

# ITK: The Insight Segmentation and Registration Toolkit



SciPy Conference  
July 11th, 2018



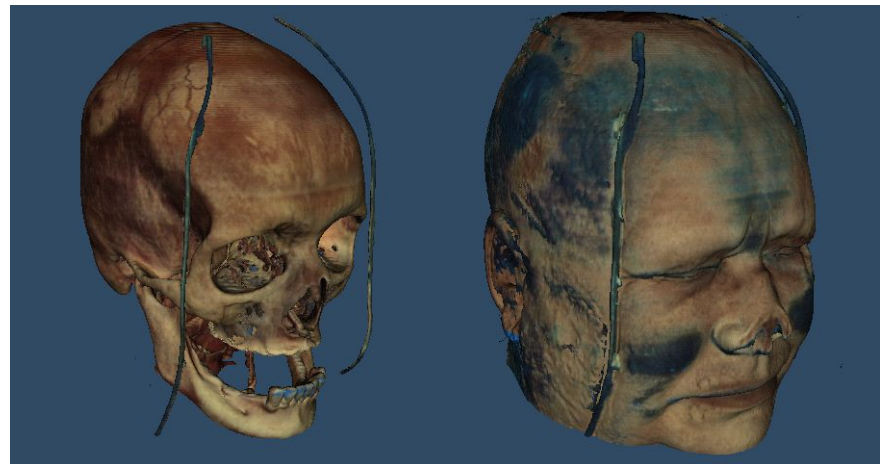
Matthew McCormick<sup>1</sup>, Francois Budin<sup>1</sup>, Dženan  
Zukić<sup>1</sup>, Deepak Chittajallu<sup>1</sup>, Beatriz Paniagua<sup>1</sup>,  
Jean-Christophe Fillion-Robin<sup>1</sup>

<sup>1</sup>*Kitware, Inc.*



# Outline

1. Background
  - a. Introduction to ITK
  - b. Python Wrapping History
2. New Developments
  - a. Python Packages
  - b. Module Packages Developed on GitHub
  - c. Pythonic Interface
  - d. NumPy Bridge
  - e. itk-jupyter-widgets
3. Learn More, Get Involved!



