

3D Slicer, Python, Xeus, and Jupyter

bit.ly/scipy2018-slicer-talk



Speaker: Jean-Christophe Fillion-Robin
Scipy 2018

Goals of this ultra lightning talk

- Introduce 3D Slicer **ecosystem , application and community**
- Describe **Python** and **Jupyter** integration



Who am I ?

- Principal Engineer [@kitware](#) in our North Carolina office, lead developer of [@3DSlicerApp](#) #3dslicer
- Maintainer of [#scikit-build](#), [#cmake](#) and [ninja](#) python packages
- Maintainer of [#python-cmake-buildsystem](#)
- Maintainer of [#dockcross](#)



[jfillionr](#)

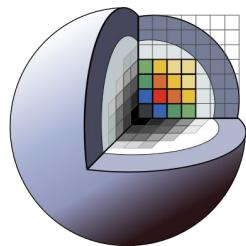


[jcfr](#)



thehiddenbrain

What is the 3D Slicer ecosystem ?



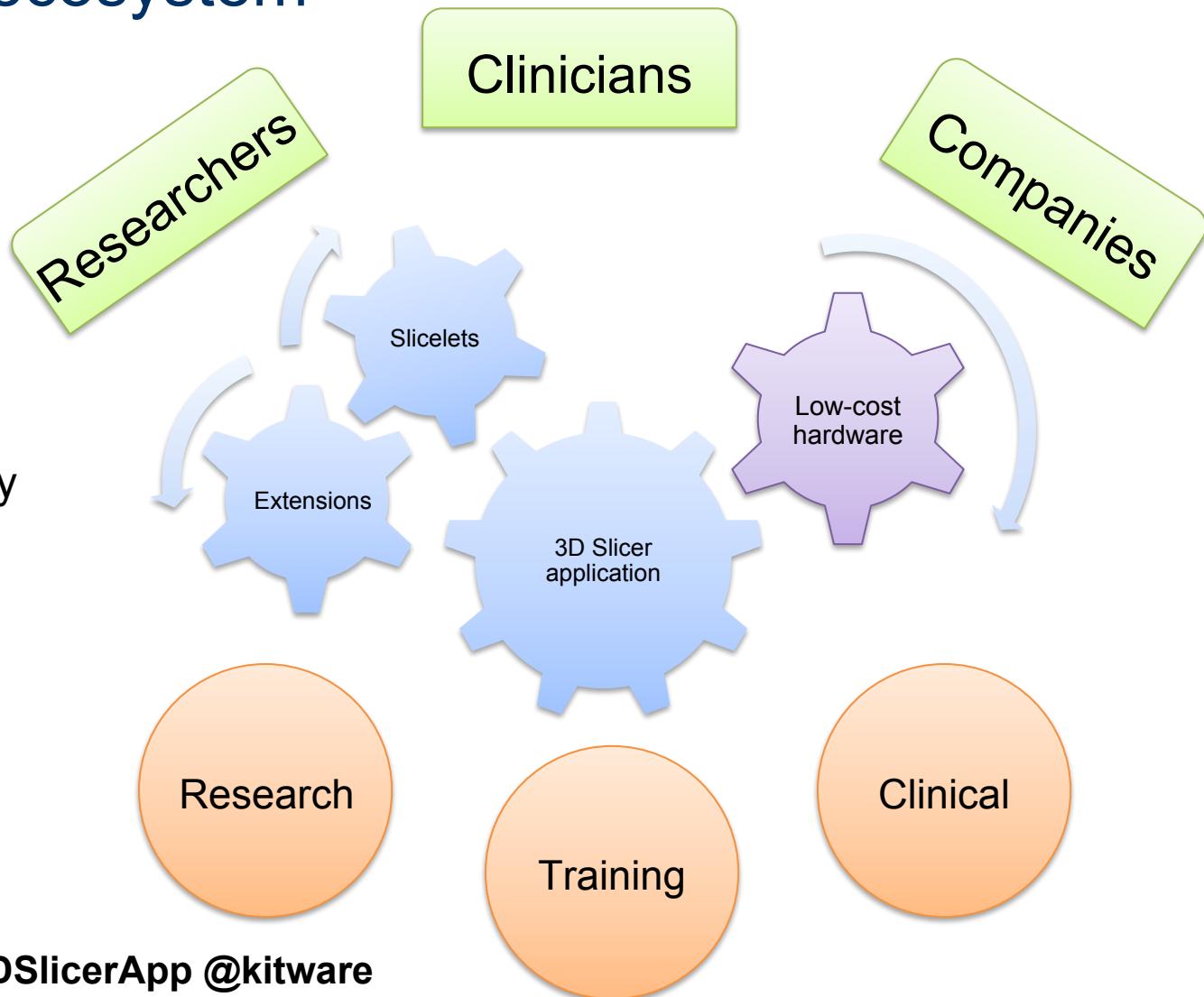
 #3dslicer @3DSlicerApp @kitware

3D Slicer ecosystem

Community

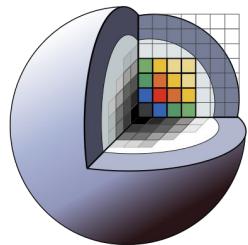
Open technology

Applications



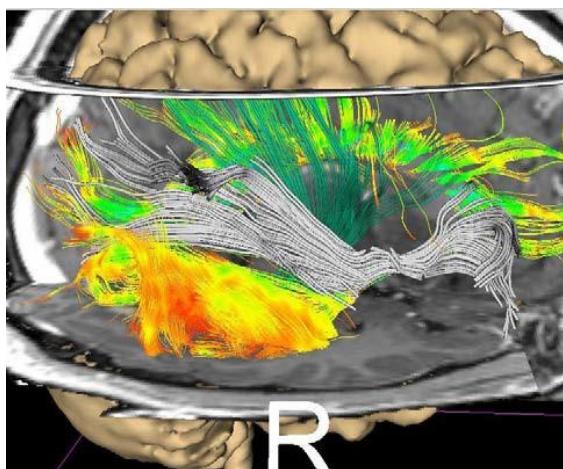
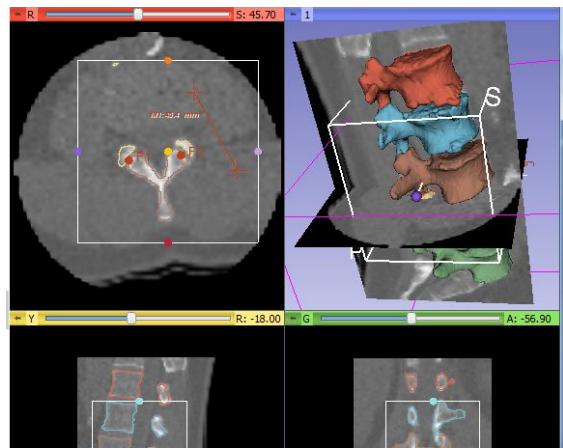
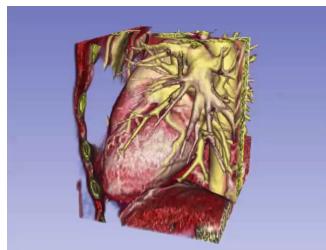
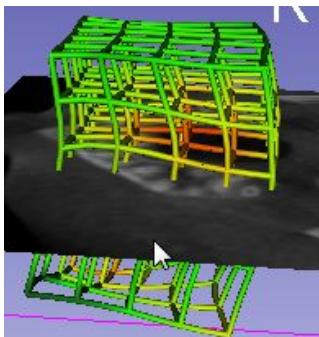
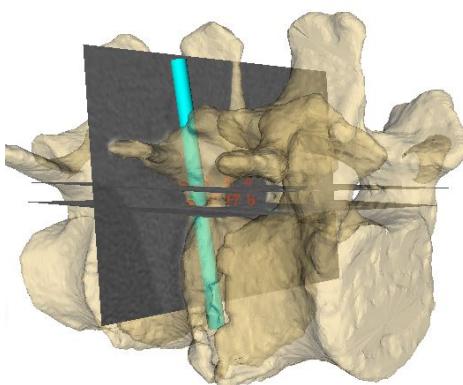
#3dslicer @3DSlicerApp @kitware

What is 3D Slicer ?



