

SimpleITK Tutorial

Image processing for mere mortals

Insight Software Consortium

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What this Tutorial is about

- Provide working knowledge of the SimpleITK platform

Program

- Virtual Machines Preparation (10min)
- Introduction (15min)
- Basic Tutorials I (45min)
- Short Break (10min)
- Basic Tutorials II (45min)
- Coffee Break (30min)
- Intermediate Tutorials (45min)
- Short Break (10min)
- Advanced Topics (40min)
- Wrap-up (10min)

Virtual Machine Preparation

Virtual Machines Preparation

- Get DVD / USB Memory Stick
- Install VirtualBox from it
- Import the VirtualMachine file
- Boot the Virtual Machine
- Log in
- Get familiar with directories

- VirtualBoxInstallers

- VirtualBox-4.0.8-71778-OSX.dmg (Mac)
- VirtualBox-4.0.8-71778-Win.exe (Windows)
- (Ubuntu Linux)
 - virtualbox-4.0_4.0.8-71778 Ubuntu lucid_amd64.deb
 - virtualbox-4.0_4.0.8-71778 Ubuntu lucid_i386.deb
 - virtualbox-4.0_4.0.8-71778 Ubuntu maverick_amd64.deb
 - virtualbox-4.0_4.0.8-71778 Ubuntu maverick_i386.deb
 - virtualbox-4.0_4.0.8-71778 Ubuntu natty_amd64.deb
 - virtualbox-4.0_4.0.8-71778 Ubuntu natty_i386.deb
 - ...

- VirtualMachine

- SimplelTK-disk1.vmdk
- SimplelTK.ovf

Install VirtualBox

- Select the installer for your platform
- Run it

- You can also install VirtualBox by doing:
- `sudo apt-get install virtualbox-ose-qt`

Importing the Virtual Machine

- Run VirtualBox
- In File Menu select Import Appliance
- Provide the filename in the DVD / USB stick
VirtualMachine/SimpleITK.ovf
- A progress bar will appear, and when it finishes you should see:

Now, on to the
tutorial...

Introductions

- Daniel Blezek, Ph.D., Mayo Clinic
- Luis Ibáñez, Ph.D., Kitware
- Hans Johnson, Ph.D., University of Iowa
- Bradley Lowekamp, Lockheed Martin (National Library of Medicine)

Tutorial Goals

- Gentle introduction to ITK
- Introduce SimpleITK
- Provide hands-on experience
- Problem solving, not direction following
- ...but please follow directions!

How many are familiar with ITK?

Ever seen code like this?

```
1  // Setup image types.
2  typedef      float InputPixelType;
3  typedef      float OutputPixelType;
4  typedef itk::Image<InputPixelType, 2> InputImageType;
5  typedef itk::Image<OutputPixelType,2> OutputImageType;
6  // Filter type
7  typedef itk::DiscreteGaussianImageFilter<
8      InputImageType, OutputImageType >
9      FilterType;
10 // Create a filter
11 FilterType::Pointer filter = FilterType::New();
12 // Create the pipeline
13 filter->SetInput( reader->GetOutput() );
14 filter->SetVariance( 1.0 );
15 filter->SetMaximumKernelWidth( 5 );
16 filter->Update();
17 OutputImageType::Pointer blurred = filter->GetOutput();
```

What if you could write this?

```
1 import SimpleITK
2 input = SimpleITK.ReadImage ( filename )
3 output = SimpleITK.DiscreteGaussianFilter( input, 1.0, 5 )
```


What if you could write this?

```
1 import SimpleITK
2 input = SimpleITK.ReadImage ( filename )
3 output = SimpleITK.DiscreteGaussianFilter( input, 1.0, 5 )
```

We are here to tell you that you can...

Goals of SimpleITK

- Be an “on-ramp” for ITK
- Simplify the use of ITK by
 - Providing a templateless, typeless layer for ITK in C++
 - Providing wrappings in scripting languages
 - Providing access to most ITK algorithms

SimpleITK Architectural Overview

- Conceptually, SimpleITK is an application library built on ITK
- All functionality provided by ITK
- Components:
 - Template expansion system
 - C++ library
 - Small SWIG definition (more details later)
 - “Glue” code for several scripting languages
 - Some language utilities
- Open Source, Apache licensed project
(<http://www.opensource.org/licenses/apache2.0.php>)
- Hosted by GitHub (<https://github.com/SimpleITK/SimpleITK>)

Templates in ITK

```
1 typedef unsigned char PixelType;
2 enum {ImageDimension = 2};
3 typedef itk::Image<PixelType,ImageDimension> ImageType;
4 typedef itk::Vector<float,ImageDimension> VectorType;
5 typedef itk::Image<VectorType,ImageDimension> FieldType;
6 typedef itk::Image<VectorType::ValueType,ImageDimension> FloatImageType;
7 typedef ImageType::IndexType IndexType;
8 typedef ImageType::SizeType SizeType;
9 typedef ImageType::RegionType RegionType;
10 typedef itk::MultiResolutionPDEDeformableRegistration
11 <ImageType, ImageType, FieldType> RegistrationType;
```

