ImageJ and the SciJava software stack

Curtis Rueden, LOCI Software Architect
https://loci.wisc.edu/software

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Motivation

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Motivation

- Stand on each others' shoulders

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Motivation

- Stand on each others' shoulders

- Discover new knowledge

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Motivation

- Stand on each others' shoulders

- Discover new knowledge

- Improve the human condition

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Computers help studies

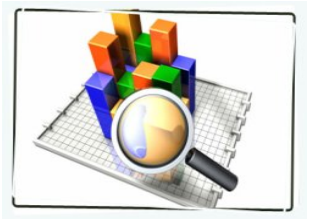
LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Computers help studies

- Quantitative research



LOCI

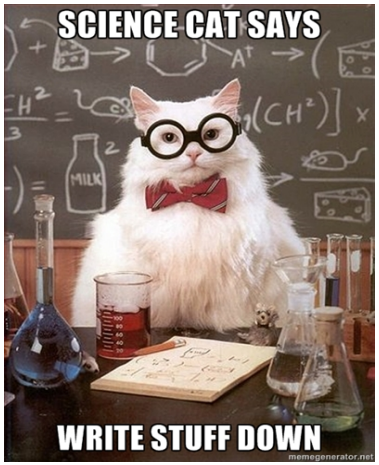
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Computers help studies

- Quantitative research

- Keep track of everything



LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Computers help studies

- Information provenance
  - Remember what you did
  - Remember how you did it

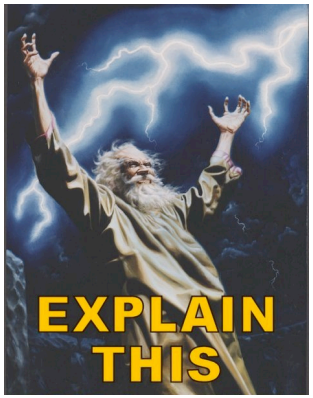
LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Computers help studies

- Information provenance
  - Remember what you did
  - Remember how you did it
  - Explain it to someone else



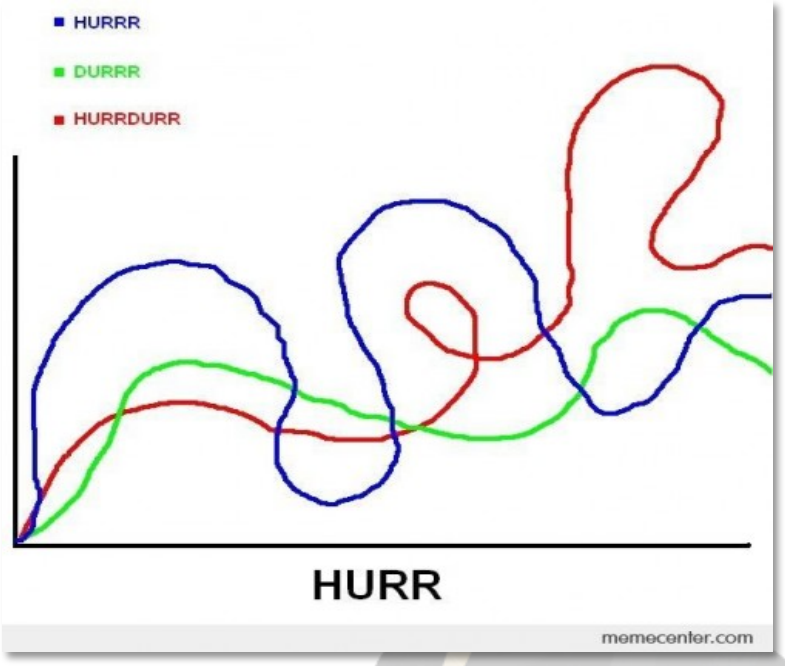
LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Computers help studies

- Information provenance
  - Remember what you did
  - Remember how you did it
  - Explain it to someone else
- Reproducibility
  - Verify or invalidate others' work



LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Computers help share

- The Internet makes sharing easy
  - Wikipedia: public encyclopedia
  - Stack Exchange: public Q & A
  - GitHub: public source control
  - Facebook: public socializing
  - Google: public etc.