 #3dslicer @3DSlicerApp @kitware

- **Software application for medical image computing**
 - data import/export
 - Visualization,
 - Segmentation,
 - Registration,
 - Quantification,
 - real-time guidance



When was 3D Slicer born ?

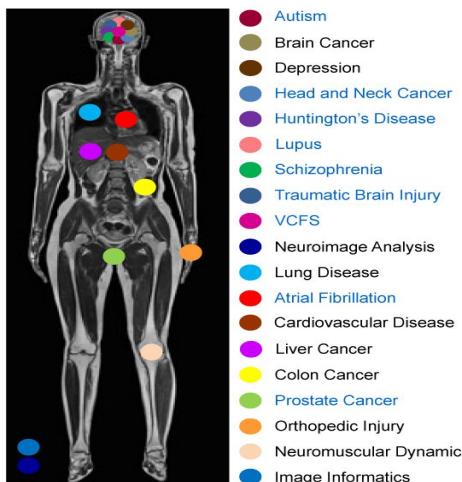
Cost ? Funding ?



#3dslicer @3DSlicerApp @kitware

1997, +\$50M

Grants, Consulting



Active

R01MH084795	U41RR019703	NSF CCF-0916526	R01EB008171	U01HL089897	R01CA124377	R01CA131718	R01CA11128
R01EB005973	U54EB005149-05S2	U54GM072970	P41RR013218	R01EB006733	R01NS050568	R21EB009900	U54EB005149-05S3
UL1RR025758	U54LM008748	U24RR025736	U24RR021992	U24RR021382	U24RR026057	AIST, Japan	UWA, Australia
Mario Negri Institute, Italy		CO-ME, Switzerland		OCAIRO, Canada			

Completed

U54EB005149-04S1

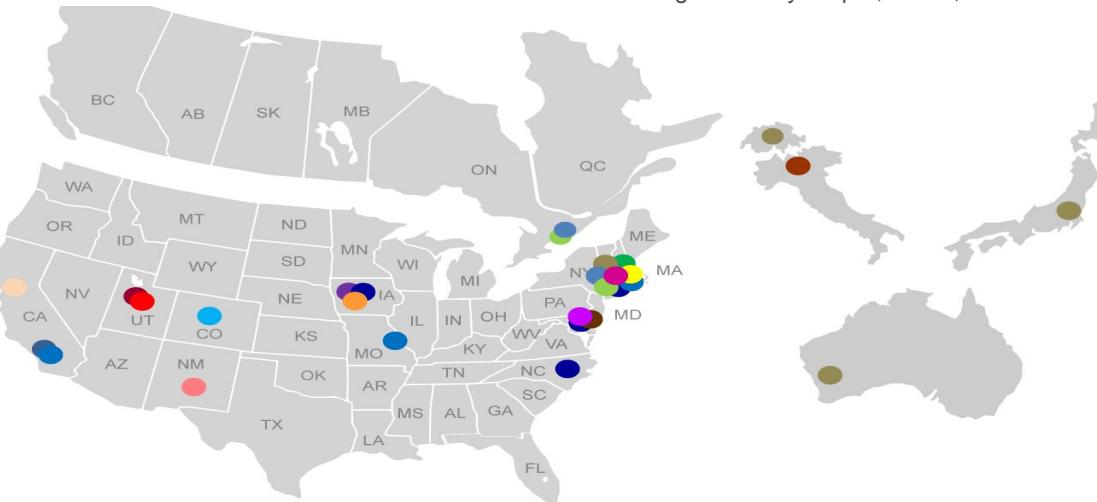


Image courtesy: Kapur, Jakab, Kikinis

Source: https://www.slicer.org/wiki/Documentation/4.x/Acknowledgments#Funding_Sources



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Only 3D ?

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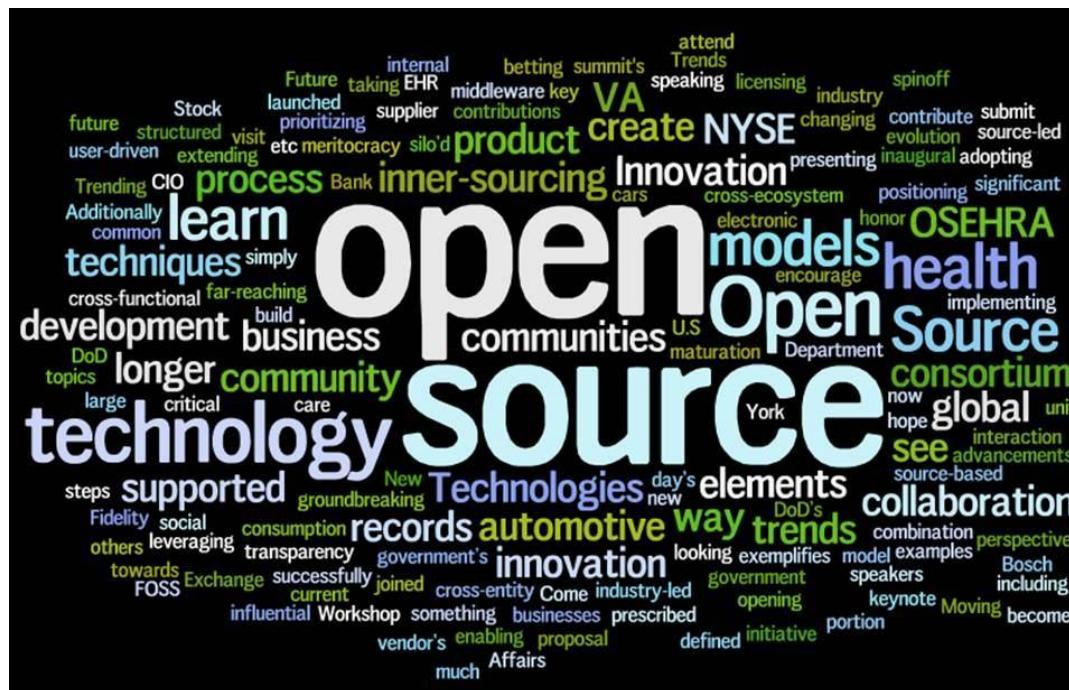
No, “3D” is in the name for historical reason

2D, 3D and 4D

Is it free ?

Yes

BSD-like license, completely free, non-restrictive license



#3dslicer @3DSlicerApp @kitware

Is it cross-platform ?

Yes



#3dslicer @3DSlicerApp @kitware

Where can I download it ?

<https://download.slicer.org>



Windows

Mac OS X

Linux

Stable Release

older releases

version 4.8.1

revision 26813
built 2017-12-27

version 4.8.1

revision 26813
built 2017-12-27

version 4.8.1

revision 26813
built 2017-12-27

Nightly Build

version 4.9.0

revision 27279
built 2018-07-12

version 4.9.0

revision 27273
built 2018-07-10

version 4.9.0

revision 27279
built 2018-07-11



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How large is the community ?