Template Freedom

```
1 using itk::simple;
2 // Read the image file
3 ImageFileReader reader;
4 reader.SetFileName ( "/my/fancy/file.nrrd" );
5 Image image = reader.Execute();
6
7 // This filters perform a gaussian blurring with sigma in
8 // physical space. The output image will be of real type.
9 SmoothingRecursiveGaussianImageFilter gaussian;
10 gaussian.SetSigma ( 2.0 );
11 Image blurredImage = gaussian.Execute ( image );
```

Programming Models

- Object oriented
- Function oriented

More about this later

Transformed by SWIG

- Parses header and “interface” files
- Automatically creates scripting “glue”
- Wrappings available for:
 - Python
 - Java
 - C#
 - Tcl, Lua, Ruby
 - Others as requested...

Basic Tutorial

Virtual Machine Check

How are we doing with the Virtual Box images?

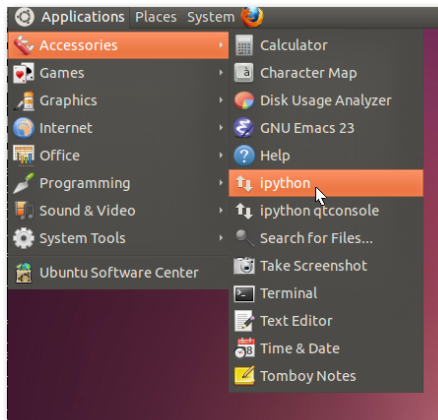
Ubuntu Introduction

- User experience oriented version of Linux
- Familiar desktop paradigm
- TODO: finish after image is ready

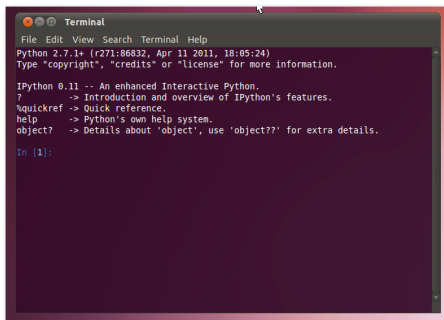
- TODO: what do we need to talk about here?

Just Enough Python to be Dangerous

- Start a terminal
- Run iPython



Just Enough Python to be Dangerous

A screenshot of a macOS Terminal window titled "Terminal". The window has a menu bar with "File", "Edit", "View", "Search", "Terminal", and "Help". The text inside the terminal shows the output of running Python 2.7.1+, followed by the IPython 0.11 startup banner. The banner includes a list of shortcuts: '?' for introduction, %quickref for quick reference, 'help' for Python's help system, and 'object?' for details about the 'object' type. The prompt "In [1]:" is visible at the bottom.

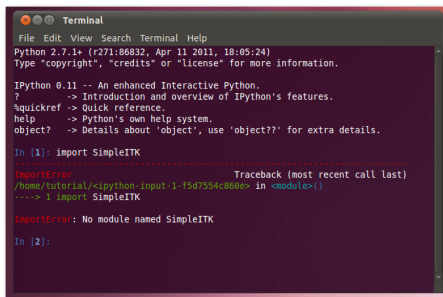
```
Python 2.7.1+ (r271:86832, Apr 11 2011, 18:05:24)
Type "copyright", "credits" or "license" for more information.

IPython 0.11 -- An enhanced Interactive Python.
?              -> Introduction and overview of IPython's features.
%quickref      -> Quick reference.
help           -> Python's own help system.
object?       -> Details about 'object', use 'object??' for extra details.

In [1]:
```

Just Enough Python to be Dangerous

Import the SimpleITK package

A terminal window titled "Terminal" with a menu bar (File, Edit, View, Search, Terminal, Help). The prompt is "Python 2.7.1+ (r271:86832, Apr 11 2011, 18:05:24)". It shows the IPython 0.11 prompt and help text. The user enters "In [1]: import SimpleITK", which results in a red "ImportError" message: "Traceback (most recent call last): /home/tutorial/cipython-input-1-f5d7554c800e in <module>() ----> 1 import SimpleITK ImportError: No module named SimpleITK". The prompt then shows "In [2]:".

```
Terminal
File Edit View Search Terminal Help
Python 2.7.1+ (r271:86832, Apr 11 2011, 18:05:24)
Type "copyright", "credits" or "license" for more information.

IPython 0.11 -- An enhanced Interactive Python.
?                -> Introduction and overview of IPython's features.
%quickref        -> Quick reference.
help             -> Python's own help system.
object?         -> Details about 'object', use 'object??' for extra details.

In [1]: import SimpleITK
-----
ImportError                               Traceback (most recent call last)
/home/tutorial/cipython-input-1-f5d7554c800e in <module>()
----> 1 import SimpleITK

ImportError: No module named SimpleITK

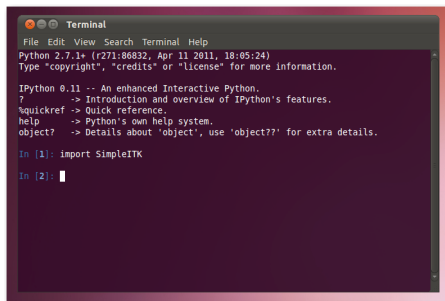
In [2]:
```

What just happened?

