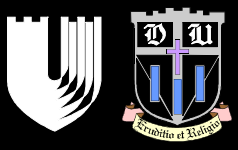
ImageJ: Open Source Imaging Solutions for Radiology



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11/29/2009

Disclosures

- My lab has a research contract for imaging core lab activities with Bristol-Meyers Squibb
- We also do software evaluation for GE Medical Systems
- None of the software discussed is FDA approved for clinical use
- I don't program C or Java, for that matter

Objectives

1. Understand the capabilities of ImageJ and how this software can be used to learn about and perform image analyses.
2. Learn how data on image DICOM headers can be used to tailor image analyses.
3. Understand how macro language scripts and plug-ins can extend the capabilities of ImageJ.

How can ImageJ help me?

- ImageJ is not:
  - A PACS substitute
  - A 3D imaging workstation substitute
- ImageJ is:
  - A platform to learn about and develop image processing solutions in a research environment
    - *Low-cost*, *automated* and *flexible*
    - *Easy to deploy*

Outline

- Introduction
- Basic moves
- Extending ImageJ
- Image processing tasks
- Deployment advantages for ImageJ
- How is ImageJ being used?

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Introduction

- Use of proprietary software has distinct disadvantages
  - Slow to evolve
  - Inflexible
  - Expensive
- Open source software will become an increasingly important part of the open science environment

Introduction

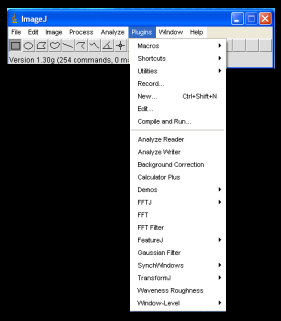
- New emphasis on deriving quantitative data from imaging sequences – "quantitative radiology"
- Transcending the limited worldview of PACs

ImageJ

- Wayne Rasband, NIH
- Multiple applications including microscopy, gels, astronomy, and medical imaging
- http://rsb.info.nih.gov/ij
- "Free"
- J is for Java
  - Works on multiple platforms: Mac, PCs, Unix

ImageJ

- Open source
  - Active collaborators world-wide
- Plug-in structure
  - Can add new commands
- Supports macros
  - Can automate program
- Can save regions-of-interest



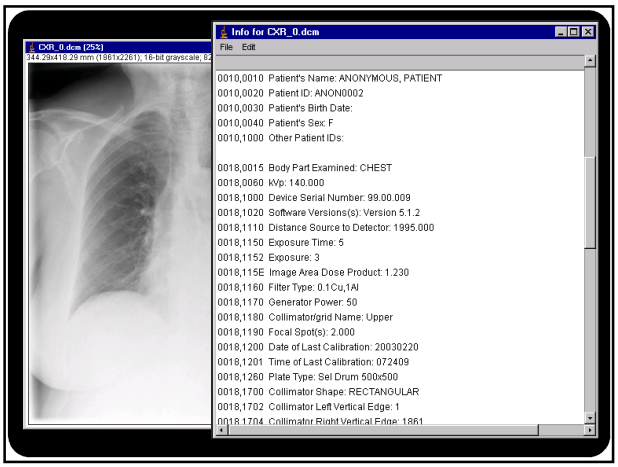
ImageJ

- Software is about …. People
- Beyond Rasband
  - Mailing list
  - Documentation wiki: http://imagejdocu.tudor.lu/doku.php
  - Meetings
  - Alternative versions
    - ImageJA applet: http://imageja.sourceforge.net/
    - Fiji (Fiji is Just ImageJ): http://pacific.mpi-cbg.de/wiki/index.php/Main_Page


http://imagejdocu.tudor.lu/doku.php?id=fotos:ijconf2008:group

ImageJ for medical applications

- Wide variety of input and output files
  - TIFF, BMP, JPG, Analyze , **NifTI, UNC, DICOM**
- Reads DICOM header metadata
- Can measure, save data in formats appropriate for Excel spreadsheets or statistical programs
- Can handle series of images
  - 3D "stacks", 4D and 5D imaging
- Make your desktop computer into a "workstation-lite"



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Basic moves

- Opening the program
- The interface
- Opening an image
- Window/level
- Measuring things
- Stacks

Basic moves

- ROIs, masks and binary images
- Image math
  - Simple, logarithmic, Boolean
- Image calculator
  - Addition, subtraction, Boolean

Example: Putting it together for DWI

- Calculate ADCs
- $S = S_0 \cdot e^{(-b\,ADC)}$
- $ADC = (\ln(S_0/S))/b$
- Radiology standard, ADC measured in 10^{-3} mm^2/sec
- If $b = 1000$ sec/mm^2, then $ADC_{radiology} = \ln(S_0/S)$.

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Extending ImageJ

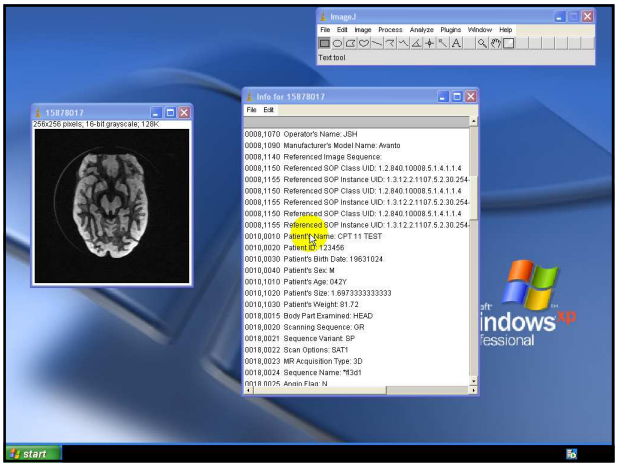
- Problem: image processing schemes generally require multiple steps.
  - How do we help the human analyst perform these efficiently and reproducibly?
- Automation
- Documentation
  - "establish provenance"

An extensible solution

- Java-language plug-in structure used to add functions
- Java libraries (e.g. Java Matrix Package JAMA http://math.nist.gov/javanumerics/jama/)
- Macros – examples
  - Macro recorder – built-in functions and many plug-ins are recordable
  - Macro language

Dealing with DICOM

- Opening DICOM images/series
- Extracting DICOM header information
- Import by DICOM image number
- Make subdirectories based on DICOM header data
- Anonymize DICOM images

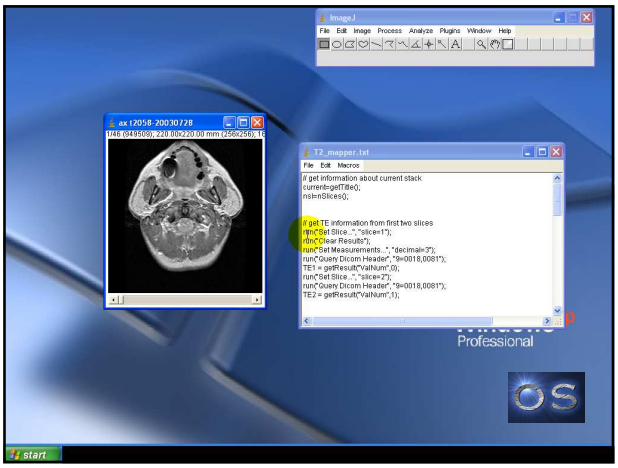


Creating tailored applications

- Why have tailored applications? Image analysis techniques may need to change depending on image parameters such as:
  - Equipment used
  - Acquisition parameters
  - Patient characteristics
- Macro scripts + DICOM header information allows tailoring

Macro

- Macros and plug-ins are even more powerful if analyses can be tailored to data on the DICOM header!
- Example: calculating T2 maps
  - In spin-echo MRI, signal intensity is proportional to $e^{-T2/TE}$
  - If you have a dual-echo T2-WI, can estimate $T2 = (TE_2-TE_1)/\ln(S_1/S_2)$



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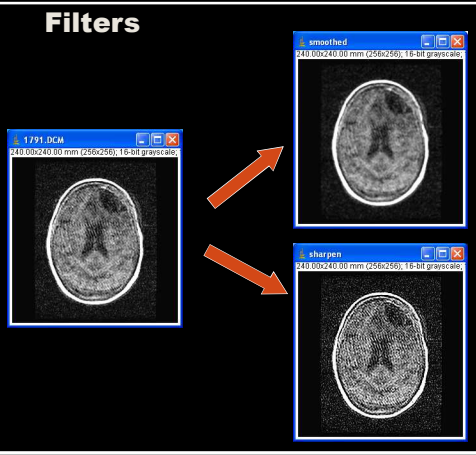
Basic tasks of image processing

- Filtration
- Segmentation
- Registration
- Display

Filters

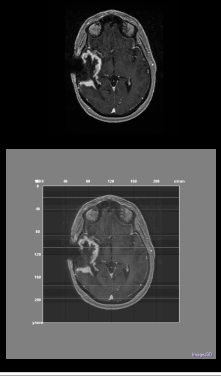


Filtration

- Gaussian smoothing, sharpening
- Median filters
- Edge-preserving filtration – anisotropic diffusion filtering

Segmentation

- Simple thresholding
- Maximum entropy, isodata, mixture modelling, Otsu thresholding
- Watershed segmentation, segmentation by k-means clustering
- Level-set segmentation

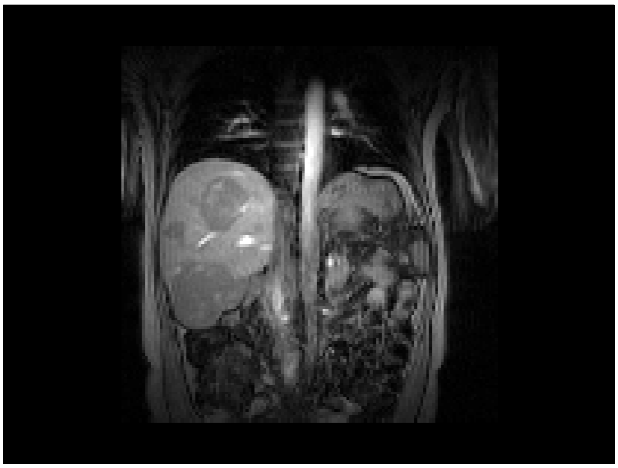


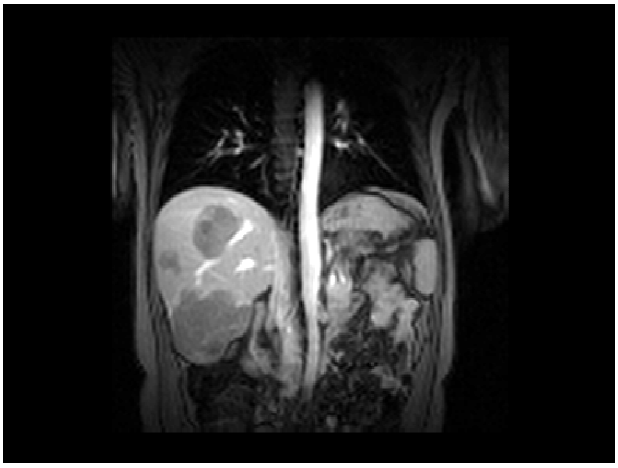
Registration

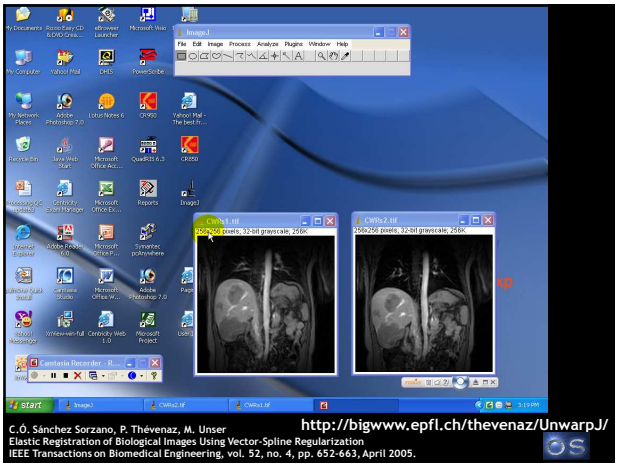
- Two-dimensional image registration supported by several plug-ins
- Three-dimensional image registration is beginning to be developed
- Non-linear spline-based registration

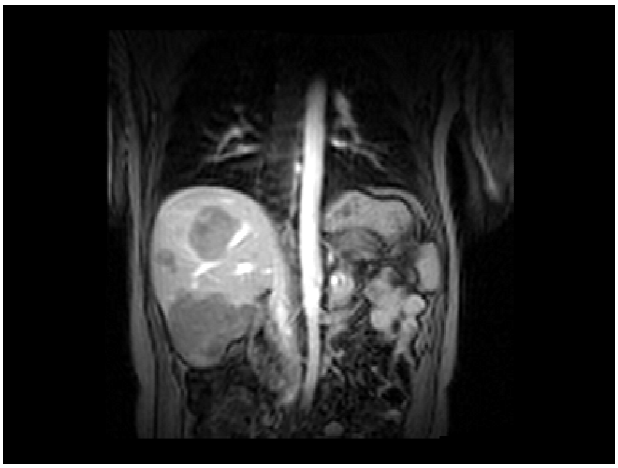
3D and 4D image analysis

- 3D spatial scaling and affine transformations supported by plug-in
- 3D erosion and dilation
- Windowed sinc and Kalman filtering on time series





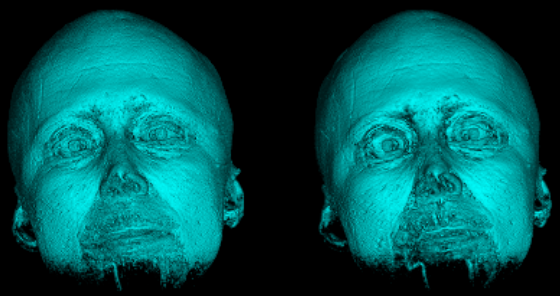




Display

- Multi-pane interface
- Relatively good viewers for 3D stacks
- Highly evolved browsers for 4D and 5D stacks
- Volume rendering, surface rendering and stereoscopic display available

Display



Data: http://www.sph.sc.edu/comd/rorden/render.html
Analysis: VolumeJ, http://bij.isi.uu.nl/index.htm

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Deployment advantages

- Runs anywhere
- Inexpensive in $
- Inexpensive in expertise
- Whole package: image processing, analysis and display
- Open source design makes ImageJ more easily *evolvable* and *correctable* than many proprietary packages

Deployment advantages

- What kind of image analysis problem are you dealing with?
- Who are your users?
- What kind of equipment and support do they have?
- A translational tool

Advanced ImageJ

- ImageJ can be run from the web as a signed or unsigned applet, or as an application
- Can be used to create web based applicatons
- Can be used by other applications
- Early efforts to use ImageJ as a PACS node: http://imagejdocu.tudor.lu/doku.php?id=plugin:inputoutput:the_tudor_dicom_toolkit:start

ImageJ – summary of capabilities

- Filtration – Good
- Segmentation – Good
- Registration – Fair
- Display – Fair to good
- Workstation – Fair to good

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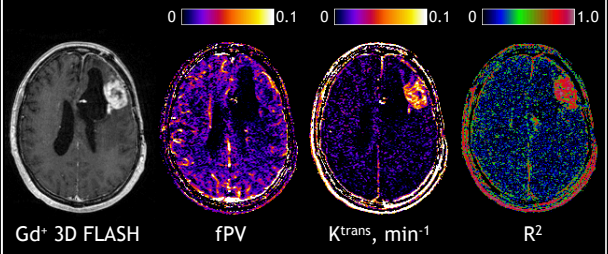
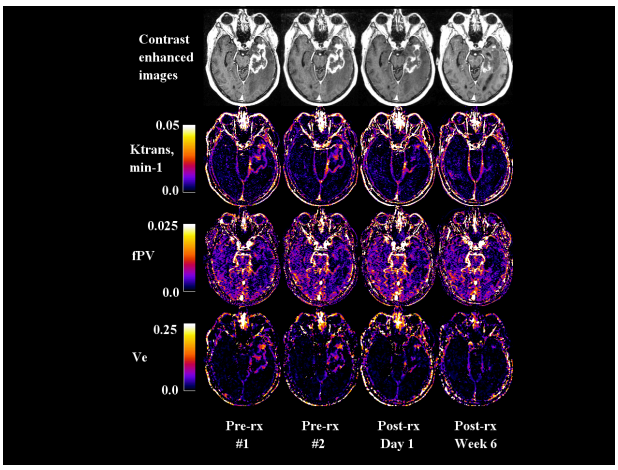
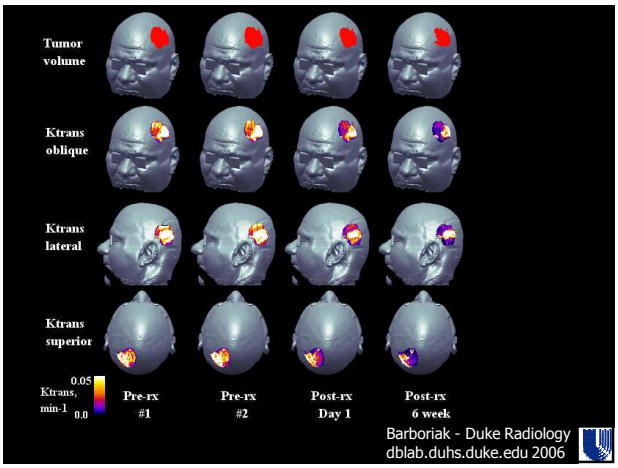
How are we using ImageJ?

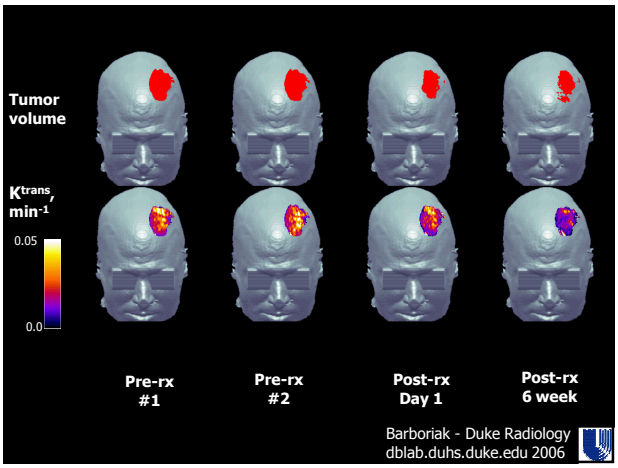
- Tumor segmentation
- Image conversion
- Perfusion and diffusion MR image analysis on 4D image sets
  - TOPPCAT (T1-weighted perfusion parameter calculating toolkit)
  - JDTI (Diffusion tensor imaging in Java)
  - DSCoMAN (Dynamic Susceptibility Contrast MR Analysis)
  - http://dblab.duhs.duke.edu
- Error checking
- Software verification

TOPPCAT





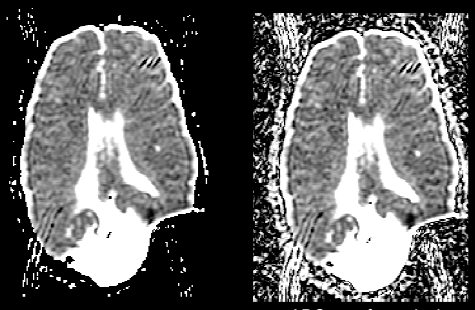




JDTI – http://dblab.duhs.duke.edu

Example of a 25 direction tensor sequence

JDTI – http://dblab.duhs.duke.edu



ADC map from scanner

ADC map from plugin

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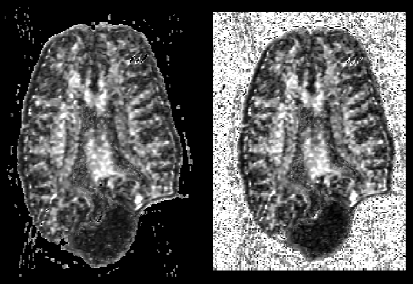


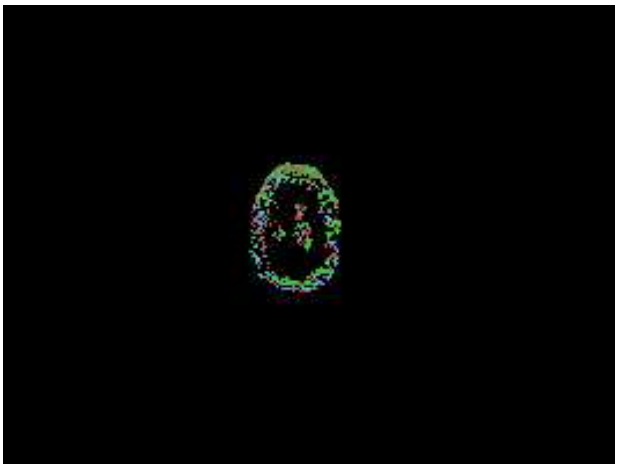
FA map from scanner

FA map from plugin

Red =
Right to Left

Green =
Ant to Post

Blue =
Sup to Inf



Summary

- Macro language + access to DICOM header data is a powerful combination
- ImageJ has a unique place as a translational medical image processing tool within the open source and open science paradigm

Finding out more about ImageJ

- ImageJ website at: http://rsb.info.nih.gov/ij/
- Documentation wiki at: http://imagejdocu.tudor.lu/doku.php

References

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- Barboriak DP, Padua AO, York GE, MacFall JR. Creation of DICOM--aware applications using ImageJ. J Digit Imaging. 2005 Jun;18(2):91-9.

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Acknowledgements

- ImageJ – Wayne Rasband, NIH and the ImageJ open source community