Thousands of download per week, world wide

<https://download.slicer.org/download-stats/>

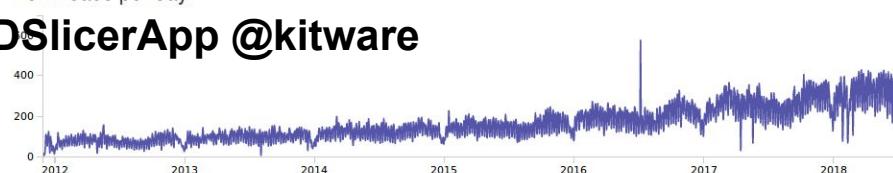
500 downloads per week in 2012

2000 downloads per week in 2017

397,340



Downloads per day



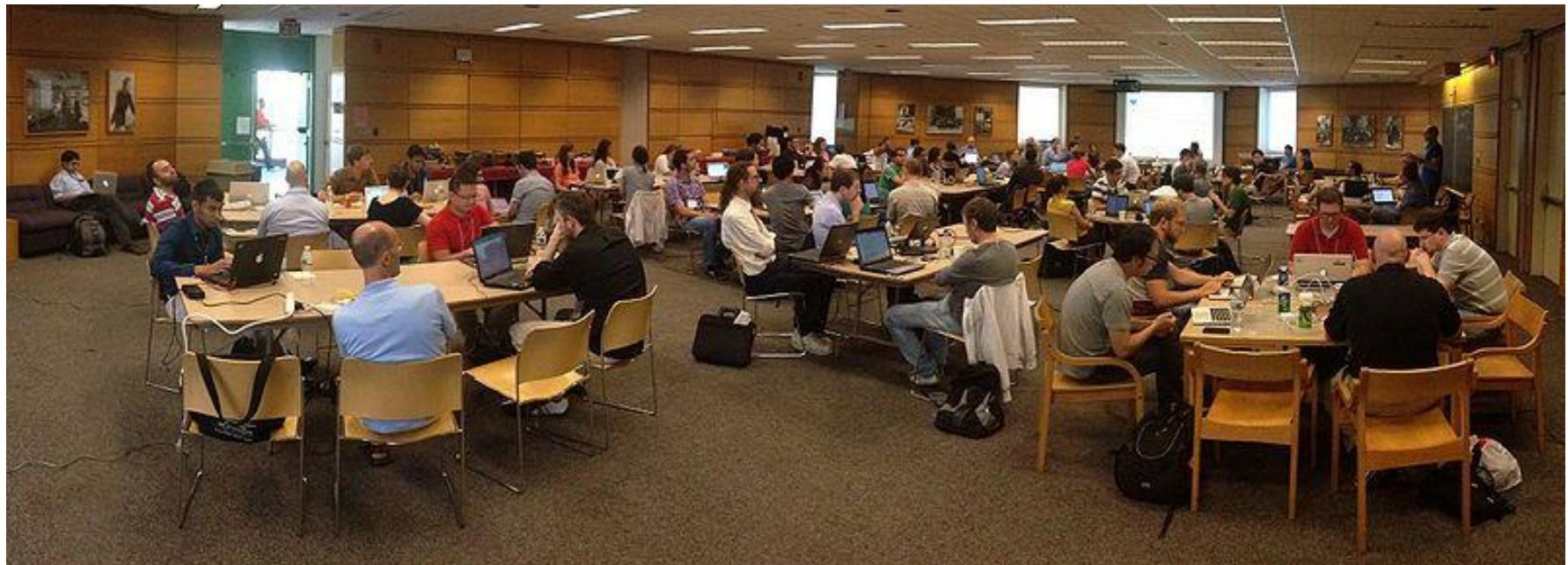
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How active is the community ?

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Project Week: Three times a year, 3 continents

- Researchers, engineers, clinicians from around the world
- Discussions, training, planning, software development...



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Discourse forum (as of June 2018)

Slicer Discourse Forum: **1145 users**

Last 30 days:

- 108 users
- 144 topics
- **732 posts**
- 98% of the topics are answered
- 62k page views
- Time to first response:
< 8 hrs for week days

	Pageviews	Today	Yesterday	Last 7	Last 30	All
Pageviews	296	2.5k	16.5k	62.4k	580k	
Web Crawlers	161	556	6.8k	23.8k	181k	
Logged In	30	853	3.5k	12.1k	132k	
Anonymous	105	1.1k	6.2k	26.5k	265k	

	Today	Yesterday	Last 7	Last 30	All
User Visits	13	68	370	1.3k	12.7k
Signups	0	6	31	108	1.1k
User Profile Views	2	8	123	581	5.9k
Topics	0	13	43	144	1.7k
Posts	0	54	210	723	9.9k
Time to first response	0	4	9	8	21
Topics with no response	0	2	2	15	190
Likes	0	5	41	145	2.1k
Flags	0	0	0	2	9
Bookmarks	0	0	2	12	147
Emails Sent	3	13.3k	51.7k	192k	1.7M
Accepted solutions	0	4	11	24	317

Any Software Process, Continuous integration and Documentation ?



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Yes, Yes, Yes

Nightly-Packages		4 builds									
Site	Build Name	Update		Configure		Build		Test			Start Time ▾
		Revision	Error	Warn	Error	Warn	Not Run	Fail ▾	Pass		
overload.kitware	Windows7-VS2013-64bits-QT4.8.7-NoVTKDebugLeaks-NoConsole-Release └─Qt5.9.1		0	0	0	1000 ⁻³	0	4	666		13 hours ago
factory.perklab	Windows-VS2013-64bits-QT4.8.7-PythonQt-With-Tcl-NoCLI-Release └─Qt5.9.1	26337	0	0	0	1000	0	4	672		15 hours ago
factory-mac-64bits.kitware	SnowLeopard-clang-3.1-64bits-QT4.8.7-NoVTKDebugLeaks-Release └─Qt5.9.1		0	0	0	66 ⁻¹⁷ ₋₂₂	0	4 ⁻¹ ₋₁	674 ⁻¹¹ ₋₁		14 hours ago
factory-south-ubuntu-64bits.kitware	Linux-g++4.4.3-64bits-QT4.8.6-NoVTKDebugLeaks-Doxxygen-Release └─Qt5.9.1		0	0	0	33 ⁻²⁹ ₋₁₇	0	0	675		14 hours ago

Continuous		5 builds									
Site	Build Name	Update		Configure		Build		Test			Start Time ▾
		Revision	Error	Warn	Error	Warn	Not Run	Fail	Pass		
factory.perklab	Windows-VS2013-64bits-QT4.8.7-PythonQt-With-Tcl-NoCLI-Release └─Qt5.9.1	26350	0	0	0	8					29 minutes ago
factory.perklab	Windows-VS2013-64bits-QT4.8.7-PythonQt-With-Tcl-NoCLI-Release └─Qt5.9.1	26349	0	0	0	8 ⁻¹	0	4	672		2 hours ago
factory.perklab	Windows-VS2013-64bits-QT4.8.7-PythonQt-With-Tcl-NoCLI-Release └─Qt5.9.1	26348	0	0	0	0 ⁻¹	0	4	672		2 hours ago
factory.perklab	Windows-VS2013-64bits-QT4.8.7-PythonQt-With-Tcl-NoCLI-Release └─Qt5.9.1	26346	0	0	0	8 ⁻¹ ₋₇₄	0	4	672		3 hours ago
factory.perklab	Windows-VS2013-64bits-QT4.8.7-PythonQt-With-Tcl-NoCLI-Release └─Qt5.9.1	26342	0	0	0	78 ⁻⁴⁰ ₋₁₁₂	0	4	672		5 hours ago

Nightly		1 build									
Site	Build Name	Update		Configure		Build		Test			Start Time ▾
		Revision	Error	Warn	Error	Warn	Not Run	Fail	Pass		
chimaera.queensu.ca	Windows10-VS2013-64bits-64bits-QT4.8.7-PythonQt-With-Tcl-NoCLI-Release └─Qt5.9.1	26337	0	0	0	1000	0	13	544 ⁻¹¹		12 hours ago



CDash

Add more commits by pushing to the `remove_qt5_positioning_dep` branch on [ihnorton/Slicer](#).