"When in doubt, make it public."
—Jeff Atwood (co-creator of Stack Overflow)

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Computers help share

- Publish a compendium, not just a result
  - Protocols & methodology
  - Raw data
  - Computer code

"An article about computational science in a scientific publication is not the scholarship itself, it is merely advertising of the scholarship."
—David Donoho, "Wavelab and Reproducible Research," 1995

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Why share?

- Reproducibility demands the source code

Science Code Manifesto

Code	All source code written specifically to process data for a published paper must be available to the reviewers and readers of the paper.
Copyright	The copyright ownership and license of any released source code must be clearly stated.
Citation	Researchers who use or adapt science source code in their research must credit the code's creators in resulting publications.
Credit	Software contributions must be included in systems of scientific assessment, credit, and recognition.
Curation	Source code must remain available, linked to related materials, for the useful lifetime of the publication.

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

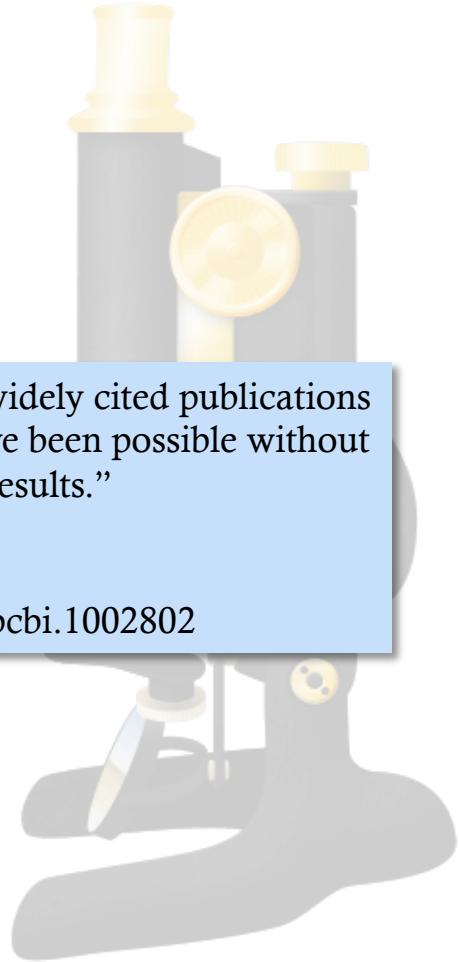
http://sciencecodemanifesto.org/

Open Science

Why share?

- Reproducibility demands the source code
- It is good for your career anyway

"Papers describing software published as open source are amongst the most widely cited publications (e.g., BLAST, and Clustal-W), suggesting many scientific studies may not have been possible without some kind of open software to collect observations, analyze data, or present results."
—Andreas Prlić & James Procter
"Ten Simple Rules for the Open Development of Scientific Software"
http://www.ploscompbiol.org/article/info%3Adoi%2F10.1371%2Fjournal.pcbi.1002802



LOCI

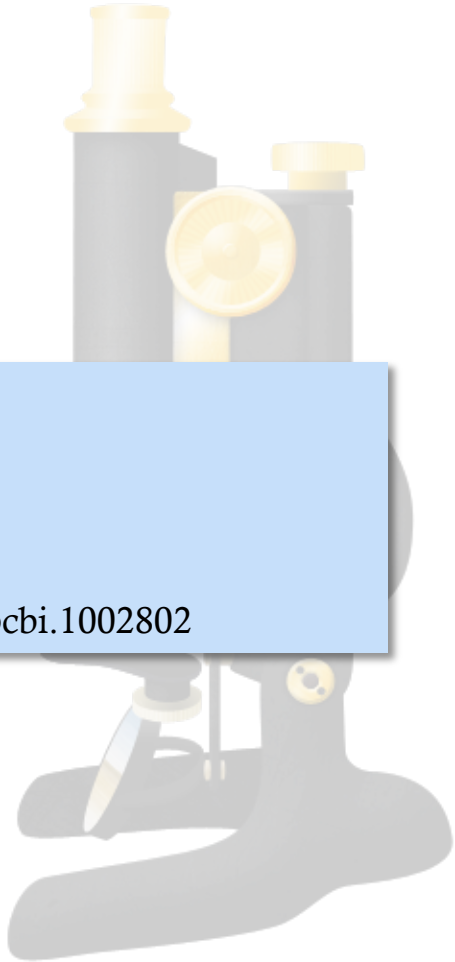
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Why share?

