-intra.nrrd, Output: CT-intra-label, CT-intra.mrml

To obtain non rigid registration between MR and intra-CT images, CT-CT registration transform T_2 will be obtained in Task (2).

1. Operate ***STEP: A*** for intra-CT image. Load "**CT-intra.nrrd**" from the dataset. The label data will be "**CT-intra-label**" automatically.
2. Save "CT-intra.nrrd", "CT-intra-label.nrrd" and this scene file as "CT-intra.mrml". Click on the "Save" button.

3. Close Slicer3

(2) STEP:C
Non-rigid Registration

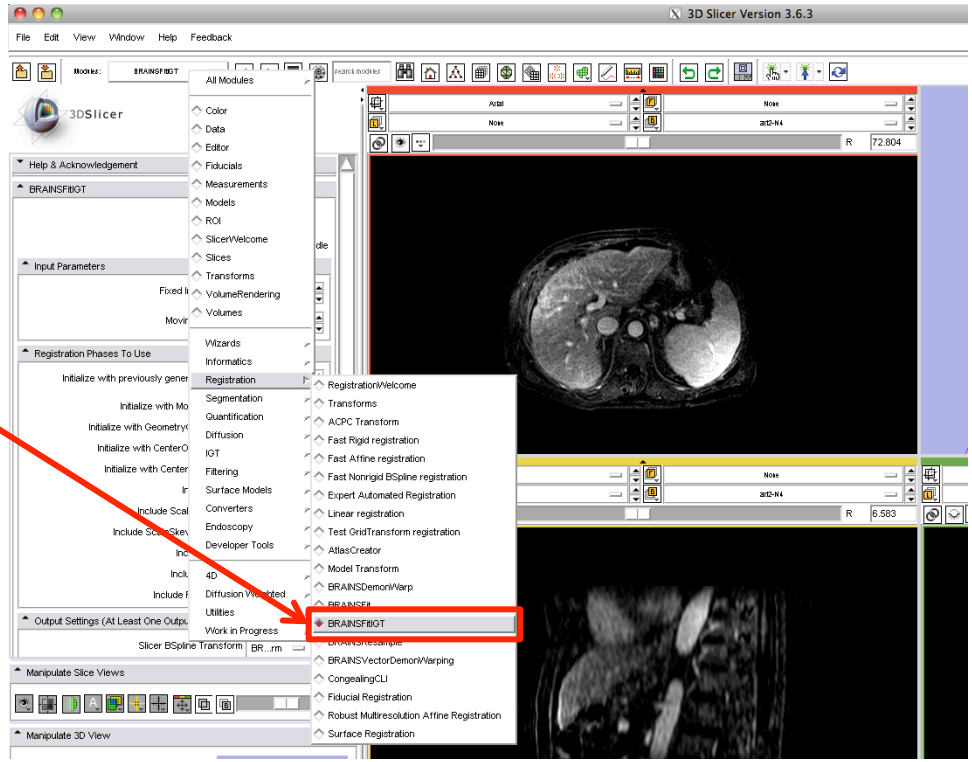
Objective:

To obtain a warped image (CT-plan-REG.nrrd) and Bspline transform matrix (T2.tfm)

(2)-C-1. Non-rigid Registration

By using the image and label data obtained the process so far, non-rigid registration will be performed.

