3D VISUALIZATION OF DICOM IMAGES FOR RADIOLOGICAL APPLICATIONS

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Course Overview

Part I: Introduction to the 3D Slicer software

Part II: 3D Data Loading and visualization of DICOM images
- Volume Rendering of thoraco-abdominal CT data
- Surface Rendering of MR head data

Part III: 3D interactive exploration of the anatomy
- Interactive Exploration of the Segments of the liver
- Interactive Exploration of the Segments of the lung
Part I: 

Introduction to the 3D Slicer open-source software
Slicer 18th year Anniversary

- 1997: Slicer started as a Master’s thesis between the Surgical Planning Lab at Harvard and the CSAIL at MIT

Image Courtesy of the CSAIL, MIT
Slicer 18th year Anniversary

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- 2015: International open-source platform used in clinical research worldwide. P.I. Prof. Ron Kikinis, BWH, Harvard
3D Slicer

- Slicer is a freely available open-source application for viewing, analyzing and interacting with biomedical imaging data.
3D Slicer

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- Slicer is multi-platform and runs on Windows, Linux, and Mac OS.
A multi-institutional effort
3D Slicer

- Slicer is distributed under a BSD-style license agreement with no restriction on use.
- Slicer is not FDA-approved nor CE-marked, and is for clinical research use only.
3D Slicer can be used by clinical researchers on their own Mac, Windows or Linux laptops with their own data.

3D Slicer workshop, PLA General Hospital, Beijing
Slicer is built every night

Slicer is under active development: the software is built every night on every platform.
An interdisciplinary platform

An open-source environment for software developers

An end-user application for clinical investigators and scientists

A software platform that is both easy to use for clinical researchers and easy to extend for programmers
3D Slicer Training

- Training effort to transfer scientific advances in medical image computing to clinical researchers
- Courses tailored for clinicians and scientists at national events, invited seminars, and international conferences
- +3,500 trainees worldwide
Core Functionalities

- Visualization
- Segmentation
- Registration
- Reconstruction
- Diffusion MRI
- Image Guided Therapy
- Quantification

Image courtesy R. Kikinis
Core Functionalities

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Image Courtesy A. Fedorov, T. Penzkofer, R. Kikinis
Core Functionalities

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Image Courtesy A. Fedorov, R. Kikinis
Slicer is Extensible

- Slicer is extensible through plugins called Slicer extensions
- The **Slicer Extension Manager** enables users to download additional Slicer modules
Getting Started with Slicer 4.5
Welcome to Slicer 4.5

To start Slicer, double-click on the Slicer icon on the Desktop.
Welcome to Slicer 4.5

To start Slicer, double-click on the Slicer icon on the Desktop
Navigating the Application GUI

The Graphic User Interface (GUI) of Slicer4 integrates four components:

- the Menu Toolbar
- the Module GUI Panel
- the 3D Viewer
- the Slice Viewer
Click on **Welcome to Slicer** and select **All Modules** to display the list of Slicer modules.
Slicer Modules

Slicer version 4.5 contains over 100 modules for segmentation, registration and 3D visualization of medical image data.
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- Interactive Exploration of the Segments of the lung
In this tutorial, we will use four different datasets:
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- **Dataset 1**: Thorax & Abdomen
Tutorial Datasets

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- **Dataset 2**: Head
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- **Dataset 3**: Liver
Tutorial Datasets

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- **Dataset 1**: Thorax & Abdomen
- **Dataset 2**: Head
- **Dataset 3**: Liver
- **Dataset 4**: Chest
To access the datasets, double click on the directory **RCB22 Pujol Slicer Data** on the Desktop.
Double click on the folder **3DVisualization** to access the 4 tutorial datasets
Loading a DICOM volume

Drag and drop the directory ‘dataset1_Thorax-Abdomen’ into Slicer
Loading a DICOM volume

The reader selecter appears

Click on **OK** to load the directory into the DICOM Database
A DICOM pop-up window appears to inform the user where Slicer will store the DICOM Database. Click on **OK** to use the default DICOM Database.
Loading a DICOM volume

The DICOM Browser window appears

Click on **Add Link** to add a link to dataset to the local database directory
Loading a DICOM volume

Slicer load the DICOM dataset
Loading a DICOM volume

Click on **OK** once the directory import is completed.
Loading a DICOM volume

Select the dataset **patient1** in the DICOM Browser window and click on **Load**
Loading a DICOM volume

Slicer displays the axial, coronal and sagittal slices of the DICOM dataset.
Click on the display icon and select the display **Conventional**.
Loading a DICOM volume

Click on DICOM to display the list of Slicer modules, and select the module Volumes.
Loading a DICOM volume

Slicer displays the GUI of the module **Volumes**

Select the Active Volume 6:CT_Thorax_Abdomen

Select the window level preset **CT-abdomen**
Loading a DICOM volume

Position the mouse cursor over the banner in the Red Viewer to display the slice menu.