- Reproducibility demands the source code
- It is good for your career anyway

> "Science is hard enough already."
>
> —Andreas Prlić & James Procter
> "Ten Simple Rules for the Open Development of Scientific Software"
> http://www.ploscompbiol.org/article/info%3Adoi%2F10.1371%2Fjournal.pcbi.1002802



LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Beyond open results

- Source code itself is just an open result

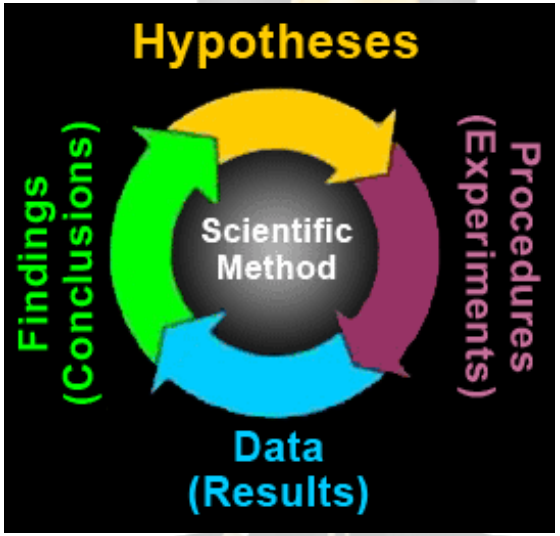
LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Open Science

Beyond open results

- Source code itself is just an open result
- We can do better!
  - Open development ***process***
  - Improve software as a community
  - Open access resources
  - Responsive, reliable maintainers
  - Powerful collaboration tools (GitHub!)



LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Why ImageJ2?

Strengths

- What's so great about ImageJ?

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Why ImageJ2?

Strengths

- What's so great about ImageJ?
  - Extensibility

What are the strengths of ImageJ in your opinion? [09/2010]

It is intuitive and easy to use.	20%	(29)
It can handle all image formats I am working with.	12%	(17)
It can be used on almost all platforms.	13%	(18)
It is easy to automate ImageJ.	11%	(16)
Its plug-in structure gives me the flexibility to adapt it to my needs.	44%	(62)

LOCI

Why ImageJ2?

Weaknesses

- What's so great about ImageJ?
  - Extensibility
- What else is needed?
  - Modularity
  - Interoperability

What are the strengths of ImageJ in your opinion? [09/2010]

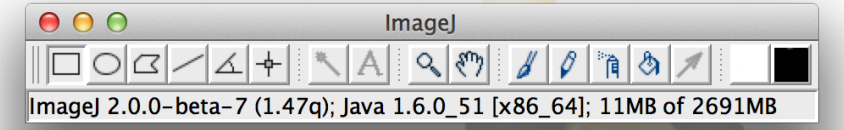
It is intuitive and easy to use.	20%	(29)
It can handle all image formats I am working with.	12%	(17)
It can be used on almost all platforms.	13%	(18)
It is easy to automate ImageJ.	11%	(16)
Its plug-in structure gives me the flexibility to adapt it to my needs.	44%	(62)

LOCI

ImageJ2

What is ImageJ2?

- ✓ A standalone application



LOCI

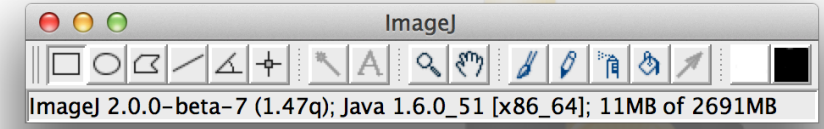
WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

http://imagej.net/

ImageJ2

What is ImageJ2?