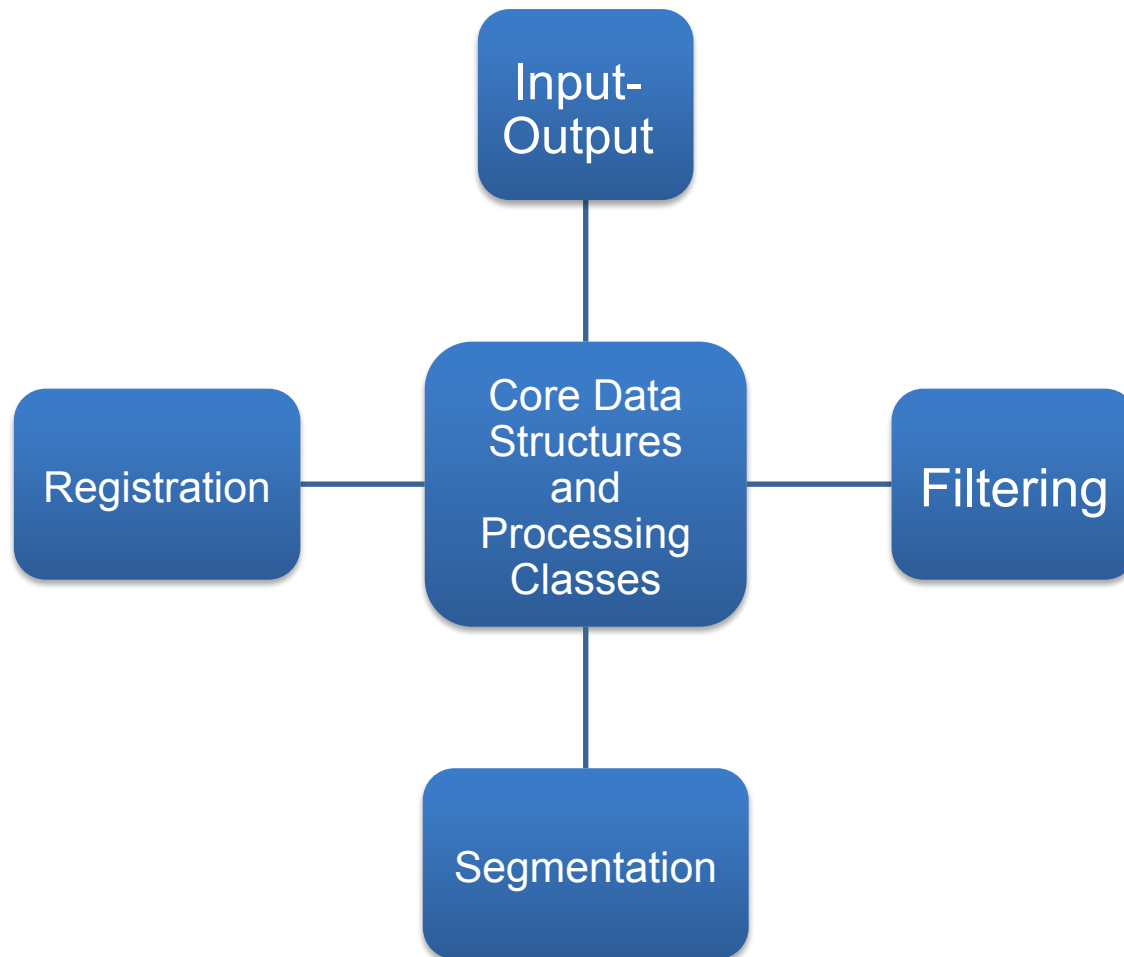
ITK: *Insight into Images*

# What is the Insight Toolkit (ITK)?

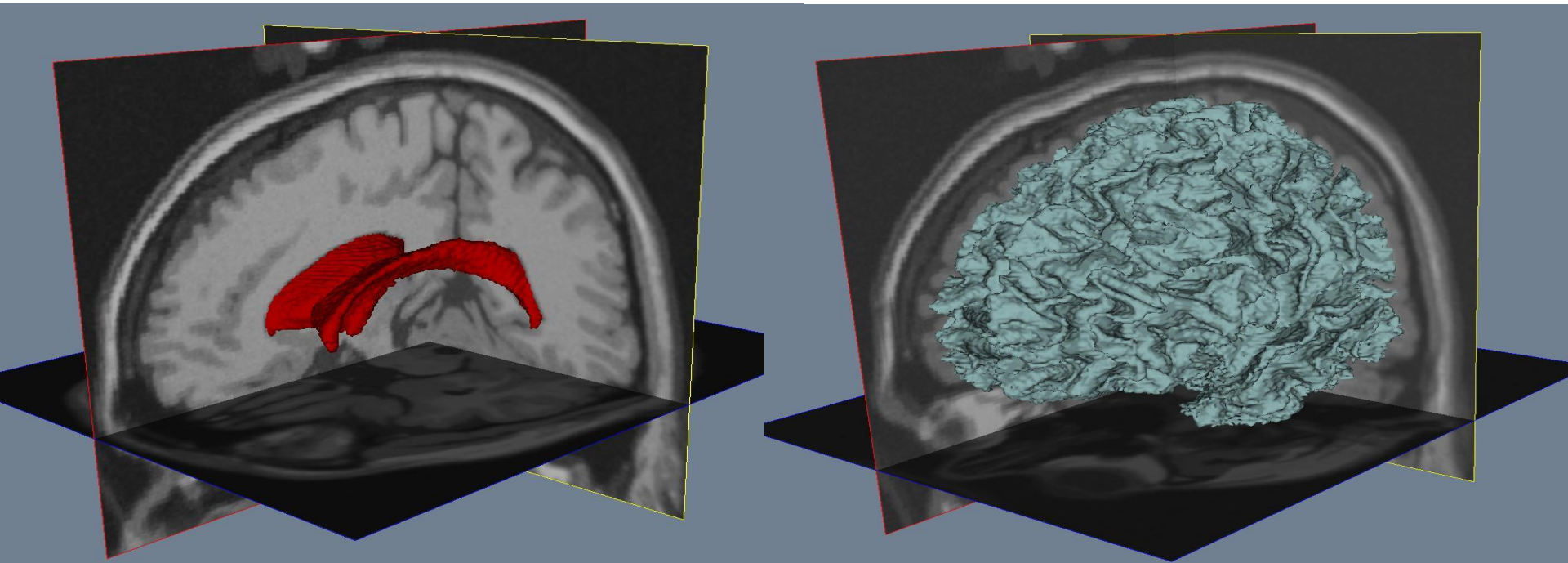
- The Insight Segmentation and Registration Toolkit (ITK) is an **open-source**, freely available, cross-platform system for **high-performance, N-dimensional image analysis**
- Extensive suite of algorithms for processing, registering, segmenting, analyzing, and quantifying scientific data.
- <https://www.itk.org/>