Click on the Links icon to link the slice controls across all Slice Viewers.

Click on the Eye icon to display the three anatomical slices in the 3D Viewer.
Loading a DICOM volume

The three anatomical slices appear in the 3D viewer. Use the right-mouse button in the 3D Viewer to zoom in/out.
Loading a DICOM volume

Use the left-mouse button in the 3D Viewer to rotate the 3D volume
Loading a DICOM volume

Position the mouse over the blue banner in the 3D viewer window to display the 3D view controller.

Click on the top left icon to center the 3D view on the scene.

Note: a shortcut to this functionality is available through the icon next to the number ‘1’ in the blue banner.
Loading a DICOM volume

Click on the Slicer layout menu icon, and select the Conventional Widescreen layout.
Loading a DICOM volume

Click on the square icon next to the letter ‘R’ in the Red Banner to adjust the field of view of the slices to the size of the window.

Use the red, yellow and green sliders to slice through the volume in all three anatomical directions.
Slicer displays the axial, sagittal and coronal slices of the DICOM volume in the 3D viewer.
Volume Rendering

Select the module **Volume Rendering** in the modules menu.
Volume Rendering

Select the volume 6:CT_Thorax_Abdomen

Click on Preset in the Display tab to display the list of available presets for the transfer function

Select the Preset CT-Cardiac3
Volume Rendering

Select the Rendering VTK GPU Ray Casting, and click on the eye icon in the Volume tab to display the volume rendered volume.
Volume Rendering

The volume rendered image of the CT Dicom dataset appears in the 3D viewer.
Move the Shift slider toward the right, to shift the transfer function and display the aorta.
Click on the eye icon in the red viewer to turn off the visibility of the anatomical slices.
Volume Rendering

Use the mouse in the 3D window to rotate the volume rendered image
Volume Rendering

Click on the eye icon in the volume rendering panel to remove the volume rendered image from the 3D viewer.
Click on **Display ROI** to display a region of interest that we will use for cropping the dataset. Check the option **Enable**.
Turn on the visibility of the DICOM images, and position the ROI around the left kidney using the ROI controls in the 2D anatomical views and in the 3D viewer.
Volume Rendering

Click on the eye icon to display the volume rendered image

Slicer displays the volume rendered image of the left kidney
Volume Rendering

Extend the ROI to the right kidney

Slicer displays the cropped volume rendered images showing the left and right kidney.
Slicer displays the cropped volume rendered images showing the left and right kidney.
Volume Rendering

Click on **File → Close Scene** to close the scene.
Click on Slicer→Quit to quit Slicer
Part IIb:
3D visualization of surface models of the brain
Loading the Head Scene

Browse to the directory **RCB22 Pujol Slicer Data**
Select the directory **3D Visualization**
Select the directory **dataset2_Head**
Loading the Head scene

Select the directory **dataset2_Head** and drag and drop the file ‘**MRHead_Scene.mrb**’ into Slicer
The **MRHead_Scene.mrb** file is composed of an MR scan of the brain and 3D surface reconstructions of anatomical structures from the SPL-PNL Brain Atlas.

The atlas by Talos, Jakab, Kikinis et al. is freely available at:

http://www.spl.harvard.edu/publications/item/view/2037
Loading the Head Scene

Click on **OK** to load the file **MRHead_Scene.mrb** into Slicer.
Viewing the 3D Scene

Slicer displays the elements of the scene, which contains an MRI scan and a series of 3D surface models of the brain.
Select the module **Models** in the list of Slicer modules.
Basic 3D Interaction

Position the mouse in the 3D Viewer.

Hold down the left mouse button and drag to rotate the model.
Basic 3D Interaction

Click on the **Slice Visibility** icon to display the Axial Slice in the 3D Viewer.
3D visualization of surface models of the brain

Slicer adds a view of the **Axial slice** in the 3D View.
3D visualization of surface models of the brain

Select the model **Skin.vtk**

Expand the **Display** tab and change the opacity of the model from 1.0 to 0.0.
3D visualization of surface models of the brain

skin model opacity = 0.5
3D visualization of surface models of the brain

The model of the skin becomes invisible in the 3D viewer.