- ✓ A standalone application



- ✓ A reusable library

```
/** Loads and displays a dataset using the ImageJ API. */
public void loadAndDisplay(final File file) throws Exception {
  // create the ImageJ application context with all available services
  final ImageJ ij = new ImageJ();

  // load the dataset
  final Dataset dataset = ij.io().loadDataset(file.getAbsolutePath());

  // display the dataset
  ij.ui().show(dataset);
}
```

LOCI

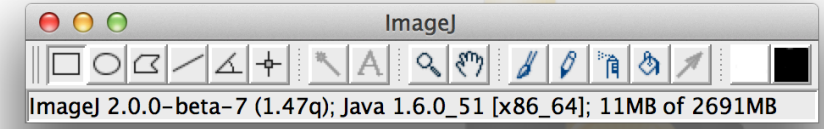
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/

ImageJ2

What is ImageJ2?

- ✓ A standalone application



- ✓ A reusable library

```
/** Loads and displays a dataset using the ImageJ API. */
public void loadAndDisplay(final File file) throws Exception {
  // create the ImageJ application context with all available services
  final ImageJ ij = new ImageJ();

  // load the dataset
  final Dataset dataset = ij.io().loadDataset(file.getAbsolutePath());

  // display the dataset
  ij.ui().show(dataset);
}
```

- ✓ An extensible collection of services & plugins

SciJava

LOCI

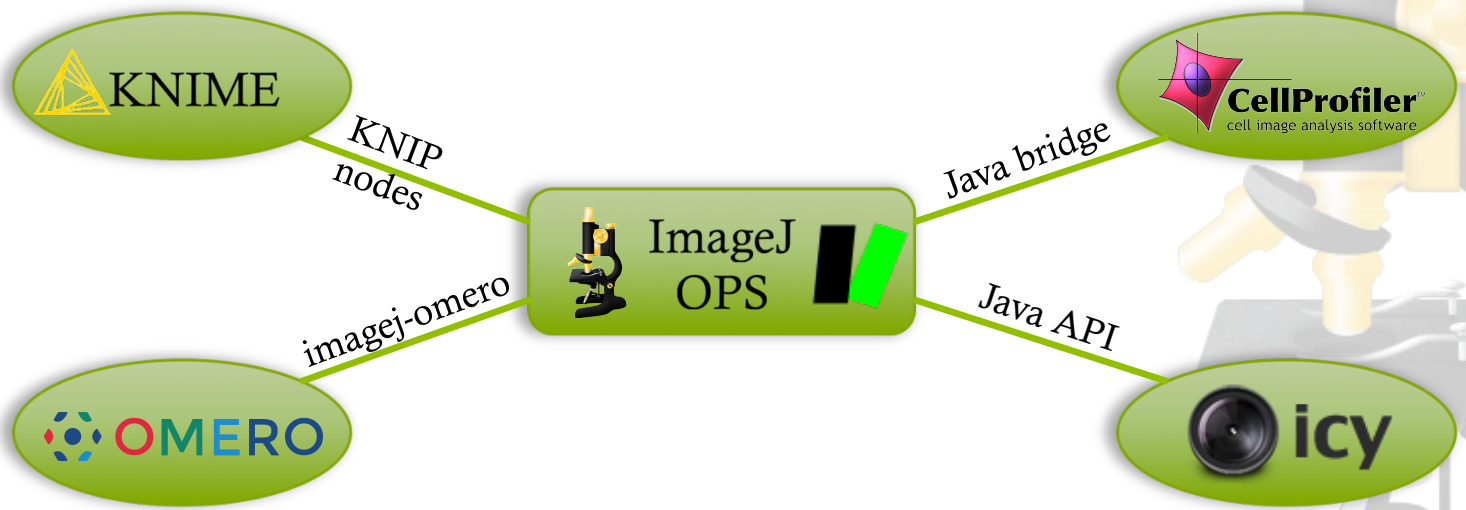
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/

ImageJ2

What is ImageJ2?