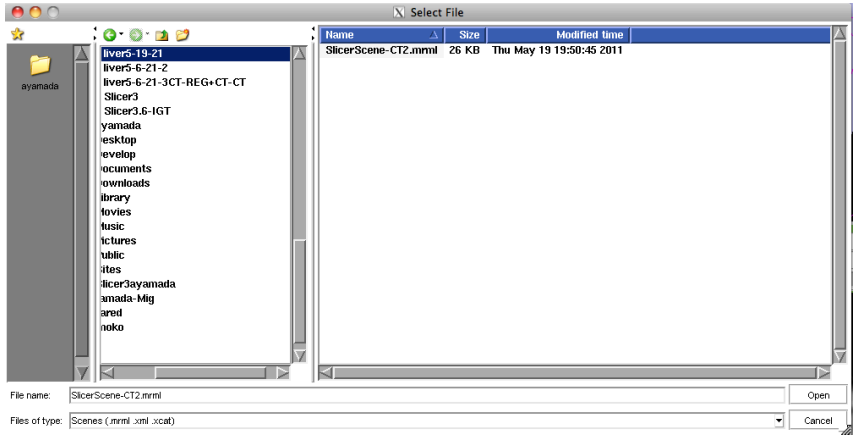
1. Go to the “BRAINSFitIGT” module from “Registration” category of module list

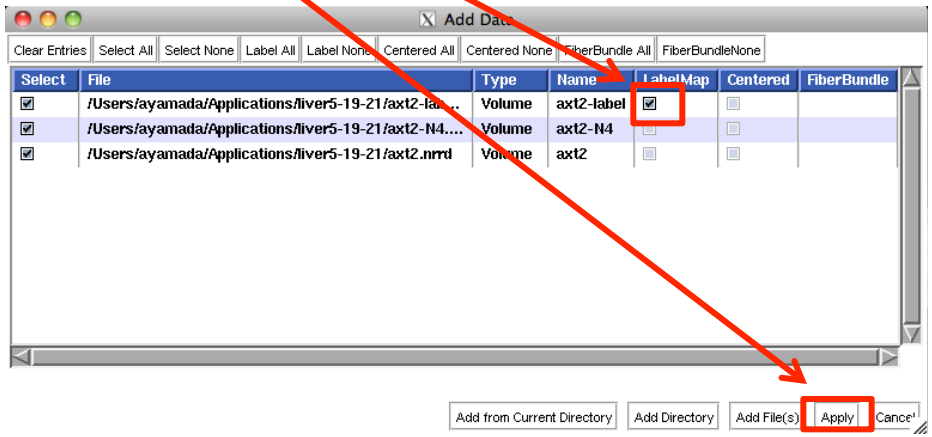


(2)-C-2. Preparation Step

Input: CT-intra.mrml, CT-plan.nrrd and CT-plan-label.nrrd

2. Start Slicer3
3. Click on the “Load Scene” and load CT-intra.mrml
4. Click on the “Add Data” and select CT-plan.nrrd and CT-plan-label.nrrd. For the CT-plan-label.nrrd, check “LabelMap” check box and click on the “Apply”



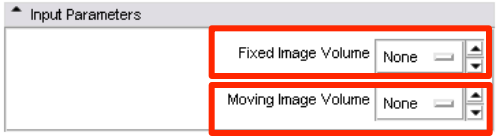


(2)-C-3. Registration Step

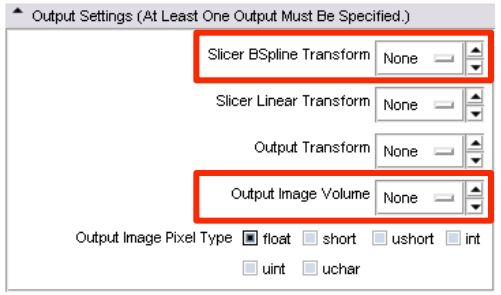
Input: CT-intra.nrrd, CT-plan.nrrd and CT-plan-label

Set “BRAINSFitIGT” module parameters as follows

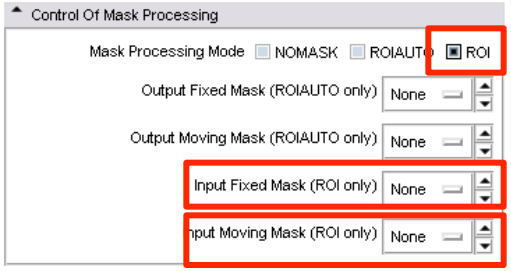
1. Set Fixed image volume = “CT-intra”, Moving image volume = “CT-plan”