✔
All checks have passed
2 successful checks

✔ ci/circleci — Your tests passed on CircleCI!	Details
✔ slicer/apidocs — API documentation published	Details

✔
This branch has no conflicts with the base branch
Merging can be performed automatically.

- Continuous Testing
- +700 tests
- [CONTRIBUTING.md](#)
- <https://wiki.slicer.org> (User and Developer Manual)
- <https://discourse.slicer.org/> (Forum)
- <http://apidocs.slicer.org/>



#3dslicer @3DSlicerApp @kitware

What are the clinical use cases ?

Many

Clinical users drive creation of technology

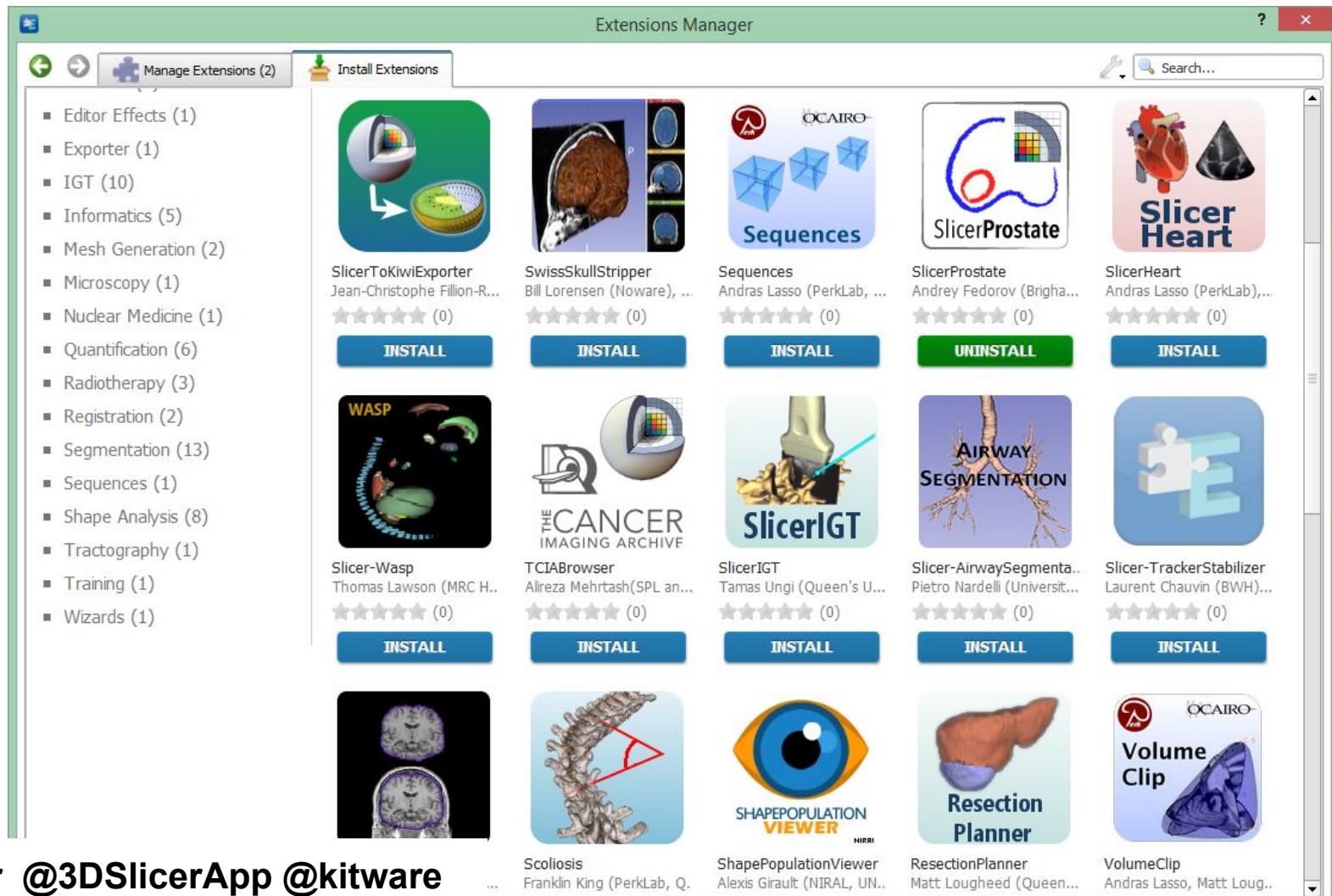
The slide features a central text "Clinical users drive creation of technology" surrounded by nine circular images, each representing a different medical application of 3D Slicer:

- Radiation dose calculations**: A screenshot of a software interface showing radiation dose calculations for a patient's head.
- Tracking peritumoral white matter fibers**: A 3D rendering of brain tissue with red fibers highlighted, and a yellow arrow pointing to a specific fiber.
- MRI-guided prostate biopsy**: An MRI scan of a prostate with a green target area.
- Breast cancer surgery guidance**: A surgeon in an operating room using a tablet for guidance.
- Diagnosis of Osteoarthritis Degeneration**: A 3D rendering of a joint with red areas indicating degeneration.
- Quantitative assessment of COPD**: A CT scan of lungs with a semi-transparent overlay showing airway obstruction.
- Surgical navigation**: A close-up of a surgical navigation system integrated with a physical model of tissue.
- Brain surgery**: A 3D rendering of a brain with a blue surgical plan overlaid.
- Model-Guided Deep Brain Simulation**: A 3D rendering of a brain with a complex multi-colored simulation overlay.
- Diagnosis of Different Tumors in Lung Cancer**: A 3D rendering of lung tissue with green and red tumor regions.

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Is 3D Slicer Extensible and customizable ?

Yes, built-in “App store” (aka Extensions Manager)



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What are the building blocks ?

Medical Scanners

software
hardware

MRI, CT, PET
scanners



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3D Slicer application and libraries

3D Slicer

VTK, ITK, CTK, QT, Python, DCMTK, ...

software

hardware

MRI, CT, PET
scanners



#3dslicer @3DSlicerApp @kitware

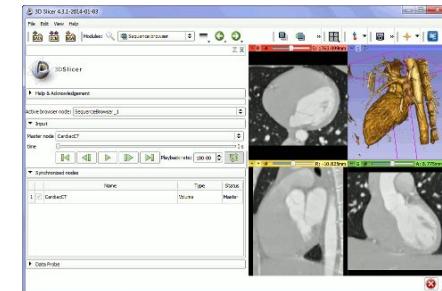
3D Slicer modules



3D Slicer extensions

... more than 100 extensions

Slicer
extensions



3D Slicer

Visualization

Registration

Segmentation

...

Quantification

VTK, ITK, CTK, QT, Python, DCMTK, ...