- ✓ A framework for image processing routines



LOCI

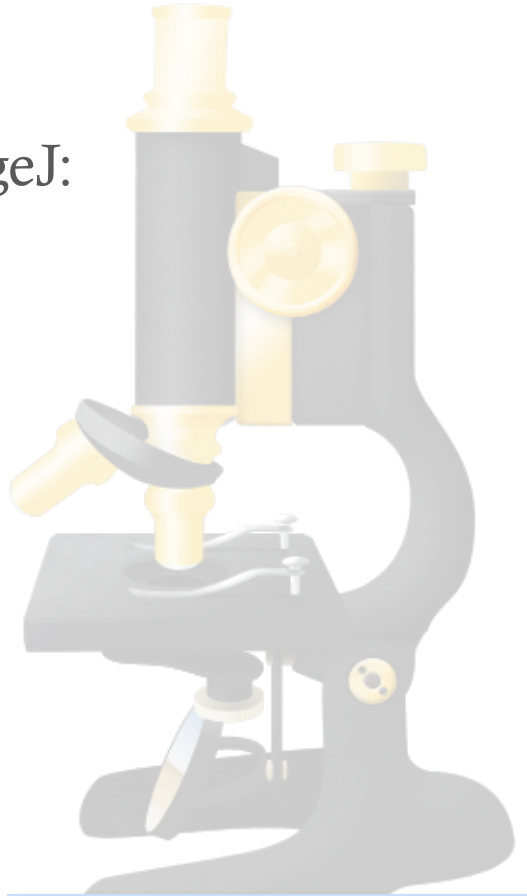
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/

ImageJ2

Technical

- An effort to overcome the constraints of ImageJ:
  - A new, supremely extensible plugin framework
  - Dimensions beyond X, Y, Z, time and channel
  - Planes larger than 2 gigapixels
  - Pixel types beyond uint8, uint16 and float32
  - Access data beyond only files on disk
  - Beyond one user, one desktop, one machine



LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/

ImageJ2

Social

- A hub for worldwide development efforts
- Central documentation resource & support
- A distributed network of >100 update sites extending ImageJ's capabilities
- A focus on interoperability & collaboration

Mission of ImageJ2

- Lead ImageJ development with a clear vision
- Create the next version of ImageJ, based on the needs of the community
- Collaborate with others whenever beneficial
- Make ImageJ useful to a broad community
- Maintain backwards compatibility with ImageJ1
- Provide a central online resource for ImageJ

LOCI

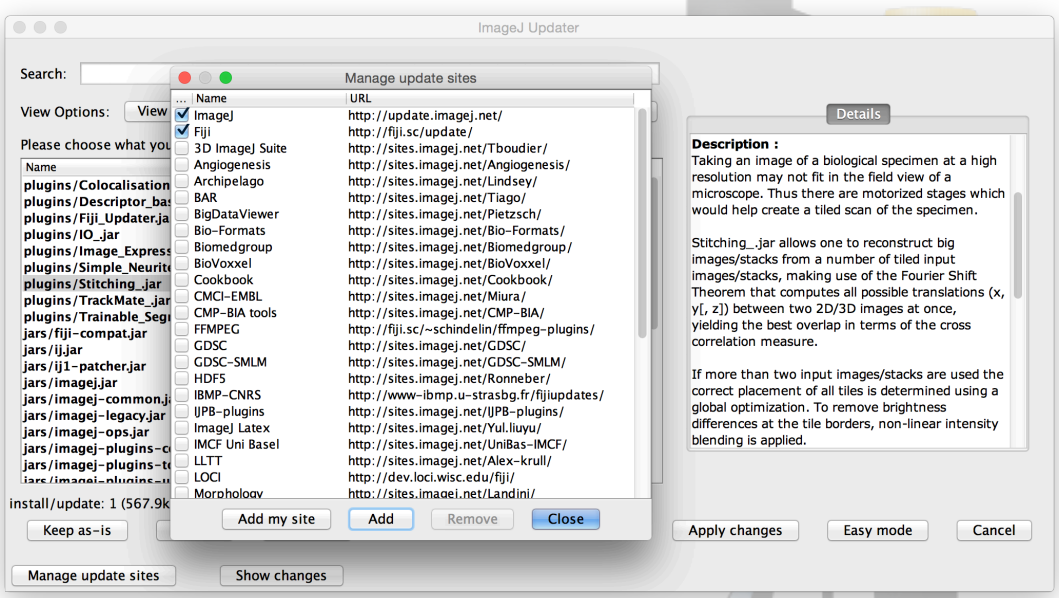
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/