2. Set BSpline transform = create a new transform and name it “T2” and Output image volume = create a new volume and name it “CT-plan-REG”



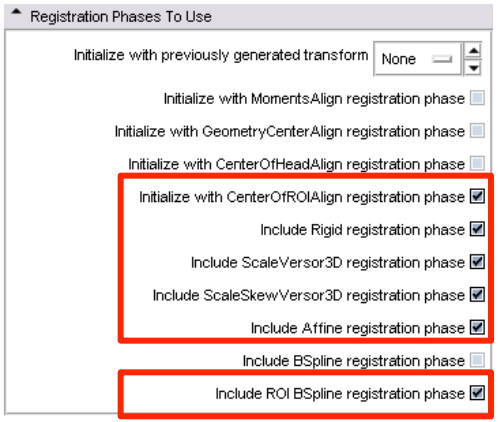
3. Set Input fixed mask = “CT-intra-label”, Input moving mask = “CT-plan-label”. Check “ROI” of Mask Proceeding



(2)-C-4. Registration Step

Output: T2 and CT-plan-REG

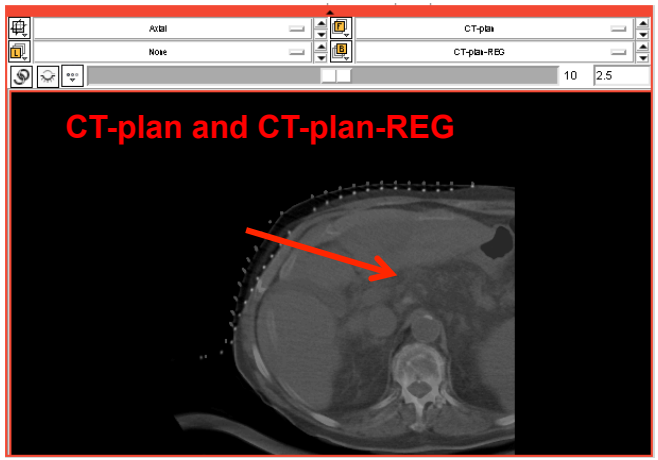
4. Check “Initialize with CenterOfROIAlign registration phase”, “Include Rigid registration phase”, “Include ScaleVersor3D registration phase”, “Include ScaleSkewVersor3D registration phase”, “Include Affine registration phase” and “Include ROI BSpline registration phase”
5. Click “Apply”

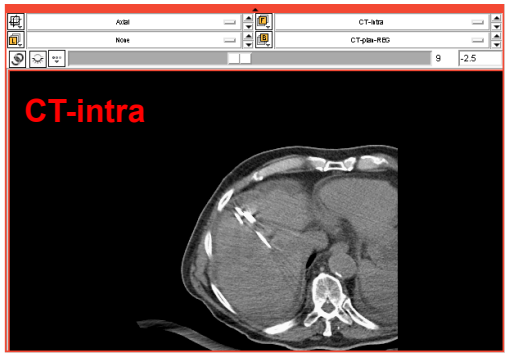


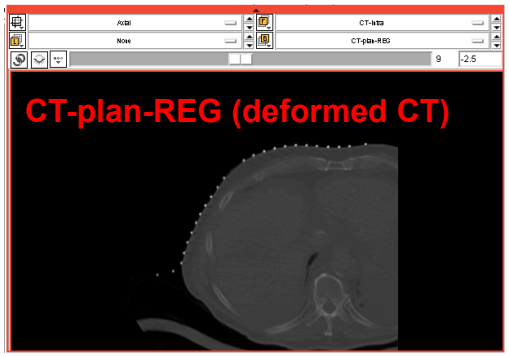
6. After about 23 sec (on the test environment), you can see the moved and deformed CT-plan image as “CT-plan-REG”.