Just Enough Python to be Dangerous

Need to tell iPython where to find SimpleITK

See `/home/tutorial/.ipython/ipython.py`

A screenshot of a terminal window titled "Terminal" with a menu bar (File, Edit, View, Search, Terminal, Help). The terminal shows the output of running Python 2.7.1+, followed by the IPython 0.11 startup banner. The banner lists shortcuts: ? for introduction, %quickref for quick reference, help for Python's help system, and object? for details about 'object'. The user enters two commands: `In [1]: import SimpleITK` and `In [2]:` followed by a cursor.

```
Terminal
File Edit View Search Terminal Help
Python 2.7.1+ (r271:86832, Apr 11 2011, 18:05:24)
Type "copyright", "credits" or "license" for more information.

IPython 0.11 -- An enhanced Interactive Python.
?      -> Introduction and overview of IPython's features.
%quickref -> Quick reference.
help    -> Python's own help system.
object? -> Details about 'object', use 'object??' for extra details.

In [1]: import SimpleITK

In [2]:
```

- Creation
- Number of dimensions, size, origin, spacing
- Pixel access

Back to iPython ([Examples/BasicTutorial1/Image.py](#))

What just happened?

```
1 # Create an image
2 image = sitk.Image ( 256, 256, 256,
3                       sitk.sitkInt16 );
4 # How about 2d?
5 twoD = sitk.Image ( 64, 64,
6                     sitk.sitkFloat32 )
```

- sitk is the module
- Image is the constructor for the Image class
- Height, width, depth (omit depth for 2D images)
- Datatype (more on this later)

Back to iPython ([Examples/BasicTutorial1/Image.py](#))

What just happened?

```
1 # Addressing pixels
2 image.GetPixel ( 0, 0, 0 )
3 image.SetPixel ( 0, 0, 0, 1 )
4 image.GetPixel ( 0, 0, 0 )
```

- Get the voxel value at [0,0,0]?
- Hmm, I don't like it, so set to 1
- What is the value at [0,0,0] now?

Back to iPython (Examples/BasicTutorial1/Image.py)

What just happened?

```
1 # Addressing pixels
2 image[0,0,0]
3 image[0,0,0] = 10
4 image[0,0,0]
```

Without warning, we sprinkled syntactic sugar on you!

- `image[0,0,0]` is shorthand for `Image.GetPixel(0,0,0)`
- `image[0,0,0] = 10` is shorthand for `Image.SetPixel(0,0,0,1)`

Summary

- Images are created using `SimpleITK.Image (w, h, d, Type)`
- Images can be 2- or 3-dimensional
- Images can describe themselves
- Images have simple pixel accessors

Questions before we move on?

Memory Management

Images...

- usually allocated on the stack
- are copy-on-write
- use internal smart-pointers

Back to `iPython (Examples/BasicTutorial1/MemoryManagement.py)`

Image Memory Management

```
1 image = SimpleITK.Image ( 32, 32, 32, SimpleITK.sitkInt16 )
2 print image
3 ...
4 Image (0x94f2d98)
5   Reference Count: 1
6 ...
7 # Clone image
8 b = SimpleITK.Image ( image )
9 print image
10 ...
11 Image (0x94f2d98)
12   Reference Count: 2
13 ...
14 print b
15 ...
16 Image (0x94f2d98)
```

Image Memory Management

```
1 print b
2 ...
3 Image (0x94f2d98)
4 ...
5 b[0,0,0] = 1
6 print b
7 ...
8 Image (0x94f4cb0)
9   Reference Count: 1
10 ...
11 print image
12 ...
13 Image (0x94f2d98)
14   Reference Count: 1
15 ...
```


Filters...

- usually allocated on the stack
- tend to clean up after themselves
- do not hold on to images

...more on this later...

Memory Management Strategies

C++...

- No need for explicit management
- Let images clean up after themselves
- Let filters clean up after themselves

Wrapped...