ImageJ2

Features

- ImageJ Updater
  - Install new plugins in a few clicks
  - Automatically receive software updates
  - Distribute your own plugins on an update site



LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/Updater

ImageJ2

Features

- Improved image I/O with the SCIFIO library
  - SCientific Image Format Input and Output
  - "Write once, run anywhere" for image formats
  - ImageJ2 uses SCIFIO for image input tasks
  - Toggle behavior in the ImageJ2 options menu

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/SCIFIO

ImageJ2

Features

- A new era of image processing with ImageJ OPS
  - Extensible, powerful and high performance
  - "Write once, run anywhere" for image processing algorithms
  - N-dimensional images built on the powerful ImgLib2 library

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/OPS

ImageJ2

Features

- Supreme extensibility with the SciJava library
  - *Modules*: parameterized commands and scripts
    - Interoperable across many applications; e.g.:
      - ImageJ, KNIME, CellProfiler, OMERO
  - *Plugins*: versatile extension points
    - Each plugin type is a tool for a particular job
    - Easily define new plugin types as needed
    - ImageJ2 and SCIFIO are both plugin-driven

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/SciJava

ImageJ2

Compatibility

- ImageJ2 includes ImageJ version 1.x
  - ImageJ 1.x features continue to work via ImageJ2's legacy user interface plugin
  - New features of ImageJ 1.x developed by Wayne Rasband also work in this way
  - Users can "mix and match" the capabilities of ImageJ 1.x and ImageJ2

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/ImageJ1

ImageJ2

Fiji

- Fiji Is Just ImageJ
  - A distribution of ImageJ for the life sciences
  - A community of ImageJ developers
  - Built on the ImageJ2 platform
  - Includes over 700 additional commands

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://fiji.sc/

SCIFIO

Summary

- Built on the ImageJ2 metadata model
  - N-dimensional data, backed by ImgLib2
- Reads 30 formats, writes 11 formats
- Integration with Bio-Formats
- Integration with ITK

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://scif.io/

SCIFIO

Mission

- A framework for metadata exchange
- Evolved from the Bio-Formats project, but more general in scope with many lessons learned
- The Open Microscopy Environment's OME-XML schema is already implemented
- Other data models are equally feasible

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://scif.io/

SciJava

Social

- A collaboration of projects providing software for scientific computing
- A pledge to cooperate and reuse code

http://scijava.org/

SciJava

Technical

- SciJava Common – a shared platform
  - Plugin framework
  - Application container
  - Module framework
  - Scripting framework
  - Utility classes
- Guideline: functionality unspecific to images

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://scijava.org/

SciJava

Technical

- A shared development paradigm
  - Open source and open process
  - Project management tools
    - Maven & Nexus
    - Git & GitHub
    - Jenkins
  - A structure enabling two developers to maintain ~300 source code repositories!