(skin model opacity = 0.0)
3D visualization of surface models of the brain

Click on the **Slice Visibility** icon in the **Green Slice Viewer** to display the Coronal Slice in the 3D Viewer.
3D visualization of surface models of the brain

Select the 3D model `skull_bone.vtk` in the Model Hierarchy.

Turn on the Clip option in the Display tab.
3D visualization of surface models of the brain

Browse through the coronal slices to expose the 3D model of the white matter, and the left and right optic nerves.
Select the **hemispheric_white_matter** model and turn off its visibility.
3D visualization of surface models of the brain

Slicer displays the **optic nerves**, **optic chiasm** and **optic tracts** overlaid on the **MR images** of the brain.
Close the existing scene and all its data

Select **File** → **Close Scene**

Select **Slicer** → **Quit** to exit the software
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Part III-a:
Interactive 3D Visualization of the segments of the liver
Anatomy of the liver
Liver dataset

The liver dataset is a contrast-enhanced CT abdominal scan of a healthy 36 year-old male.
3D segments of the liver

- Segment II
- Segment III
- Segment IVa
- Segment IVb
- Segment VI
- Segment VII
- Segment V
3D segments of the liver

Segment II
Segment I
Segment VII
Segment III
Segment IVb
IVC
Segment VI
Segment V
Liver vasculature

- Middle hepatic vein
- Left portal vein
- Left hepatic vein
- Caudate vein
- Main portal vein
- IVC
- Right portal vein
- Right hepatic vein
Loading the Liver Scene

Browse to the directory **RCB22 Pujol Slicer Data**

Select the directory **3D Visualization**

Select the directory **dataset3_Liver**
Loading the Liver scene

Select the directory `dataset3_Liver` and drag and drop the file `LiverSegments_Scene.mrb` into Slicer.
Loading the Liver Scene

Click on OK to load the scene into Slicer
Liver Segments Scene

The elements of the scene appear in the Viewer
3D models of the liver

Segment VIII
Segment IVa
Segment II
Segment VIII
Segment IVb
Segment III
Segment VI
Segment V
Segment VII
3D models of the liver

- Segment II
- Segment I
- Segment VII
- Segment III
- Segment IVb
- IVC
- Segment VI
- Segment V
3D models of the liver

- Middle hepatic vein
- Left portal vein
- Left hepatic vein
- Caudate vein
- Main portal vein
- IVC
- Right portal vein
- Right hepatic vein
Example:
What organ abuts the left-most margin of segment II in this patient?
3D Exploration of Liver Segments

Click on **Welcome to Slicer** and select the module **Models**
3D Exploration of Liver Segments

Click on the Liver Structures Models Hierarchy
3D Exploration of Liver Segments

Select the model **Liver_Segment II**

Turn on/off its visibility to locate it in the 3D viewer.
Position the mouse in the 3D Viewer, hold down the left mouse button and drag to orient the 3D model to a superior view.
Question 1:
What organ abuts the left-most margin of segment II in Patient 1?
Question 1: What organ abuts the left-most margin of segment II in this patient?

Answer 1: Stomach
3D Exploration of Liver Segments

**Question 2:**
Which segment would most likely be affected by an aggressive tumor invading locally from the right adrenal gland?
Question 2: Which segment would most likely be affected by an aggressive tumor invading locally from the right adrenal gland?

Answer 2: Segment VII
Question 3:
Which vessel separates Segment IVb and Segment V?
Question 3: Which vessel separates Segment IVb and Segment V?

Answer 3: The middle hepatic vein
Closing the Liver Scene

Select File → Close Scene and Slicer → Quit
Part IIIb: Interactive 3D Visualization of the segments of the lungs
Segments of the lung

**Right Lung** (10 segments)
- Right Upper Lobe (RUL)
  - RUL Apical
  - RUL Posterior
  - RUL Anterior
- Right Middle Lobe (RML)
  - RML Lateral
  - RML Medial
- Right Lower Lobe (RLL)
  - RLL Superior
  - RLL Medial Basal
  - RLL Anterior Basal
  - RLL Lateral Basal
  - RLL Posterior Basal

**Left Lung** (8 segments)
- Left Upper Lobe (LUL)
  - LUL Apical Posterior
  - LUL Anterior
- Left Upper Lobe Lingula (LUL Lingula)
- Left Lower Lobe (LLL)
  - LLL Superior
  - LLL Anteromedial Basal
  - LLL Lateral Basal
  - LLL Posterior Basal
Loading the Lung Scene

Browse to the directory **RCB22 Pujol Slicer Data**
Select the directory **3D Visualization**
Select the directory **dataset4_Chest**
Loading the Lung scene

Select the directory **dataset4_Chest** and drag and drop the file ‘**ChestCT_Scene.mrb**’ located in the folder **case1** into Slicer.
Chest CT case 1

Click on OK to load the file into Slicer
Select the **Markups** module from the Modules menu
Chest CT case 1

Slicer displays the list of annotated segments in the GUI of the Markups module.
Chest CT case 1

The lung segments are annotated on a 2D axial plane.
Browse through the slices to explore the annotated structures
Question 1: Which segments are Q1, Q2 and Q3?
Chest CT case 1

Answer 1
Q1: Right Lower Lobe (RLL) anterior basal
Q2: RLL lateral basal
Q3: RLL posterior basal
Chest CT case 1

Select File → Close Scene
Loading the Lung Scene

Browse to the directory **RCB22 Pujol Slicer Data**
Select the directory **3D Visualization**
Select the directory **dataset4_Chest**
Loading the Lung scene

Select the directory `dataset4_Chest` and drag and drop the file `‘LungSegments_Scene.mrb’` located in the folder `case2` into Slicer.
Chest CT case 2

Click on **OK** to load **LungSegments_Scene.mrb** to Slicer.
Chest CT case 2

Select the module **Models**
Chest CT case 2

Slicer displays the list of models of lung segments and pulmonary vessels.
Lung Segments

Question 1: Why is there a gap in the vessels at the arrows?
Lung Segments

Answer 1: Major Fissure
Question 2: Classify the segments of the lower lobe by size
Chest CT case 2

Answer 2a: Smallest: Lower Lobe Medial Basal
Chest CT case 2

Answer 2b: Largest: Lower Lobe Anterior/Posterior Basal
Question 3: Which segment would most likely be damaged by a fracture of the right posterolateral 2nd rib?
Lung Segments

Answer 3: Upper Lobe Posterior Segment

2nd Rib
Question 4: Which segment abuts the distant oesophagus?
Lung Segments

Answer 4: Lower Lobe Medial Basal

oesophagus
Conclusion

• 3D Slicer is an open source platform for medical imaging research

• Interactive interface to manipulate and visualize DICOM volumes, labelmaps and 3D models

• User-defined 3D views of the anatomy
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3D Slicer Exhibit – QIRR
RSNA Learning Center (Lake Side)

3D Slicer: An Open-Source Software Platform for Segmentation, Registration, Quantitative Imaging and 3D Visualization of Multi-Modal Image Data
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About 3D Slicer
3D Slicer is a multi-platform, free, open source & extensible software package for 3D visualization and medical image computing. The software platform is community created for the purpose of subject specific medical image analysis and visualization.

Multi-modality imaging including:
- MRI, CT, US, nuclear medicine, and PET/CT
- Multi-organ from head to toe
- Intra-operative interface for devices
- Mandible and interfaced to multiple Slicer plugins
- Anatomical features
- 3D vascular recoloring

Segmentation & Registration
Segmentation is required for defining features of interest in imaging data for quantification and analysis.

Multi-modality visualization
3D Slicer integrates standard radiological viewing capabilities for MR, CT, PET and ultrasound data in multiple image file formats, including DICOM. A combined visualization of multiple imaging modalities and derived data can provide clinicians scientists with an integrated understanding of anatomy and pathology.

Quantitative Analysis
Many hundreds of imaging biomarkers are used in clinical practice, drug discovery and development. A free and open source platform can improve access to standard methods of image quantification and rapidly transcribe experimental methods into the clinical research setting for validation and refinement.

Clinical Research Applications
3D Slicer has been used in clinical research, with IRB clinical protocols appropriately created and managed. The extensible architecture of the software allows the development of specialized packages such as SlicerRT for radiotherapy research, and SlicerGIG for image-guided therapy.

Community, Training & Support
To support user and developer communities and the effective translation of tools into the clinical research setting, the 3D Slicer Project provides many outreach materials and activities.

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