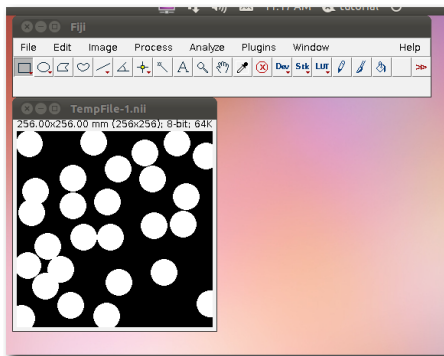
- Utilize language-specific memory management
- Automatic in Python, Java, Ruby, C#, Lua
- More manual in Tcl

Input/Output

Read/Write/Display Images

Back to iPython (`Examples/BasicTutorial1/InputOutput.py`)

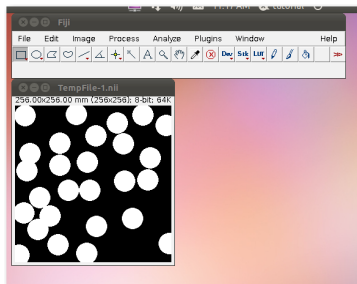
Display



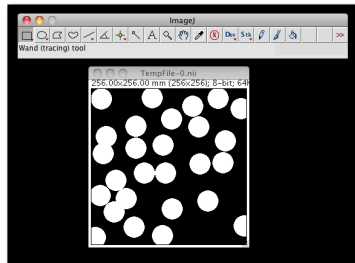
What just happened?

```
1 # What's the image look like?
2 sitk.Show ( image )
```

Display



Ubuntu



Mac

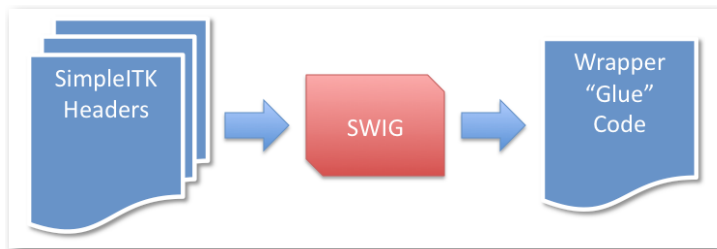
- ImageJ/Fiji used for display
- SimpleITK looks in most likely location for ImageJ
- Image written in Nifti format
- Need to install Nifti plugin for ImageJ
- <http://rsbweb.nih.gov/ij/plugins/nifti.html>

Questions/Break

Basic Tutorial 2

Wrapped Languages

Wrapping Process



- SimpleITK headers are constructed for wrapping
- SWIG is an open source package
 - Parses C/C++ code, produces “glue” code
 - Well supported, covers 10+ languages
- Main languages: Python, Java, C#
- Also supported: Tcl, Lua, R

Object Paradigm (Python)

The paradigms translate to the wrapped languages (C++ \rightarrow Python)

```
1 #include <SimpleITK.h>
2 using itk::simple;
3 ...
4 // Create a smoothing filter
5 SmoothingRecursiveGaussianImageFilter gaussian;
6 // Set a parameter
7 gaussian.SetSigma ( 2.0 );
8 // "Execute" the Filter
9 Image blurredImage = gaussian.Execute ( image );
```

```
1 from SimpleITK import *
2 # Create a smoothing filter
3 SmoothingRecursiveGaussianImageFilter gaussian
4 # Set a parameter
5 gaussian.SetSigma ( 2.0 );
6 # "Execute" the Filter
7 blurredImage = gaussian.Execute ( image );
```

Object Paradigm (Java)

```
1 import SimpleITK.*;
2 ...
3
4 // Create a smoothing filter
5 SmoothingRecursiveGaussianImageFilter gaussian =
6     new SmoothingRecursiveGaussianImageFilter();
7
8 // Set a parameter
9 gaussian.SetSigma ( 2.0 );
10
11 // "Execute" the Filter
12 Image blurredImage = gaussian.Execute ( image );
```

Object Paradigm (C#)

```
1 using System;
2 using itk.simple;
3 ...
4 // Create a smoothing filter
5 SmoothingRecursiveGaussianImageFilter gaussian =
6     new SmoothingRecursiveGaussianImageFilter();
7
8 // Set a parameter
9 gaussian.SetSigma ( 2.0 );
10
11 // "Execute" the Filter
12 Image blurredImage = gaussian.Execute ( image );
```

Note on the Tutorial

- Most examples will be Python
- Obvious translation to other languages
- C++ usage (generally) obvious

Hands On

What just happened?

```
1 # Simple smoothing
2 smooth = SimpleITK.SmoothingRecursiveGaussian ( image, 2.0 )
3 SimpleITK.Show ( SimpleITK.Subtract ( image, smooth ) )
4 ...
5 RuntimeError: Exception thrown in SimpleITK Subtract: ...
6 sitk::ERROR: Both images for SubtractImageFilter don't match type or dimension!
7 ...
```

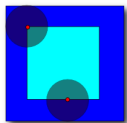
- The output of SmoothingRecursiveGaussian is of type float
- The input image is signed short
- Most SimpleITK filters with 2 inputs require the same type
- Let's fix the problem