# What are ITK's primary features?

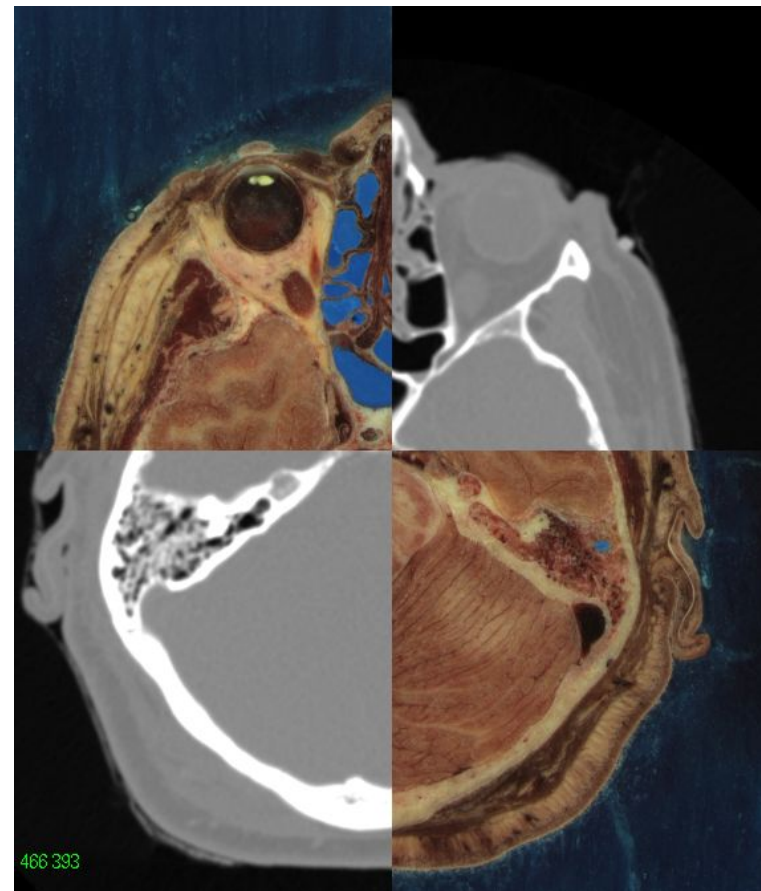
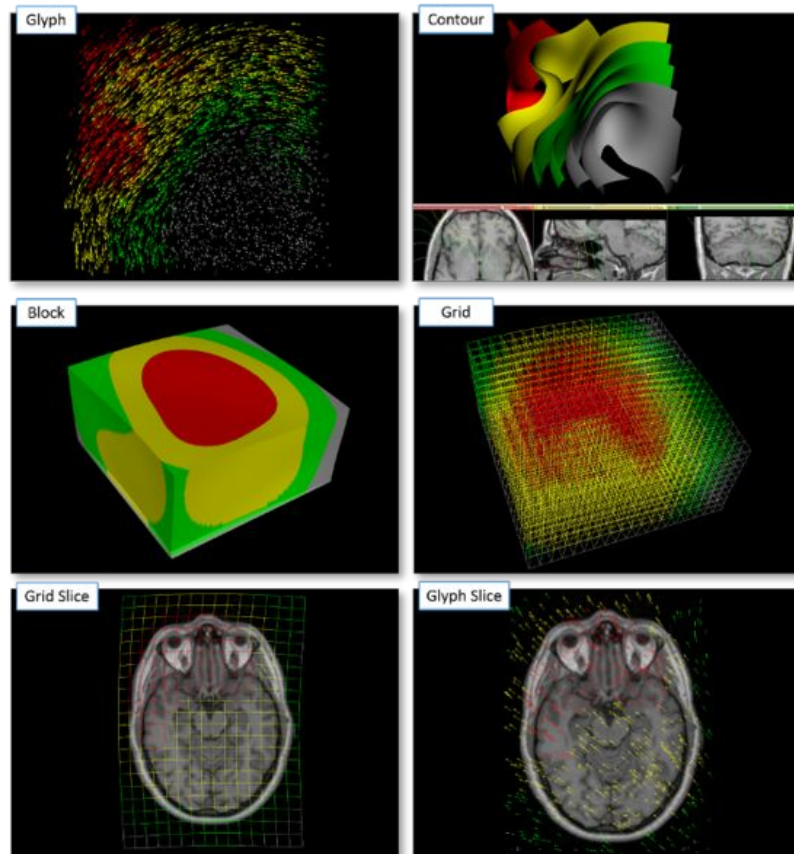


# Segmentation





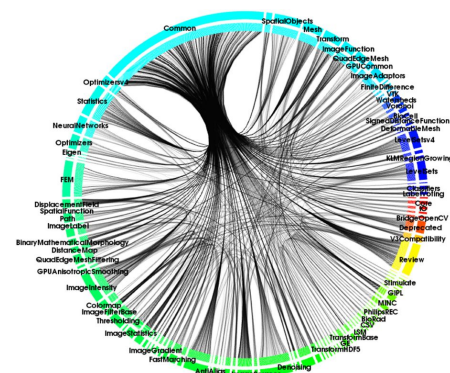
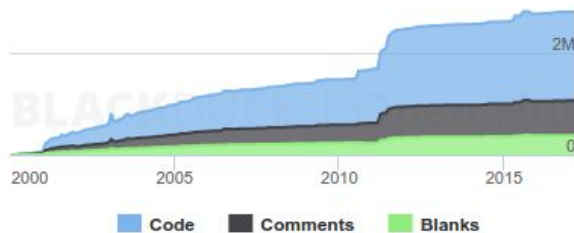
# Registration



*ITK Transforms Visualized in 3D Slicer*

# Code and algorithms - how much?

- 1.7 million lines of code<sup>1</sup>
- Estimated 497 years of person-effort (COCOMO model)<sup>1</sup>
- First commit in January, 2000<sup>1</sup>
- 48,690 commits<sup>2</sup>
- Over 130 modules<sup>3</sup>



## Module dependencies<sup>2</sup>

- 1 <https://www.openhub.net/p/itk>  
2 <https://github.com/InsightSoftwareConsortium/ITK>  
3 <https://doi.org/10.3389/fninf.2014.00013>

## Image input-output formats - 22

- BMP
- NIFTI
- MRC
- DICOM
- Stimulate
- GE formats
- TIFF
- VTK
- IPL
- GIPL
- LSM
- HDF5
- PNG
- MINC
- BioRad
- MetaImage
- NRRD
- RAW
- Siemens
- SCIFIO-supported
- JPEG
- PhilipsREC