http://imagej.net/Architecture

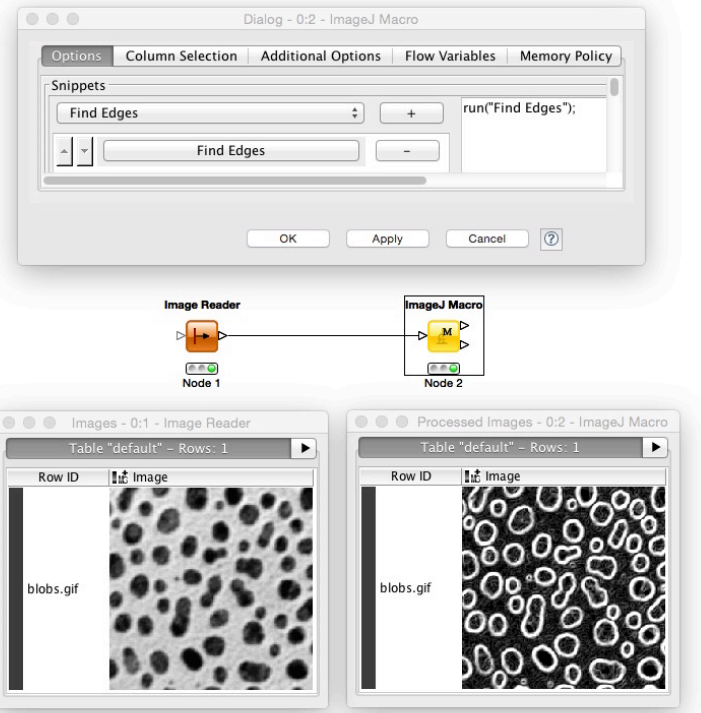
LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

SciJava

KNIME

- KNIME, the KoNstanz Information MinEr, has an Image Processing extension integrating KNIME with SciJava, ImageJ and SCIFIO
- Any headless SciJava module, including all ImageJ OPS plugins, can be embedded in a KNIME workflow as KNIME nodes



LOCI

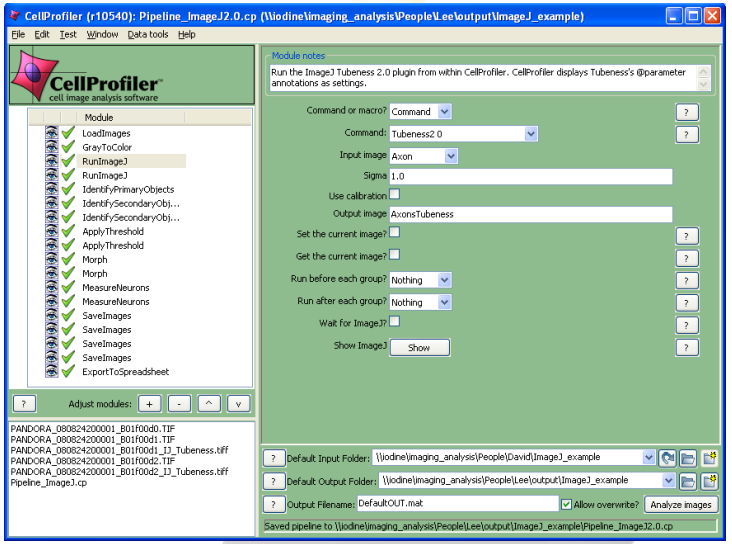
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://knime.imagej.net/

SciJava

CellProfiler

- The Broad Institute's CellProfiler supports execution of SciJava modules from a CellProfiler pipeline
- CellProfiler also integrates support for Bio-Formats via a Python-Java bridge



LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://cellprofiler.org/

SciJava

OMERO

- The OMERO database stores and manages life sciences images in a unified way
- The ImageJ-OMERO project can:
  - Download pixels from OMERO into ImageJ
  - Upload images as new OMERO data
  - Execute SciJava modules as OMERO scripts on the server side

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

http://imagej.net/OMERO

Acknowledgements


Kevin Eliceiri

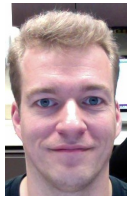

Jason Swedlow


Pavel Tomancak


Anne Carpenter


Michael Berthold


Mark Hiner

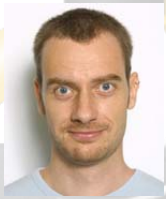

Johannes Schindelin


Christian Dietz


Lee Kamentsky


Tobias Pietzsch


Stephan Preibisch


Stephan Saalfeld

And everyone supporting open science and open software!

LOCI

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON