Segmentation for 3D printing

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Learning Objective

This tutorial demonstrates image segmentation in the Segment Editor module of 3D Slicer for the purpose of 3D printing.















Clinical utility of the created spine phantom

- Training phantom for • needle insertion
- Electromagnetic marker • holder
- Filled with gel (~soft-• tissue)
- Covered with sheet (~skin)
- Tube with water in the • center

Moult et al. 2013



3





Material

This tutorial requires the installation of a recent 3D Slicer stable release (at least 5.6.1), which is available at the **Slicer** download page:

http://download.slicer.org/

Tutorial dataset: Phantom base STL model

https://raw.githubusercontent.com/Slicer/SlicerSegmentationFor3DPrintingTutorial/main/BasePiece.stl (source: <u>PerkLab Model Catalog</u>)

User documentation pages:

https://slicer.readthedocs.io/en/latest/user_guide/modules/segmentations.html https://slicer.readthedocs.io/en/latest/user_guide/modules/segmenteditor.html











Platforms

• Developed and maintained on Windows 64bit, macOS, and Linux 64bit & 32bit



- Slicer requires
 - Minimum 4GB RAM (more is recommended)
 - Dedicated GPU for fast rendering (OpenGL 3.2+)









A quick guide on how to use this tutorial

Slicer is a comprehensive platform. Hence, there's usually more than one ways to work with your data and achieve the same result.

During the course of this tutorial, we sometimes show more than one possibility, so you will see three kinds of slides:

- Slides that are common to both approaches, have a white background.
- If you are interested in somewhat **more details**, then simply follow all the slides. Slides with a **light green tint** show different ways to achieve the same results.
- If you want a **quicker** solution, without going too much into the details, in addition to the white ones, follow the slides marked with a clock (shown in the corner), and a slighty **red-tinted** background.













Segment Editor module

- Real-time 3D surface
 update
- Editing on oblique slices
- Overlapping segments
- Intuitive tools
- Manual
- Semi-automatic
- Advanced settings













Overview

1. Load CT image

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- 2. Segment vertebrae to be 3D printed
- 3. Add phantom base to segmentation
- 4. Merge and finalize phantom
- 5. Save phantom segment to STL file for 3D printing











Part 1: Load CT image

Overview:

- Load sample "CTChest" dataset \bullet
- Set image contrast for better visibility •







1/1: Load CTChest dataset

🕒 3D Slicer		
Weld	come	
Add Data		I 3D Slicer
📧 Install Extensions	🚳 Download Sample Data 🔞	Help & Acknowledgement
🛞 Customize Slicer	Explore Added Data	▼ Builtin
		MRHead
		Image: MRBrainTumor2 Image: Constraint of the second s
		Image: CBCTDentalSurgery Image: CT-MR Brain Image: CBCT-MR Head Image: CT-MR Head
		CTP Cardio Sequence
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1/2: Sample CT loaded

Requesting download CT-chest.nrrd from https://github.com/Slicer/SlicerTestingData/releases/download/ SHA256/4507b664690840abb6cb9af2d919377ffc4ef75b167cb6fd0f747befdb12e38e ...

Downloaded 4.0 MB (10% of 40.2 MB)...

Downloaded 40.2 MB (100% of 40.2 MB)...

Download finished

Verifying checksum

Checksum OK

Requesting load CTChest from C:/Users/attila/AppData/Local/Temp/Slicer/RemoteIO/CT-chest.nrrd ...

Load finished











1/3/A: Change contrast





1/3/B: Change contrast

Switch to the *Data* module

Subject hierarchy Trans	form hierarchy All nodes	
Node		
▼ Scene		
CTChest	Rename	
	Clone	
	Delete	
	Edit properties	
	Register this	_
	Segment this	
	Export to file	
	Export to DICOM	
	Create child folder	
at click on the		
IL-CIICK OII LITE		

active volume and click on the preset Active Volume: CTChest Ŧ Volume Information Display Lookup Table: Grey Interpolate: ~ Window/Level: Ě \bigcirc CT-Abdomen W: 350 🗘 Manual W/L ▼ L: 40 \$ /iew abdominal CT volume. 000 Off Threshold: 3071 🌲 -3024 000 Histogram Color Legend

Select *CTChest* as







1/3/C: Change contrast







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Part 2: Segment vertebrae

Overview:

- Add new segment
- Threshold bone
- Remove speckles with Islands
- Cut out vertebrae with Scissors











2/1: Switch to Segment Editor module





2/2: Add new segment

🕒 3D	Slicer	
Help & Acknown	owledgement	
Segmentation:	Segmentation	-
Source volume:	CTChest	
	+ Add Remove	•
	Empty sec w empty *• Image: Sec w empty Name Image: Sec w empty	
24		
0		

Segmentation
automatically
created
CT volume
automatically
selected as source

(Source volume is the segmented volume that defines the resolution of the segments)











2/3: Set terminology

Segmentation:	Segmenta	tion		•		
Source volume:	CTChoct			- 1		
Add		Remove	Show 3D			Terminology
	•10		Name	P		Roperty type
	ୁ (ମୁ)	Segment_1		0		[None]
	Ľ	/				Tissue
					I₹	Artery
*						Body fat
						Bone 😱
						Select type modifier
979) 					Na	me: bone
					Co	lor:
						Select

 Double-click on the segment's color
 Pick a Terminology for the given segment (A name and a color for the segment.)

You can also set a different name and color if needed.

It is not required, but makes your workflow more robust.



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•

Cancel



2/4: Set threshold to get bone











See it in 3D!





21

2/5: Remove speckle with the Islands effect

	bone			
	Select the	Islands		_
	ISIAIIUS EIIECI	Edit islands (connected components) in a Keep largest island Remove small islands	segment <u>Show details.</u> Keep selected island Remove selected island	
		Minimum size: 1000 voxels		*
30		Æ	Apply	



2/5: Remove speckle with the Islands effect



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2/6: Cut out vertebrae with Scissors



Select the Scissors effect
 Choose Erase outside as operation
 Choose Free-form shape









2/7: Cut out vertebrae with Scissors



Trace around the desired vertebrae with the scissor on the coronal view (green slice)







Orient the 3D view





2/8: Remove remaining parts with Scissors



Select the vertebrae in the 3D view to erase the unnecessary parts (ribs on the anterior side in this case)





2/9: Vertebrae are segmented





Part 3: Add phantom base

Overview:

- Load phantom base STL file
- Transform model to desired position and orientation
- Import model to segmentation node
- Cut hole through middle of the spine









3/1: Load phantom base as model node

Download phantom base STL file from https://www.slicer.org/wiki/File:BasePiece.zip





3/2: Load phantom base as model node

🕒 Add data into th	e scene			- 🗆	×
Choose Directory to Add	Choose File(s) to Add			Show	Options
✓		File		Descri	ption
✓ D:/Onedrive-SZTE/(/BasePiece.stl	Model	*
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3/2: Load phantom base as model node







3/1: Make base semi-transparent in Models

(b) 3D Slicer 5.2.2	<u>File Edit View Help</u>	
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📩 📩 Modules: 🤍 🧭 Segment Editor 🗸 🗖 🄇	BANA DOM SAVE Products. Corridocis	₩ ₩
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When both the segmentation and	Information	
the model are opaque, it is hard to	Display Visibility	
see when they are in a good		
are in a good	Visibility: V Opacity:	
relative position	View: All	•
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3/1: Make base semi-transparent

Switch to the Data ゆ **3D Slicer** module Help & Acknowledgement Subject hierarchy Transform hierarchy All nodes Node 0.0 ۹<u>ش</u> Scene CTChest Segmentation Ħ bone BasePiece Opacity 2D visibility 3D visibility

Right-click on the eye icon next to *BasePiece*, and hover your pointer over the *Opacity* option. Set it to about 3/4.

When both the segmentation and the model are opaque, it is hard to see when they are in a good relative position



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3/2/A: Create transform





Switch to the *Transforms* module Create linear transform Name it '*BaseToSpineTransform*'

	Active Transform:	Select a LinearTransform	
	Information	Rename current node Create new LinearTransform	
		Create new LinearTransform as	
	▼ Edit	Create new BSplineTransform Create new BSplineTransform as	
	Identity	Create new GridTransform Create new GridTransform as	
1	Display	Create new Transform Create new Transform as	
	Apply transfor	rm	



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3/3/A: Apply transform to base







3/4/A: Move base into place



1. First rotate the model 180 degrees Left-Right by dragging the "LR" slider to the left 2. Move sliders until the base is in the correct position (values in picture are the final ones)









X

Cancel

7

OK

3/2/B: Create transform



3/4/B: Move base into place

(We don't need 3/3 when we do it this way)

Right-click the transform again, and choose *Edit* properties...



Transform Matrix

1.00

0.00

0.00

55.00

\$

1. First rotate the model 180 degrees Left-Right by dragging the "LR" slider to the left 2. Move sliders until the base is in the correct position (values in picture are the final ones)





3/6/A: Base is in the correct position







3/6/B: Base is in the correct position





3/7: Use Scissors effect to remove slack



Switch back to Segment Editor
 Erase slack







Part 4: Merge and finalize phantom

Overview:

- Create segmentation from base piece
- Copy base piece segment into vertebrae segmentation
- Merge two segments
- Cut hole through phantom









4/1: Import base into segmentation



Mode
<u>{</u>
port M





4/1/A Import base into segmentation

Switch to the Data module, right click on Basepiece, and select "Convert model to segmentation node"



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🕒 3D Slic	er			
Help & Acknowled	gement			
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Node			•10	
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🔻 👒 Segmentatio	n		*	===
bone		0	*	
BasePiece		2 Kg	*	囲
SpineToBase	Transform		\mathcal{Q}	=
🕶 👒 BasePiece-se	gmentation		٠	Ħ
			144	

Drag and drop "Basepiece" from the "Basepiece segmentation" to below the "Bone" segment.











4/2: Merge the two in Segment Editor

Segmentation:	Segmentat	tion				*
Source volume:	CTChest					-
🛖 Ac	bt	Re	move	😫 She	ow 3D	- 🔾 -
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	Operation:	Add 🕥	-	Apply 🕥	✓ Bypass	masking
	Add segme	nt: (3)		(5)		
5	bone	8				1
	Base	ePiece_1	R			0
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Back to Segment Editor

- 1. Select *Logical operators*
- 2. Select spine (bone)
- 3. Choose Add operation
- 4. Select *BasePiece*
- 5. Click *Apply*





4/3: Remove base piece segment











4/3: Remove base piece segment

Switch to the Data module



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Right-click the *BasePiece* segment node and choose *Delete*









4/4: Cut hole through phantom using Scissors

Scissors			
Cut through the entire se	gment from the (current viewpoint <u>Show details.</u>	
Operation: Erase inside Trase outside Fill inside Fill outside Apply to visible segments	Shape: Free-form Circle Cectangle Centered	Slice cut: Unlimited Positive Negative Symmetric 	





48



4/4: Cut hole through phantom using Scissors

	Scissors		
	Cut through the entire se	gment from the (current viewpoint <u>Show details.</u>
<i>e</i>	Operation:	Shape:	Slice cut:
	Erase inside	O Free-form	 Unlimited
	Cdrase outside	Circle	O Positive
	O Fill inside	Rectangle	O Negative
	Fill outside	Centered	○ Symmetric
	Apply to visible segments	:	0.000mm 🗘
			·

You can also cut the hole from within the 3D view.











Phantom is ready!





50



Part 5: Save phantom to STL

Overview:

- Export phantom segment to model node
- Save model to STL file



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5/1: Export phantom segment into model

Switch to the Segmentations module

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Segmentation: Source volume	Segmenta	tion	Segmentations Transforms View Controllers	
🐥 A	dd	— R	Views	0
14 14 14	••	bone	Volumes Welcome to Slicer Wizards	1



1. Select the segment

- 2. Select *Export*
- 3. Select *Models*
- 4. Choose Export models to new folder
- 5. Click *Export*





5/2: Save model into STL



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1	Chang	Stanford Polygon ((P)	Cancel

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5/1: Export phantom segment into model

Switch to the *Data* module, right-click on the segment, and click *Export visible* segments to models



You can set the visibility of a segment by clicking the eye icon











5/2: Save model into STL





Filena	ame:	bone.vtk				
Direc	tory:	C:/Users/	/Docur	nents		•
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- 1. Set the output directory by clicking on the 3 dots.
- 2. Click Export format dropdown and select '.stl'
- 3. Click Export

Filename:	bone.stl			
Directory:	C:/Users/ /Docu	ments	*	<u> </u>
Export format:	Stereolithography Mesh (.: ✓ Compress	stl)		
Export format:	Stereolithography Mesh (.:	stl)	Canc	el



Conclusion

In the tutorial we summarized through an example, how we can load, and segment an anatomical region in 3D Slicer, and also, what steps it takes to prepare the created model for 3D printing.











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