# Types of filtering algorithms - 16

Comparison

Smoothing

Distance Map

Image Label

Thresholding

Mathematical  
Morphology

Gradient

Compose

FFT

Bias  
Correction

Interpolation

Noise

Denoising

Convolution

Deconvolution

Features

# Types of segmentation algorithms - 6

LevelSets

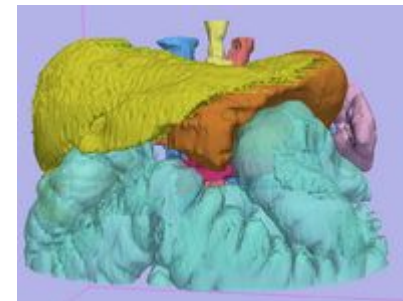
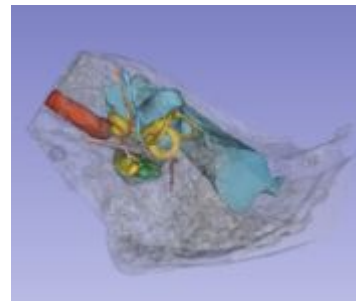
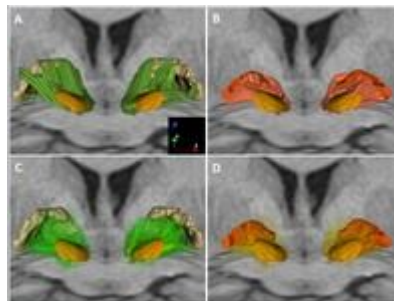
Watersheds

Connected  
Components

Label Voting

Region Growing

Classifiers

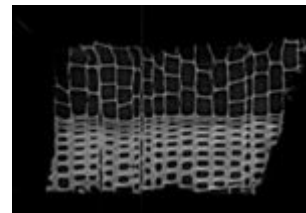
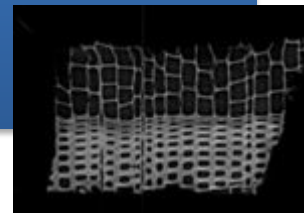
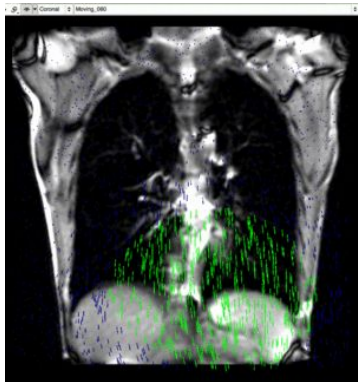
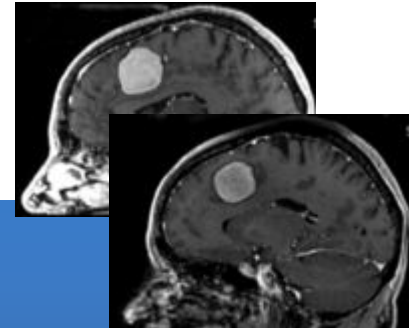


# Types of registration algorithms - 3

Registration Optimization Framework

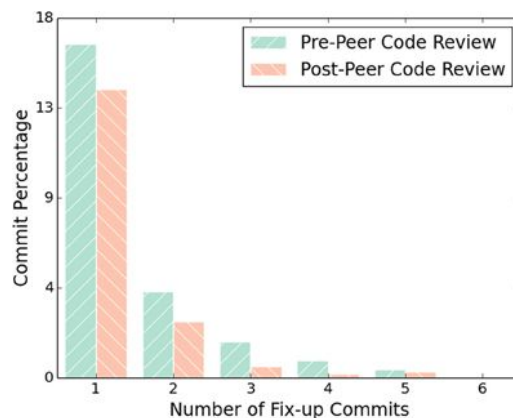
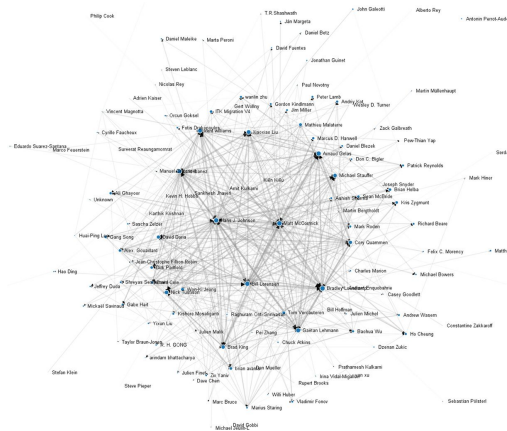
PDE Deformable Registration (Demons)

FEM Registration



# What is the size of the community and what are the software quality practices?

- 2,818 regression tests<sup>1</sup>
- 88.63% code testing coverage<sup>1</sup>
- Over 6,000 code reviews<sup>2</sup>