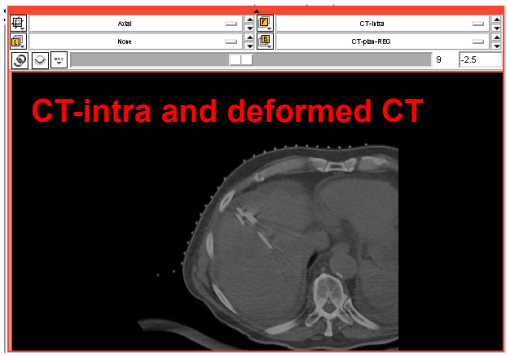
(2)-C-5. Result

1. Select “CT-plan-REG” at Background layer and “CT-plan” at Foreground layer. The movement and deformation can be confirmed.
2. Select “CT-intra” at Foreground layer. You can see that the shape of the liver on CT-plan was deformed and fitted the liver on CT-intra image.





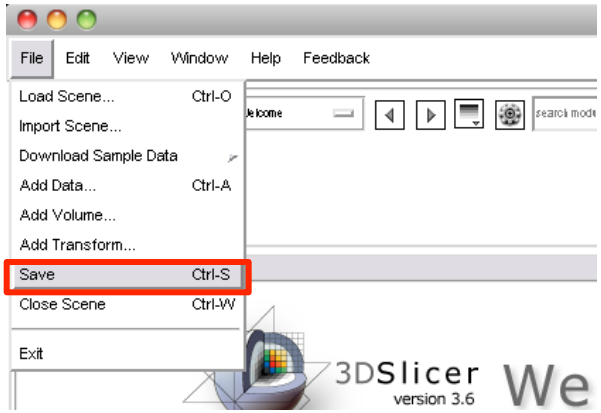




(2)-C-6. Save the scene

Output: T2.tfm, CT-plan-REG.nrrd and CT-intra-REG.mrml

1. Save “T2.tfm” and “CT-plan-REG.nrrd” and this scene as “CT-intra-REG.mrml”. Click on the “Save” button.



3. Close Slicer3

(3) STEP:D
MR-Intra-CT Image Registration

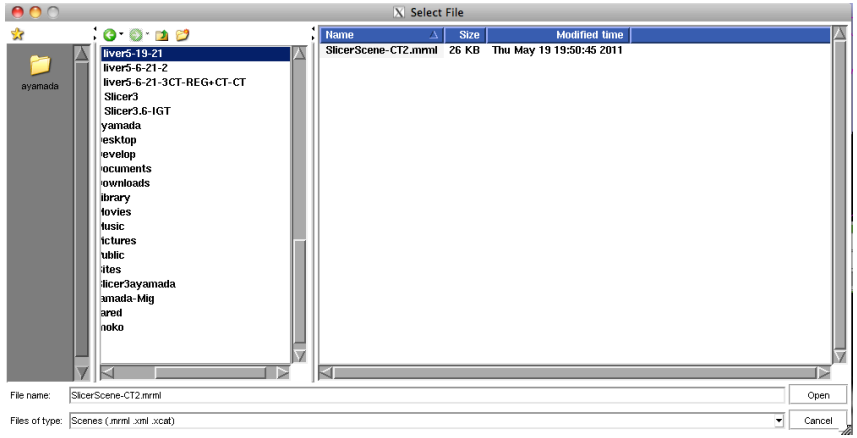
Objective:

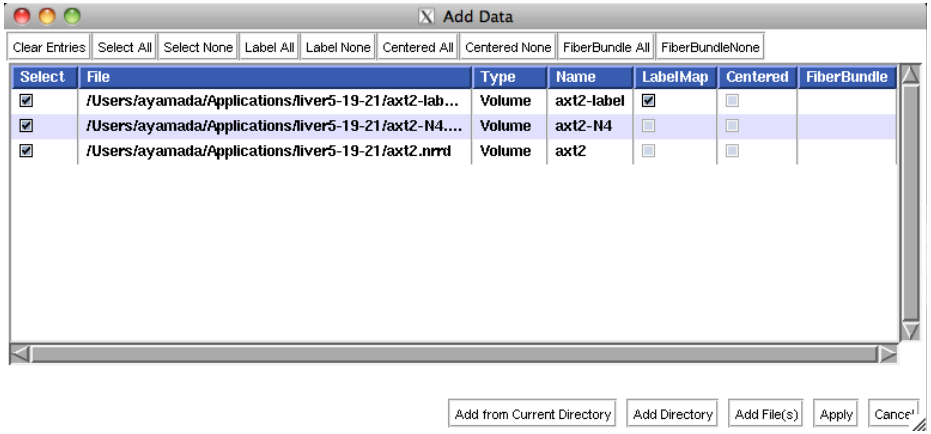
To obtain a warped image (MR-CT-intra-REG.nrrd) by using t2ax-REG.nrrd, CT-intra.nrrd and T2.tfm.

(3)-D-1. Preparation Step

Input: CT-intra.mrml, t2ax-N4.nrrd t2ax-REG.nrrd and T2.tfm

1. Start Slicer3
2. Click on the “Load Scene” and load CT-intra.mrml
3. Click on the “Add Data” and select t2ax-REG.nrrd and T2.tfm. Click on the “Apply”

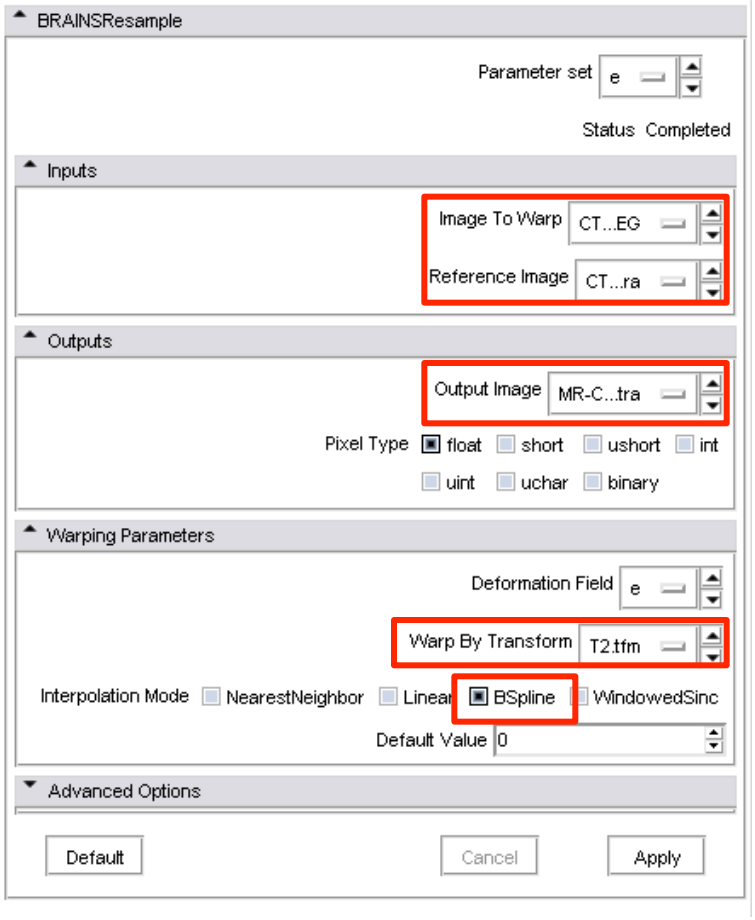




(3)-D-2. BSpline Warping

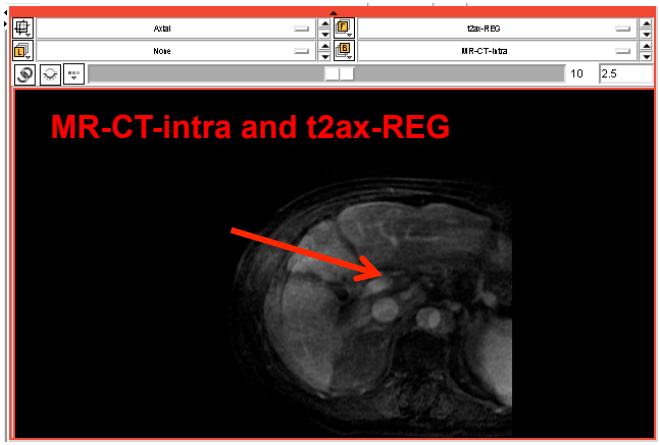
Input: t2ax-REG.nrrd, CT-intra.nrrd, T2.tfm, Output: MR-CT-intra.nrrd

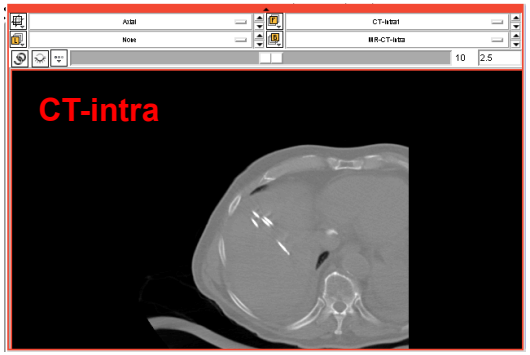
1. Go to BRAINSResample module
2. Set Image To Warp = “t2ax-REG”, Reference Image = “CT-intra”, Output Image = create a new volume and name it “MR-CT-intra”, Warp By Translation = “T2.tfm”.
3. Check “BSpline” of Warping Parameters
4. Click “Apply”
5. After about 6 sec (on the test environment), you can see the moved and deformed t2ax-REG image as “MR-CT-intra”.

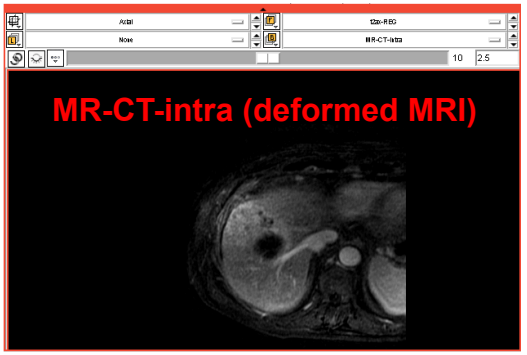


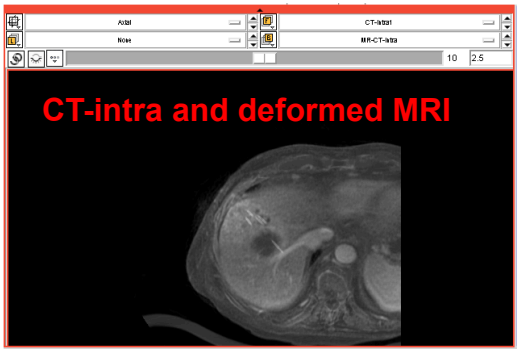
(3)-D-3. Result

1. Select “MR-CT-intra” at Background layer and “t2ax-REG” at Foreground layer. The movement and deformation can be confirmed.
2. Select “CT-intra” at Foreground layer. You can see that the shape of the liver of MR-CT-intra was deformed and fitted the liver on CT-intra image.









Conclusion

- 3D Slicer with BRAINSFitIGT module allows performing non-rigid image registration.
- 3D Slicer with BRAINSResample module allows performing non-rigid image deformation using Bspline transform matrix.
- In cryoablation of liver case, the distance between cryoprobe on CT image and tumor on MR image can be confirmed easily by using the non-rigid MR-CT image registration.

Acknowledgments

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