DICOM

software
hardware

MRI, CT, PET
scanners



#3dslicer @3DSlicerApp @kitware

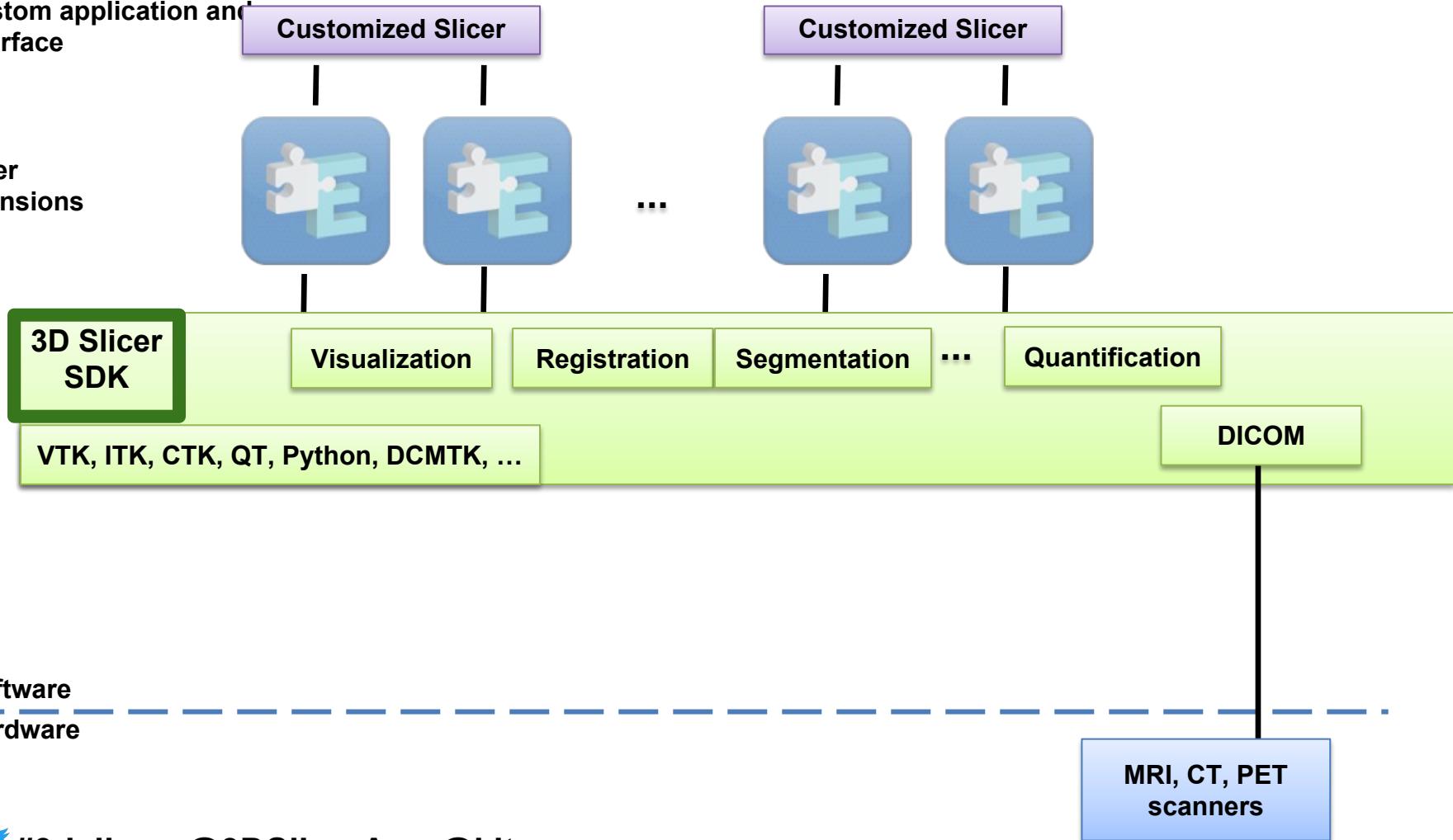
Can 3D Slicer be
customized,
re-packaged and
distributed ?



#3dslicer @3DSlicerApp @kitware

YES -> Slicer Custom Application

Custom application and interface



Example: Radiation Therapy - slicerrt.org

Custom application and interface



Slicer extensions

3D Slicer
SDK

Visualization

Registration

Segmentation

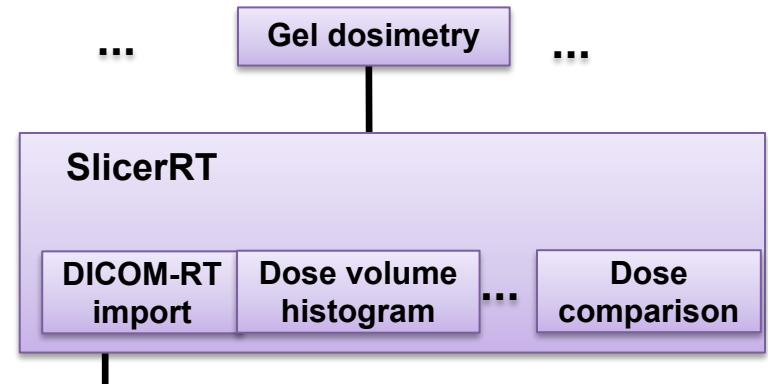
Quantification

DICOM

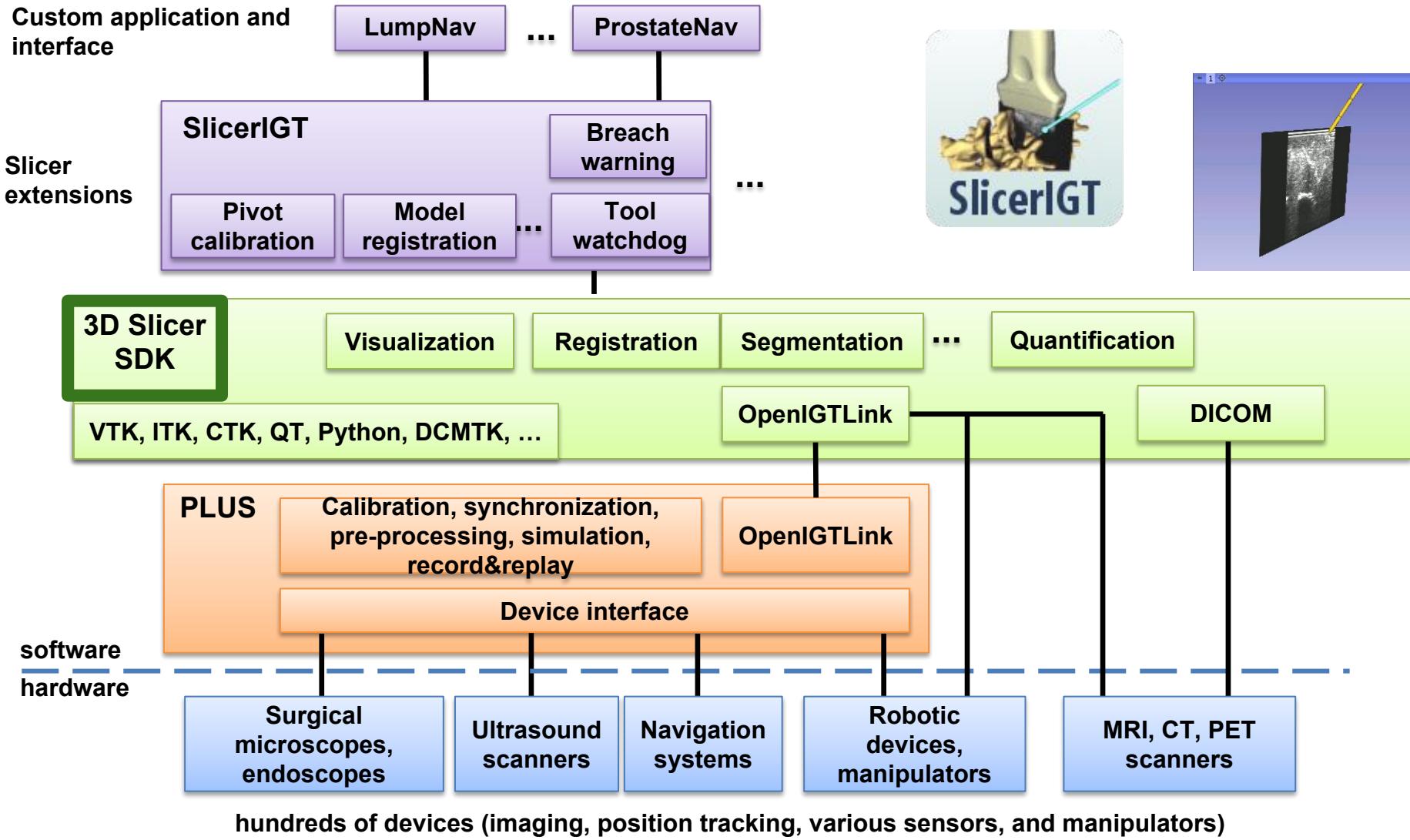
VTK, ITK, CTK, QT, Python, DCMTK, ...

software
hardware

MRI, CT, PET
scanners



Example: Real time guidance - slicerigt.org



How to create custom 3D Slicer App?

A possible approach: SlicerCustomAppTemplate

```
$ pip install cookiecutter
```

```
$ cookiecutter \
```

```
gh:KitwareMedical/SlicerCustomAppTemplate
```



#3dslicer @3DSlicerApp @kitware

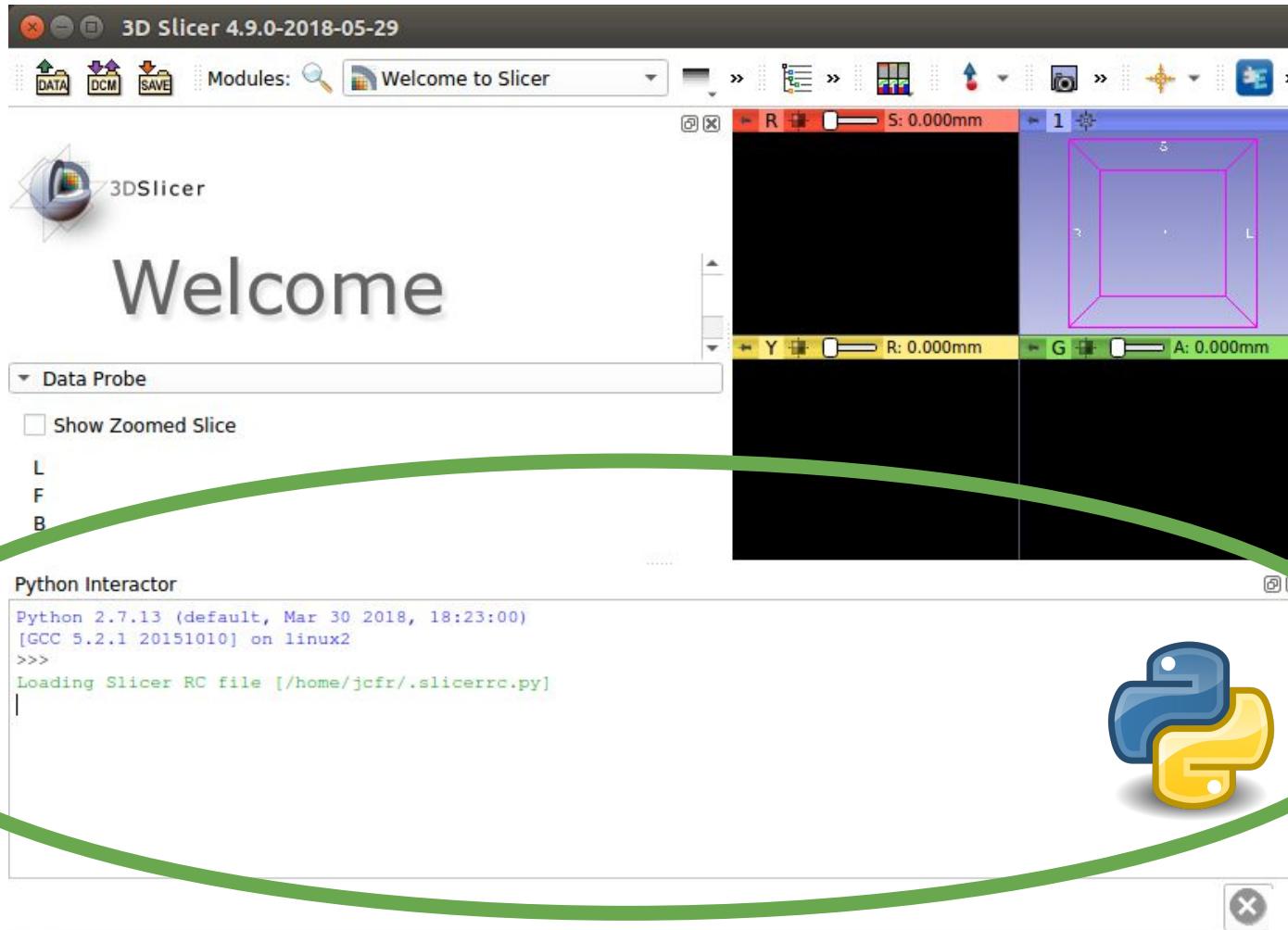
Where is Python ?

How is Python integrated ?



#3dslicer @3DSlicerApp @kitware #python

Slicer Python Interactor



#3dslicer @3DSlicerApp @kitware #python

At (mostly) every level

Custom application and interface



Customized Slicer



...

Customized Slicer



Slicer extensions



3D Slicer



Visualization

Registration

Segmentation

Quantification

Module

...



VTK, ITK, CTK, QT, Python, DCMTK, ...



OpenIGTLINK

DICOM

PLUS



Calibration, synchronization,
pre-processing, simulation,
record&replay

OpenIGTLINK

Device interface

software
hardware

Surgical
microscopes,
endoscopes

Ultrasound
scanners

Navigation
systems

Robotic
devices,
manipulators

MRI, CT, PET
scanners

hundreds of devices (imaging, position tracking, various sensors, and manipulators)

C_Python for

- Implementing Modules and plugins
- Rapid prototyping
- Implementing tests
- Runtime introspection and scripting



#3dslicer @3DSlicerApp @kitware #python

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Cython is embedded

 [python-cmake-buildsystem / python-cmake-buildsystem](#)

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[Code](#) [Issues 31](#) [Pull requests 16](#) [Insights](#) [Settings](#)

A cmake buildsystem for compiling Python [Edit](#)

[cpython](#) [cmake](#) [build-system](#) [cross-platform](#) [Manage topics](#)

 569 commits  8 branches  0 releases  17 contributors  Apache-2.0

 #3dslicer @3DSlicerApp @kitware #python

Python 2 or 3 ?



#3dslicer @3DSlicerApp @kitware #python

Python 2.7.15

- Switch to Python 3.7 by the end of the year



#3dslicer @3DSlicerApp @kitware #python

Can I install official wheels ?



#3dslicer @3DSlicerApp @kitware #python



No



Yes



Yes



#3dslicer @3DSlicerApp @kitware #python

Can I build Slicer against conda or my own Python ?



#3dslicer @3DSlicerApp @kitware #python

bit.ly/scipy2018-slicer-talk

Yes



#3dslicer @3DSlicerApp @kitware #python

Does 3D Slicer support translational research ?



#3dslicer @3DSlicerApp @kitware #python

Yes



jigani.com



m



www.senkox.com

Technological prototype



Research tool



Clinical tool

Can it be done?

Innovative,
not robust,
usually single developer
supported

Should it be done?

Robust and usable
enough for clinical
evaluation, flexible,
open, portable,
community supported

Patient ready

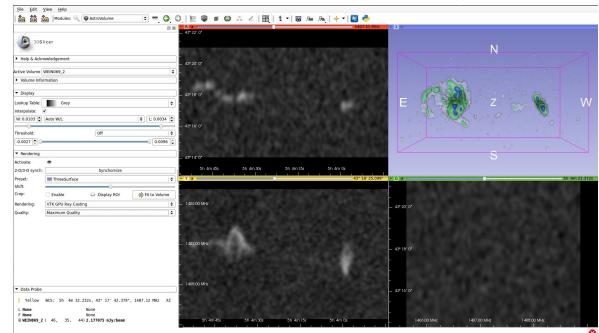
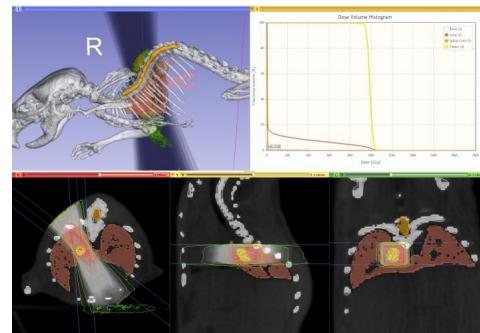
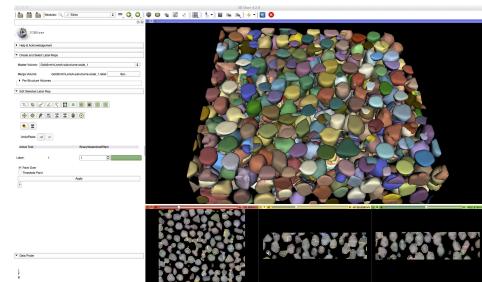
FDA approved, company
supported, closed source

Which type of data ?
Which scale ?



#3dslicer @3DSlicerApp @kitware #python

Handle data from Microscopy to Astronomy



IASEM: ion-abrasion scanning electron microscopy

Source:

<https://www.slicer.org/wiki/Documentation/Nightly/Extensions/IASEM>

Source:

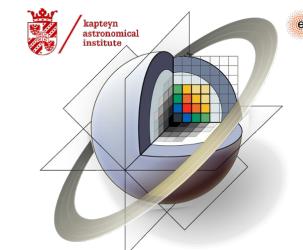
<https://blog.kitware.com/kitware-customer-highlight-muriplan-from-xstrahl-a-3d-slicer-based-radiotherapy-treatment-planning-system/>

Made possible leveraging to ITK, VTK, DCMTK, Teem, ...



#3dslicer @3DSlicerApp @kitware #python

Slicer Astro



Can I use 3D Slicer from Jupyter ?



#3dslicer @3DSlicerApp @kitware #python

Yes

localhost:8888/notebooks/My%20first%20Slicer%20notebook.ipynb

jupyter My first Slicer notebook Last Checkpoint: 2 minutes ago (unsaved changes) Logout

File Edit View Insert Cell Kernel Widgets Help Trusted Slicer release

In [2]:

```
slicer.mrmlScene.Clear(False)
import SampleData
sampleDataLogic = SampleData.SampleDataLogic()
volume = sampleDataLogic.downloadMRHead()
slicer.app.layoutManager().setLayout(slicer.vtkMRMLLayoutNode.SlicerLayoutFourUpView)
display()
```

Out[2]:

In [3]:

```
slicer.app.layoutManager().setLayout(slicer.vtkMRMLLayoutNode.SlicerLayoutOneUpRedSliceView)
display()
```

Out[3]:

Can I use 3D Slicer from JupyterLab ?

 #3dslicer @3DSlicerApp @kitware #python #jupyter

Yes

JupyterLab X | + | - | X

localhost:8889/lab

File Edit View Run Kernel Tabs Settings Help

Files + + ↑ C

Running + X □ My first Slicer n ×

Commands Code

Slicer release

In [11]:

```
slicer.mrmlScene.Clear(False)
import SampleData
sampleDataLogic = SampleData.SampleDataLogic()
volume = sampleDataLogic.downloadMRHead()
#volume = sampleDataLogic.downloadCTChest()
slicer.app.layoutManager().setLayout(slicer.vtkMRMLLayoutNode.SlicerLayoutFourUpView)
slicer.app.layoutManager().setLayout(slicer.vtkMRMLLayoutNode.SlicerLayoutOneUpRedSliceView)
display()
```

Out[11]:

R S: -10.214mm

The screenshot shows a JupyterLab interface running a Python notebook. The notebook cell In [11] contains code to initialize Slicer, download sample data, and set up the user interface. The resulting output Out[11] displays a grayscale axial MRI scan of a head. A red color bar at the bottom of the image indicates the slice position as S: -10.214mm. The JupyterLab interface includes a sidebar with tabs for Files, Running, Commands, Cell Tools, and Tabs. A green oval highlights the 'Slicer release' button in the top right corner of the interface.

How does this work ?

 #3dslicer @3DSlicerApp @kitware #python #jupyter

Interactively running Jupyter and Slicer

My first Slicer notebook X +

jupyter My first Slicer notebook

File Edit View Insert Cell Kernel Widgets Help Trusted Logout Slicer release

In [11]:

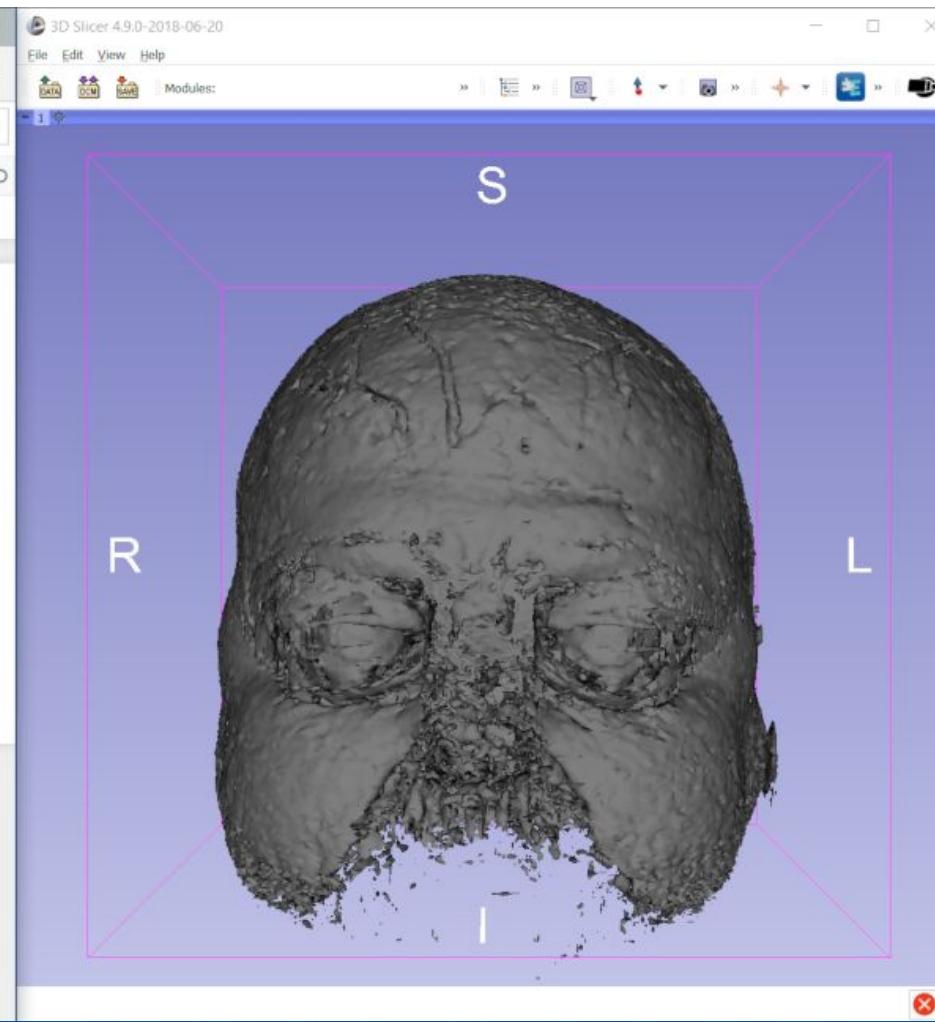
```
slicer.mrmlScene.Clear(False)
import SampleData
sampleDataLogic = SampleData.SampleDataLogic()
volume = sampleDataLogic.downloadMRHead()
slicer.app.layoutManager().setLayout(slicer.vtkMRMLLayoutNode.SlicerLayoutFourUpView)
```

Out[11]:

In [12]:

```
parameters = {}
parameters["InputVolume"] = volume.GetID()
outModel = slicer.vtkMRMLModelNode()
slicer.mrmlScene.AddNode( outModel )
parameters["OutputGeometry"] = outModel.GetID()
grayMaker = slicer.modules.grayscalemodelmaker
slicer.cli.runSync(grayMaker, None, parameters)
slicer.app.layoutManager().setLayout(slicer.vtkMRMLLayoutNode.SlicerLayoutOneUpView)
```

Out[12]:



Why would you do this ?

 #3dslicer @3DSlicerApp @kitware #python #jupyter

Interactive Tutorial

- Slicer is Qt-based application with own event loop
- Traditional kernel embedding do not work

How is it implemented ?

 #3dslicer @3DSlicerApp @kitware #python #jupyter

bit.ly/scipy2018-slicer-talk

Implemented a custom C++ kernel based on XEUS

QuantStack / **xeus**

Watch ▾ 26 Star 331 Fork 26

Code Issues 6 Pull requests 0 Projects 0 Wiki Insights

C++ implementation of the Jupyter kernel protocol

jupyter-kernels interpreter jupyter c-plus-plus

181 commits 1 branch 26 releases 7 contributors BSD-3-Clause



xeus

 #3dslicer @3DSlicerApp @kitware #python #jupyter #xeus

Improved XEUS to support event-loop integration

Thanks to @SylvainCorlay and @JohanMabille for review

Merge pull request #70 from jcfr/allow-customized-zmq-server-to-start...	...	Verified		dfca717			
SylvainCorlay committed 13 days ago ✓							
xserver_zmq: Allow custom implementation to start publisher and heart...	...			450f90a			
jcfr committed 13 days ago ✓							
Merge pull request #69 from jcfr/require-cmake-greater-or-equal-38	...	Verified		596e9a5			
JohanMabille committed 13 days ago ✓							
Merge pull request #68 from jcfr/support-event-loop-integration-appro...	...	Verified		a304f3d			
JohanMabille committed 13 days ago ✓							
cmake: Require version >= 3.8 to ensure try_compile consider CMAKE_(C...	...			c106277			
jcfr committed 13 days ago ✓							
api/xserver_zmq: Add "poll(long timeout)" function		Verified		c7eac6b			
jcfr committed 13 days ago ✓							
xkernel: Support non-blocking implementation of kernel start function	...	Verified		bc6a212			
jcfr committed 13 days ago ✓							
xserver_zmq: Add zmq implementation to public API	...	Verified		a569af0			
jcfr committed 13 days ago ✓							
style: Rename "xserver_impl" header to "xserver_zmq"	...	Verified		5a30ffe			
jcfr committed 13 days ago ✓							
Merge pull request #66 from jcfr/improve-cmake-config-file	...	Verified		654005d			
JohanMabille committed 14 days ago ✓							
Commits on Jun 28, 2018							
cmake: Ensure public dependencies are found in xeusConfig file	...	Verified		a5d5d47			
jcfr committed 15 days ago ✓							

bit.ly/scipy2018-slicer-talk

Then, we created SlicerJupyter extension



<https://github.com/Slicer/SlicerJupyter>



#3dslicer @3DSlicerApp @kitware #python #jupyter #xeus

Build status

Extensions-Nightly									3 builds
Site	Build Name	Configure		Build		Test			Start Time ▾
		Error	Warn	Error ▾	Warn ▾	Not Run ▾	Fail	Pass	
factory-south-macos.kitware	27279-SlicerJupyter-git97d5640-g++-64bits-Qt5.10-Release 	0	0	6	32	2	0	0	14 hours ago
metroplex.kitware	27279-SlicerJupyter-git97d5640-g++-64bits-Qt5.11-Release 	0	0	4	1				15 hours ago
overload.kitware	27279-SlicerJupyter-git97d5640-MSBuild-64bits-Qt5.10-Release 	0	0	0	28	0	0	2	6 hours ago



#3dslicer @3DSlicerApp @kitware #python #jupyter #xeus

How to install it ?



#3dslicer @3DSlicerApp @kitware #python #jupyter #xeus

SlicerJupyter Extension available for the user

- Install Python and Jupyter notebook
- Install 3D Slicer
- Install SlicerJupyter extension
- Restart Slicer
- Install Slicer Kernel
 - Switch to JupyterKernel module
 - Select Python Scripts folder. This is the folder where jupyter-kernelspec executable is located.
On Windows by default it is a location such as
c:\Users(username)\AppData\Local\Programs\Python\Python37-32\Scripts.
 - Click **Install Slicer kernel in Jupyter**.



What is next ?

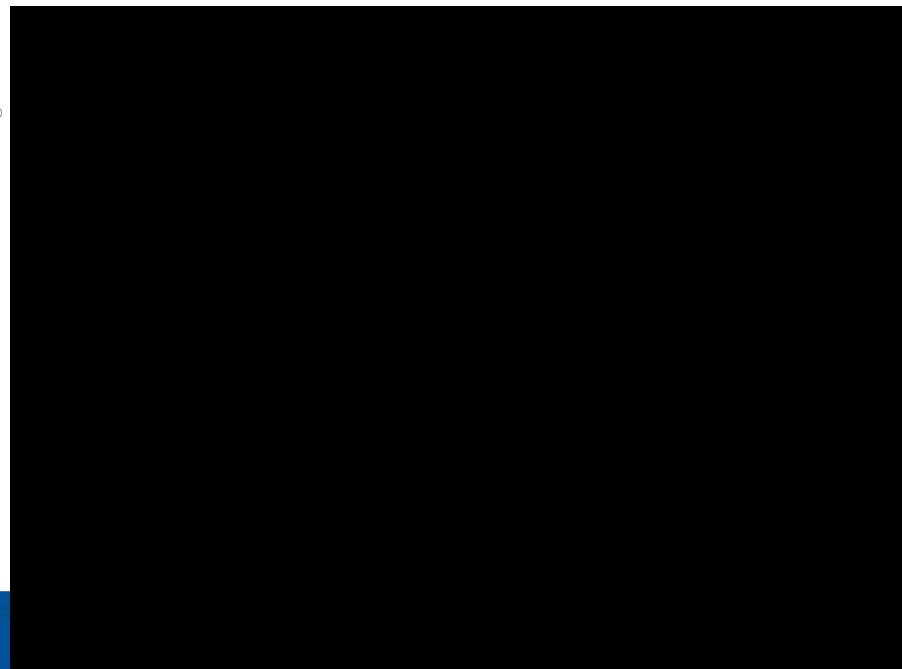


#3dslicer @3DSlicerApp @kitware #python #jupyter #xeus

- Integrate and reuse component from existing ipython kernel
- Docker, Girder, Girder Worker, JupyterHub integration



- Integrate with itkwidgets



Thanks to the Jupyter, Xeus, Slicer and the wider SciPy community. Thanks Andras Lasso for contributing.

slicer.org

Slides: bit.ly/scipy2018-slicer-talk



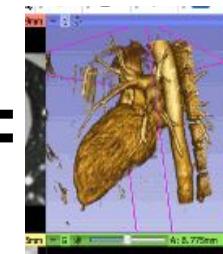
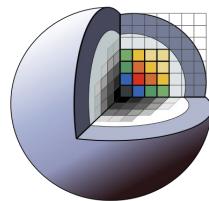
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#3dslicer @3DSlicerApp @kitware #python #jupyter #xeus