CDash Dashboard

Friday, March 31 2017 12:47:56

Site	Build Name	Period	Time	Error	Warn	Test	Test Run	Fail	Pass	Time	Start Time	
kitware.com	Linux-64-gcc-5-m32	20170321	2m 51s	0	0	43m 10s	0	0	43m 10s	14m 2s	10 hours ago	
kitware.com	Ubuntu-GCC-5.1-Release	20170321	1m 42s	0	254	1h 8s	0	0	2732	6m 59s	5 hours ago	
kitware.com	Win-VS11-Visual-Studio-15-2017-World4-Release-Shared	20170321	6m 54s	0	199	1h 10m 39s	0	0	2732	6m 44s	6 hours ago	
kitware.com	Linux-64-gcc-4.7.1	20170321	3m 11s	0	0	11m 51s	0	0	2528	6m 39s	48 minutes ago	
kitware.com	Linux-64-gcc-5.1-t11	20170321	3m 36s	0	0	12m 22s	0	0	2528	6m 36s	1 hour ago	
kitware.com	Linux-64-gcc-5.1	20170321	2m 50s	0	0	17m 50s	0	0	2528	6m 31s	2 hours ago	
kitware.com	Linux-64-gcc-5-m32	20170321	2m 51s	0	0	15m 49s	0	0	2528	6m 55s	2 hours ago	
kitware.com	Linux-64-gcc-5	20170321	2m 51s	0	0	16m 22s	0	0	2528	6m 49s	2 hours ago	
kitware.com	Linux-64-gcc-5.1	20170321	2m 57s	0	0	27m 34s	0	0	2528	13m 24s	3 hours ago	
kitware.com	Win-VS14-Ninja-Release-Shared	20170321	8m 27s	0	0	1h 28m 50s	0	0	2732	8m 17s	3 hours ago	
kitware.com	Linux-64-gcc-9-c11	20170321	3m 4s	0	0	12m 3s	0	0	2528	6m 49s	3 hours ago	
kitware.com	Linux-64-gcc-9	20170321	2m 57s	0	0	13m 5s	0	0	2528	6m 44s	4 hours ago	
kitware.com	Win-VS10-Release-Shared	20170321	14m	0	14m	1h 18m 20s	0	0	2523	8m 16s	4 hours ago	
kitware.com	Linux-64-gcc-8-release-shared	20170321	2m 56s	0	0	11m 45s	0	0	2528	1m 34s	4 hours ago	
kitware.com	Darwin-c++	20170321	0s	0	0	56s	0	0	0	0	54s	4 hours ago
kitware.com	Linux-64-gcc-8-m32	20170321	2m 55s	0	0	13m 49s	0	0	2528	6m 55s	4 hours ago	
kitware.com	Win32-Compiler-Debug	20170321	4m 42s	0	0	55m 7s	0	0	2404	52m 39s	2 hours ago	
kitware.com	Linux-64-gcc-8	20170321	2m 57s	0	0	16m 22s	0	0	2528	6m 55s	5 hours ago	
kitware.com	Ubuntu-gcc-6-Release-VCCompatibility	20170321	2m 54s	0	0	2h 15m 21s	0	0	2622	6m 30s	5 hours ago	
kitware.com	Ubuntu-g++-4.8.2-m64-vs-Installed	20170321	0s	0	0	2s	0	0	0	0s	5 hours ago	
kitware.com	Win32-C-Compiler-Performance	20170321	1m 57s	0	0	39m 47s	0	0	2634	2m 47s	5 hours ago	
kitware.com	Ubuntu-g++-4.8.2-Submodule-Release	20170321	46s	0	0	4m 20s	0	0	0	0s	5 hours ago	

Expected Nightly

42 of 47 builds

Peer code reviews over 3 years<sup>2</sup>

Fix-up commits before and after code review<sup>2</sup>

Nightly testing results on CDash<sup>2</sup>

1 <https://open.cdash.org/index.php?project=Insight>

2 <https://doi.org/10.3389/fninf.2014.00013>

Where has ITK been  
in the SciPy  
community?