Introducing Cast

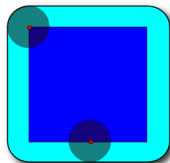
```
1 # Much better
2 smooth = SimpleITK.Cast ( smooth, image.GetPixelIDValue() )
3 print image.GetPixelIDTypeAsString()
4 print smooth.GetPixelIDTypeAsString()
5 SimpleITK.Show ( SimpleITK.Subtract ( image, smooth ) )
```

Morphology

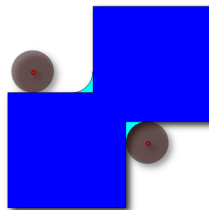
Operators



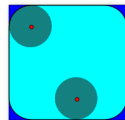
Erosion



Dilation



Closing



Opening

Images from

http://en.wikipedia.org/wiki/Mathematical_morphology

Back to iPython

Label Maps

Let's take a break

True utility of SimpleITK

- Interacting with data

Image Statistics

Label Statistics

Pixel-wise Operators

Table: SimpleITK Pixel-wise Operators

Operator	Description	Usage [†]
+	Addition	$A + B, s + A, s + B$
-	Subtraction	$A - B, s - A, s - B$
*	Multiplication	$A * B, s * A, s * B$
/	Division	$A/B, s/A, B/s$
&	Logical “and”	$A \& B$
	Logical “or”	$A B$
	Logical “not”	$\neg A$

[†] A and B are images (2D or 3D), s is a scalar

Masking

Edge Detection

Threshold-based Segmentation

Building SimpleITK in 5 Easy Commands

```
git clone --recursive https://github.com/SimpleITK/SimpleITK
( cd SimpleITK && git checkout va01 )
mkdir SimpleITK-build && cd SimpleITK-build
cmake ../SimpleITK/SuperBuild
make -j 5
```

More complete version

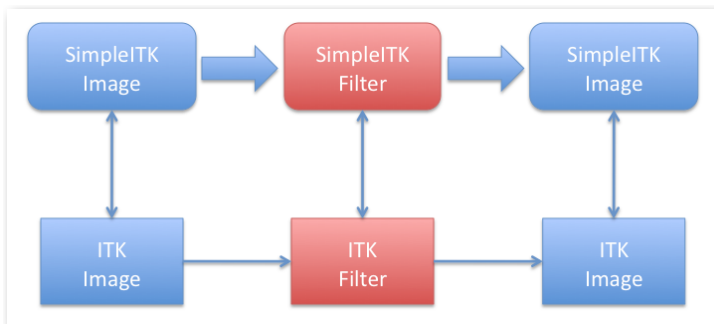
- Check out the code from GitHub
(<https://github.com/SimpleITK/SimpleITK>)
- Run CMake (<http://www.cmake.org/>) using SimpleITK/SuperBuild as the source directory
- Build using your favorite compiler

Supported Platforms

- Windows: Visual Studio 10
- Windows: Visual Studio 9 (Requires TR1 service pack)
- Mac OSX: gcc 4.x
- Linux: gcc 4.x

SimpleTK Architecture

Filter Anatomy



- SimpleITK filters create ITK filters
- Templated based on input type
- Output type is usually the same as input type
- Instantiated for many possible image types

Image and Filter Types

- Dimensions

- 2 dimensional
- 3 dimensional

- Scalar types

- *int8_t*
- *uint8_t*
- *int16_t*
- *uint16_t*
- *int32_t*
- *uint32_t*
- *float*
- *double*
- *std :: complex < float >*
- *std :: complex < double >*

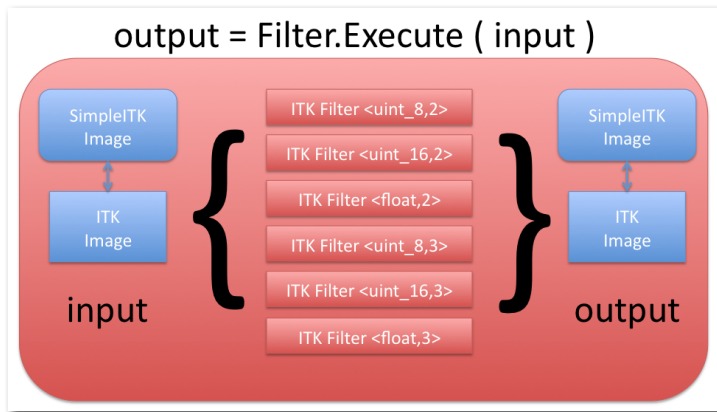
- Vector Types

- *int8_t*
- *uint8_t*
- *int16_t*
- *uint16_t*
- *float*
- *double*

- Label Types

- *uint8_t*
- *uint16_t*
- *uint32_t*

Filter Anatomy



- Filter interrogates *input*
- Instantiates proper ITK filter
- Executes ITK filter
- Constructs *output* from ITK image

Using Filters

Object Paradigm (C++)

```
1 #include <SimpleITK.h>
2 namespace sitk = itk::simple;
3 ...
4 // Create a smoothing filter
5 sitk::SmoothingRecursiveGaussianImageFilter gaussian;
6
7 // Set a parameter
8 gaussian.SetSigma ( 2.0 );
9
10 // "Execute" the Filter
11 sitk::Image blurredImage = gaussian.Execute ( image );
```

Object Paradigm (C++)

Flexibility

```
1 #include <SimpleITK.h>
2 namespace sitk = itk::simple;
3 ...
4 // Create a smoothing filter
5 sitk::SmoothingRecursiveGaussianImageFilter gaussian;
6
7 // Set parameter(s), then execute
8 sitk::Image blurredImage = gaussian
9                               .SetSigma ( 2.0 )
10                               .Execute ( image );
```

Object Paradigm (C++)

```
1 #include <SimpleITK.h>
2 namespace sitk = itk::simple;
3 ...
4 blurredImage = sitk::SmoothingRecursiveGaussianImageFilter()
5                 .SetSigma ( 2.0 )
6                 .SetRadius ( 5 )
7                 .Execute ( image );
```

One line: create anonymous filter, set parameters, and execute

“Function” Paradigm (C++)

```
1 #include <SimpleITK.h>
2 namespace sitk = itk::simple;
3 ...
4 // Call the function version
5 // NB: Drop the "ImageFilter"!
6 // Signature:
7 /*
8     sitk::Image SmoothingRecursiveGaussian (
9         const Image&,
10         double inSigma = 1.0,
11         bool inNormalizeAcrossScale = false );
12 */
13 sitk::Image blurredImage = sitk::SmoothingRecursiveGaussian (
14     image,
15     2.0,
16     false );
```

Mix & Match (C++)

```
1 #include <SimpleITK.h>
2 namespace sitk = itk::simple;
3 ...
4 // Get our gaussian ready
5 sitk::SmoothingRecursiveGaussianImageFilter gaussian;
6 gaussian.SetSigma ( 2.0 );
7
8 // What is the effect on the image
9 sitk::Image difference = sitk::Subtract (
10     image,
11     gaussian.Execute ( image )
12 );
13 sitk::Image difference2 = sitk::Subtract (
14     image,
15     sitk::SmoothingRecursiveGaussian (
16     image, 2.0
17     )
18 );
```

Code Philosophy

Filter Class Overview (C++)

```
1 class SmoothingRecursiveGaussianImageFilter :  
2     public ImageFilter {  
3     typedef SmoothingRecursiveGaussianImageFilter Self;  
4  
5     /** Default Constructor that takes no arguments  
6     and initializes default parameters */  
7     SmoothingRecursiveGaussianImageFilter();
```

- In line 1, we declare a subclass of ImageFilter
- Line 3 creates a special typedef for use later
- The default constructor is line 7 (never any parameters)

Filter Class Overview (C++) Continued

```
1  /** Define the pixels types supported by this filter */  
2  typedef BasicPixelIDTypeList  PixelIDTypeList;
```

- Notice *PixelIDTypeList* in line 2
- Used to instantiate ITK filters
- Determines valid input image types
- *BasicPixelIDTypeList* expands to:
 - *int8_t, uint8_t*
 - *int16_t, uint16_t*
 - *int32_t, uint32_t*
 - *float, double*

Filter Class Overview (C++) Continued

```
1 Self& SetSigma ( double t ) { ... return *this; }
2 double GetSigma() { return this->m_Sigma; }
3
4 Self& SetNormalizeAcrossScale ( bool t ) { ... }
5 Self& NormalizeAcrossScaleOn() { ... }
6 Self& NormalizeAcrossScaleOff() { ... }
7
8 bool GetNormalizeAcrossScale() { ... }
```

- Get/Set parameters
- Set methods always return *Self&* (more later)
- Generally, a direct mapping to ITK
- Boolean parameters generate *On* and *Off* methods

Filter Class Overview (C++) Continued

```
1  /** Name of this class */  
2  std::string GetName() const { ... }  
3  
4  /** Print ourselves out */  
5  std::string ToString() const;
```

- Return the name and description of the filter

Filter Class Overview (C++) Continued

```
1  /** Execute the filter on the input image */
2  Image Execute ( const Image & );
3
4  /** Execute the filter with parameters */
5  Image Execute ( const Image &,
6      double inSigma,
7      bool inNormalizeAcrossScale );
8  }; /* End of class SmoothingRecursiveGaussian */
9
10 Image SmoothingRecursiveGaussian ( const Image& ,
11     double inSigma = 1.0,
12     bool inNormalizeAcrossScale = false );
```

- Run the filter on an image and return the result
- Notice extra function (line 10), adds flexibility
- Drop *ImageFilter* from class name to get function name

Questions?

Using ITK with SimpleITK

Problem: Use ITK from SimpleITK (or vice versa)

```
./ToITK input.nii output.nii
```

Steps:

- Load image using SimpleITK
- Filter using ITK
- Save using OpenCV

Starting code: ToITK/ToITK.cxx

Directory:

SimpleITK-MICCAI-2011-Tutorial/Examples/AdvancedTutorial

```
1 namespace sitk = itk::simple;
2 ...
3 // Load the image via SimpleITK
4 sitk::Image sitkImage = sitk::ReadImage ( inputFilename );
5
6 // Construct the ITK Pipeline
7 // Link pipeline to SimpleITK
8 // Update pipeline
9 // Create output SimpleITK image
10 // Save image via SimpleITK
11 sitk::WriteImage ( sOutput, outputFilename );
12 return EXIT_SUCCESS;
```

ToITK – Step 1: Construct the ITK Pipeline

```
1 // Construct the ITK Pipeline
2 typedef itk::Image<float,3> ImageType;
3 typedef itk::MirrorPadImageFilter<ImageType,ImageType> PadFilterType;
4 PadFilterType::SizeType upperBound, lowerBound;
5
6 PadFilterType::Pointer pad = PadFilterType::New();
7 for ( unsigned int i = 0; i < 3; i++ )
8 {
9     upperBound[i] = sitkImage.GetSize()[i];
10    lowerBound[i] = sitkImage.GetSize()[i];
11 }
12 pad->SetPadUpperBound ( upperBound );
13 pad->SetPadLowerBound ( lowerBound );
```

ToITK – Step 2: Link pipeline to SimpleITK

```
1 // Link pipeline to SimpleITK
2 ImageType::Pointer inputImage = (ImageType*) sitkImage.GetImageBase();
3 pad->SetInput ( inputImage );
```

ToITK – Step 3: Update ITK Pipeline

```
1 // Update pipeline
2 pad->Update();
```

ToITK – Step 4: Create the SimpleITK output image

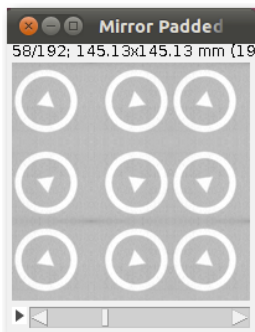
```
1 // Create output SimpleITK image
2 sitk::Image sOutput ( pad->GetOutput() );
```

ToITK – (Optional) Step 5: Show

```
1 // (Optional) Show the results
2 sitk::Show ( sOutput );
```


To ITK Solution

```
~/Source/AdvancedTutorial-build/ToITK/ToITKSolution \  
~/Source/SimpleITK/Testing/Data/Input/RA-Float.nrrd \  
/tmp/foo.nii
```



To OpenCV

Problem: Use SimpleITK from another image processing library (OpenCV)

`./ToOpenCV input.png output.png`

Steps:

- Load image using SimpleITK
- Convert to OpenCV
- Filter using OpenCV
- Save using OpenCV

Starting code: ToOpenCV/ToOpenCV.cxx

Directory:

SimpleITK-MICCAI-2011-Tutorial/Examples/AdvancedTutorial

```
1  #include <SimpleITK.h>
2  #include <opencv2/opencv.hpp>
3  namespace sitk = itk::simple;
4  ...
5      sitk::Image sitkImage = sitk::ReadImage ( inputFilename );
6
7      // Convert SimpleITK to OpenCV image
8      cv::Mat ocvImage;
9
10     // Filter and write using OpenCV
11     cv::Mat output;
12     cv::medianBlur ( ocvImage, output, 5 );
13
14     cv::imwrite ( outputFilename, output );
15     ...
```

Convert the SimpleITK image to a float

```
1  if ( sitkImage.GetPixelIDValue() != sitk::sitkFloat32 )
2  {
3      std::cout << "Input image is " << sitkImage.GetPixelIDTypeAsString()
4              << " converting to float" << std::endl;
5      sitkImage = sitk::Cast ( sitkImage, sitk::sitkFloat32 );
6  }
```

Get SimpleITK pixel data

```
1 // Convert SimpleITK to OpenCV image
2 cv::Mat ocvImage ( sitkImage.GetHeight(), sitkImage.GetWidth(), CV_32F,
3   (void*)sitkImage.GetBufferAsFloat() );
```

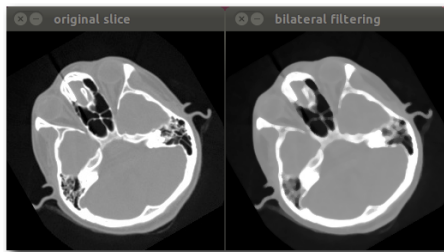
ToOpenCV – Step 3 (Optional)

Display the before and after

```
1 // NB: the imshow function requires 8-bit data, so convert
2 cv::Mat temp;
3 cvImage.convertTo ( temp, CV_8U );
4 cv::imshow ( "original slice", temp );
5 output.convertTo ( temp, CV_8U );
6 cv::imshow ( "bilateral filtering", temp );
7
8 std::cout << "Press any key to continue" << std::endl;
9 cv::waitKey();
```

To OpenCV Solution

```
~/Source/AdvancedTutorial-build/ToOpenCV/ToOpenCV \  
~/Source/SimpleITK/Testing/Data/Input/cthead1.png \  
/tmp/head.png
```



To OpenCV and Back

Problem: Use OpenCV to process a SimpleITK volume slice-by-slice
`./ToOpenCVAndBack input.nii output.nii`

Steps:

- Load image using SimpleITK
- Extract slice
- Convert to OpenCV
- Filter using OpenCV
- Past slice back to SimpleITK
- Save result

To OpenCV and Back

Starting code: ToOpenCVAndBack/ToOpenCVAndBack.cxx

Directory:

SimpleITK-MICCAI-2011-Tutorial/Examples/AdvancedTutorial

```
1  namespace sitk = itk::simple;
2  ...
3  sitk::Image sitkImage = sitk::ReadImage ( inputFilename );
4
5  for ( unsigned int s = 0; s < sitkImage.GetDepth(); s++ )
6  {
7      // Extract a slice
8      // Go through ITK to grab the data
9      // Convert ITK to OpenCV image
10     // Filter using OpenCV
11     // Convert back to SimpleITK
12     // Paste the image back into SimpleITK
13 }
14 sitk::WriteImage ( sOutput, outputFilename );
```

To OpenCV and Back - Step 1: Extract a slice

```
1 // Extract a slice
2 std::vector<unsigned int> size = sitkImage.GetSize();
3 size[2] = 1;
4 std::vector<int> index ( 3, 0 );
5 index[2] = s;
6 std::cout << "Extracting: " << s << std::endl;
7 sitk::Image slice = sitk::RegionOfInterest ( sitkImage, size, index );
8
9 if ( slice.GetPixelIDValue() != sitk::sitkFloat32 )
10 {
11     slice = sitk::Cast ( slice, sitk::sitkFloat32 );
12 }
```

To OpenCV and Back - Step 2: Convert to OpenCV

```
1 // Convert ITK to OpenCV image
2 cv::Mat ocvImage ( slice.GetHeight(), slice.GetWidth(),
3                   CV_32F, (void*)sitkImage.GetBufferAsFloat() );
```

To OpenCV and Back - Step 3: Filter using OpenCV

```
1 // Filter using OpenCV
2 cv::Mat output;
3 cv::Sobel ( ocvImage, output, -1, 1, 1 );
```

To OpenCV and Back - Step 4: Back to SimpleITK

```
1 // Convert back to SimpleITK
2 sitk::ImportImageFilter importer;
3 importer.SetSize ( size );
4 importer.SetSpacing ( sitkImage.GetSpacing() );
5 importer.SetOrigin ( sitkImage.GetOrigin() );
6 importer.SetBufferAsFloat ( output.ptr<float>() );
7
8 sitk::Image toSimpleITKImage = importer.Execute();
```

To OpenCV and Back - Step 5: Paste back into SimpleITK volume

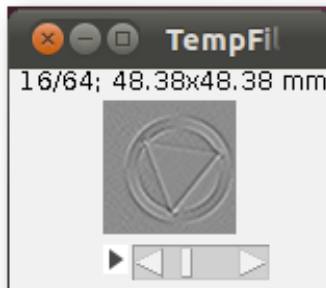
```
1 // Paste the image back into SimpleITK
2 // Paste ( Destination, Source, SourceSize, SourceIndex, DestIndex )
3 sOutput = sitk::Paste ( sOutput, toSimpleITKImage,
4                       toSimpleITKImage.GetSize(), std::vector<int> ( 3,0 ), index );
```

To OpenCV and Back – (Optional) Step 6: Show

```
1 // (Optional) Show the results
2 sitk::Show ( sOutput );
```

To OpenCV and Back Solution

```
~/Source/AdvancedTutorial-build/\  
ToOpenCVAndBack/ToOpenCVAndBack \\  
~/Source/SimpleITK/Testing/Data/Input/RA-Float.nrrd \  
/tmp/foo.nii
```



- Gentle introduction to ITK
- Introduce SimpleITK
- Provide hands-on experience
- Problem solving, not direction following

Where to go next

Some resources for using and extending SimpleITK

- Documentation
<http://erie.nlm.nih.gov/~blowek1/SimpleITK/pages.html>
- Conventions
<http://erie.nlm.nih.gov/~blowek1/SimpleITK/Conventions.html>
- Contributions
<http://erie.nlm.nih.gov/~blowek1/SimpleITK/Developer.html>

SimpleITK Tutorial

Image processing for mere mortals

Insight Software Consortium

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