# Initial ITK Python wrapping



Brad King



Circa 2002

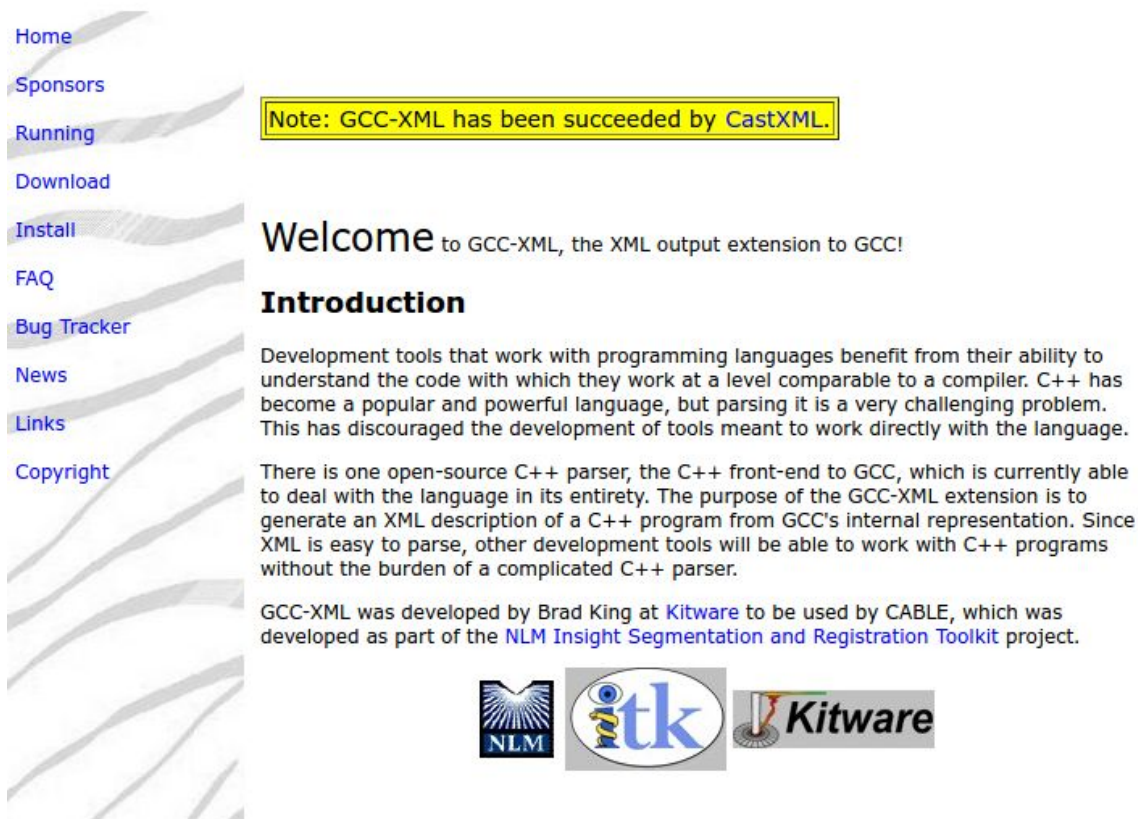


- King B., Schroeder W., Automated Wrapping of Complex C++ Code, C/C++ Users Journal, 2003

# CableSWIG and GCC\_XML

## <GCC\_XML

*description="XML output for GCC"/>*



The screenshot shows the GCC\_XML website interface. On the left is a vertical navigation menu with links: Home, Sponsors, Running, Download, Install, FAQ, Bug Tracker, News, Links, and Copyright. The main content area features a yellow-bordered note stating: "Note: GCC-XML has been succeeded by CastXML." Below this is a "Welcome" message to GCC-XML, the XML output extension to GCC. An "Introduction" section follows, explaining that development tools benefit from understanding code at a compiler level, but parsing C++ is challenging. It mentions the C++ front-end to GCC and the purpose of GCC-XML to generate XML from GCC's internal representation. The text concludes by stating GCC-XML was developed by Brad King at Kitware for the CABLE project, which is part of the NLM Insight Segmentation and Registration Toolkit.

Home  
Sponsors  
Running  
Download  
Install  
FAQ  
Bug Tracker  
News  
Links  
Copyright

**Note:** GCC-XML has been succeeded by CastXML.




**Welcome** to GCC-XML, the XML output extension to GCC!

**Introduction**

Development tools that work with programming languages benefit from their ability to understand the code with which they work at a level comparable to a compiler. C++ has become a popular and powerful language, but parsing it is a very challenging problem. This has discouraged the development of tools meant to work directly with the language.

There is one open-source C++ parser, the C++ front-end to GCC, which is currently able to deal with the language in its entirety. The purpose of the GCC-XML extension is to generate an XML description of a C++ program from GCC's internal representation. Since XML is easy to parse, other development tools will be able to work with C++ programs without the burden of a complicated C++ parser.

GCC-XML was developed by Brad King at [Kitware](#) to be used by CABLE, which was developed as part of the [NLM Insight Segmentation and Registration Toolkit](#) project.

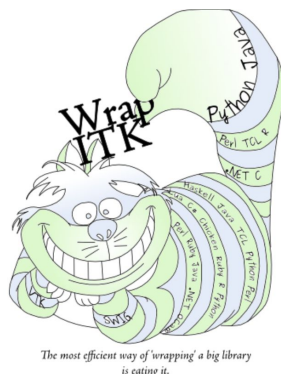
  

# Heroic efforts to improve the wrapping

## New wrapping infrastructure: WrapITK - 2008 to 2010



Gaëtan Lehmann

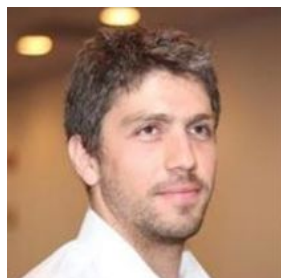


# pygccxml

- The original author is Roman Yakovenko (2004-2011).
- Forked multiple times by different authors to add Python 3 support.
- In May 2014, Michka Popoff and the Insight Software Consortium revived pygccxml.



Michka Popoff



Francois Budin



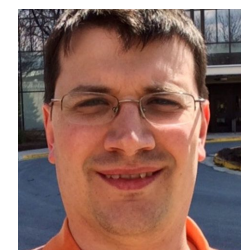
Lucas Gandel



Thomas "Hastings" Greer



Mayeul Chassagnard



Bradley Lowekamp

# Linux and Homebrew ITK Python packages



Steve Robbins



Mario Ceresa



Gianfranco  
Costamagna



Gert Wollny



Christopher  
Mullins





# Breaking down barriers: scikit-build



Omar Padron



Jean-Christophe Fillion-Robin



Mike Sarahan

June, 2017:

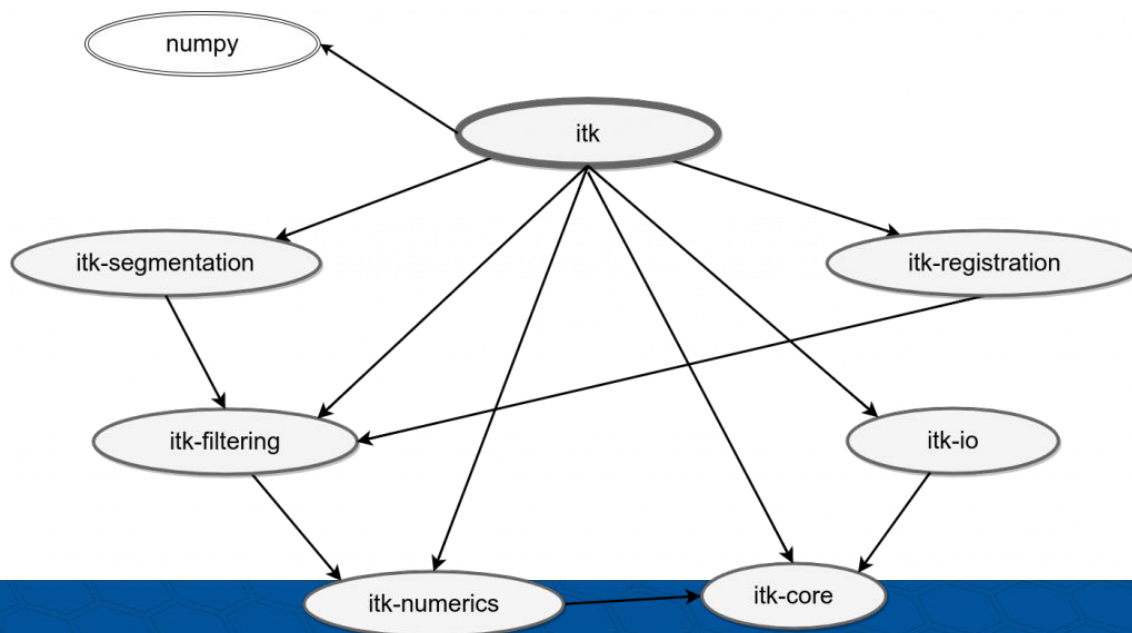


```
pip install itk
```

```
conda install -c conda-forge itk
```



Anthony Scopatz





# Python packages from ITK modules on GitHub

```
python -m pip install cookiecutter
```

```
python -m cookiecutter gh:InsightSoftwareConsortium/ITKModuleTemplate
```

```
# Fill in the information requested at the prompts
```

58 commits 14 branches 0 releases 7 contributors Apache-2.0

Branch: master New pull request Create new file Upload files Find file Clone or download

This branch is 31 commits ahead of fbudin69500:master. Pull request Compare

thetext Merge pull request #13 from thetext/ci-update Latest commit 5550842 4 hours ago

.circleci	ENH: Add cross-platform CI configurations	11 hours ago
examples	COMP: Set the minimum required CMake version to 3.10.2.	a month ago
include	ENH: Add Python wrapping	11 hours ago
test	ENH: Add Python wrapping	11 hours ago
wrapping	ENH: Add Python wrapping	11 hours ago
.travis.yml	ENH: Add cross-platform CI configurations	11 hours ago
CMakeLists.txt	COMP: Set the minimum required CMake version to 3.10.2.	a month ago
CTestConfig.cmake	ENH: Converting ITKUtils to ITK remote module.	2 years ago
LICENSE	BUG: Fix source code executable bit setting	11 hours ago
README.rst	ENH: Add setup.py	5 hours ago
appveyor.yml	ENH: Add cross-platform CI configurations	11 hours ago
itk-module.cmake	ENH: Add setup.py	5 hours ago
setup.py	ENH: Add setup.py	5 hours ago

## README.rst

### ITKFixedPointInverseDisplacementField

Linux	macOS	Windows
circleci passing	build passing	build passing

ITKFixedPointInverseDisplacementField takes a displacement field as input and computes the displacement field that is its inverse. If the input Displacement field was mapping coordinates from a space A into a space B, the output of this filter will map coordinates from the space B into the space A.

The fixed point algorithm is described in the paper:

Mingli Chen, Weiguo Lu, Quan Chen, Kenneth J. Ruchala and Gusavo H. Olivera  
"A simple fixed-point approach to invert a Displacement field",  
Medical Physics, vol. 35, issue 1, p. 81,

The FixedPointInverseDisplacementFieldImageFilter has been implemented and described in the Insight Journal article:

Luethi M.  
"Inverting Displacement fields using a fixed point iteration scheme."  
<http://hdl.handle.net/10380/3222>  
<http://www.insight-journal.org/browse/publication/768>  
October 2010.

# Python packages from ITK modules on GitHub

```
python -m pip install cookiecutter
```

```
python -m cookiecutter gh:InsightSoftwareConsortium/ITKModuleTemplate
```

```
# Fill in the information requested at the prompts
```

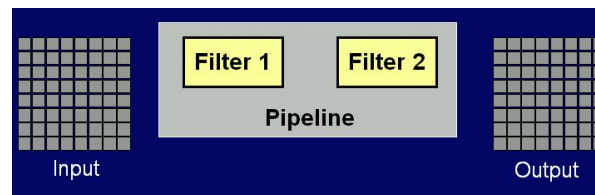
`pip install %s`

- itk-anisotropicdiffusionlbr
- itk-bonemorphometry
- itk-cuberille
- itk-isotropicwavelets
- itk-krcahsheetness
- itk-morphologicalcontourinterpolation
- itk-polartransform
- itk-ringartifact
- itk-texturefeatures
- itk-ultrasound
- itk-binarythinning3d

# Towards a more Pythonic API

Python interface reflects C++-based, object-oriented API for **pipeline streaming**:

```
median_filter = itk.MedianImageFilter[ImageType, ImageType].New()  
median_filter.SetInput(input_image)  
median_filter.SetRadius(radius)  
median_filter.Update()  
result = median_filter.GetOutput()
```

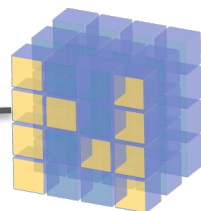
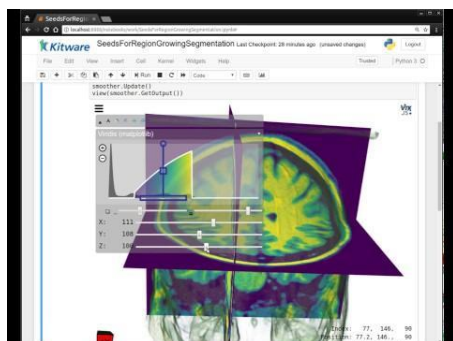


Optional, **procedural**, more Pythonic, **snake\_case** interface (ITK 5):

```
result = itk.median_image_filter(input_image, radius=radius)
```



# NumPy Bridge



NumPy

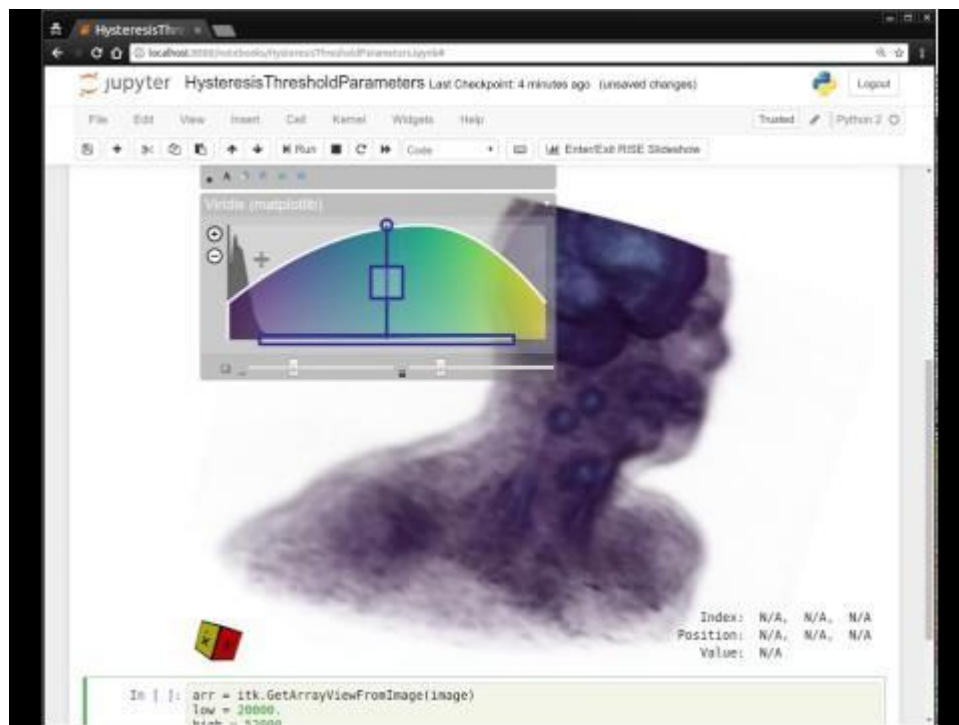
- Python Buffer Protocol
- Arrays
- Array Views



PYTORCH



# itk-jupyter-widgets



**scikit-image:** *In the context of thresholding, hysteresis means that areas above some **low** threshold are considered to be above the threshold if they are also connected to areas above a **higher**, more stringent, threshold.*





# Learn More, Get Involved!

- Jupyter Tutorial - <https://goo.gl/L1EwAf>
- ITK Software Guide - <https://itk.org/ITKSoftwareGuide/html/>
- Sphinx Examples - <https://itk.org/ITKExamples/>
- Discourse - <https://discourse.itk.org/>

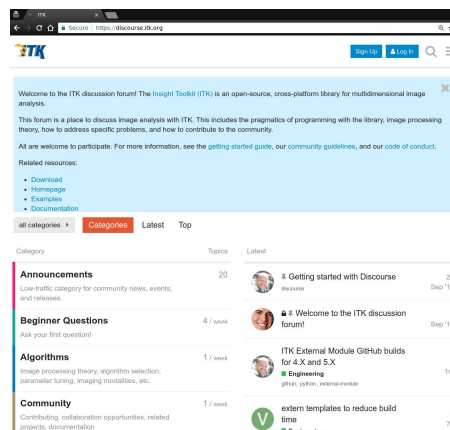


Slides: [bit.ly/scipy2018-itk-talk](https://bit.ly/scipy2018-itk-talk)

[matt.mccormick@kitware.com](mailto:matt.mccormick@kitware.com)

<https://twitter.com/thewtex>

Enjoy ITK!



 Kitware

Hans J. Johnson,  
Matt McCormick, Luis Ibáñez  
and the Insight Software Consortium

 Kitware