Learn More

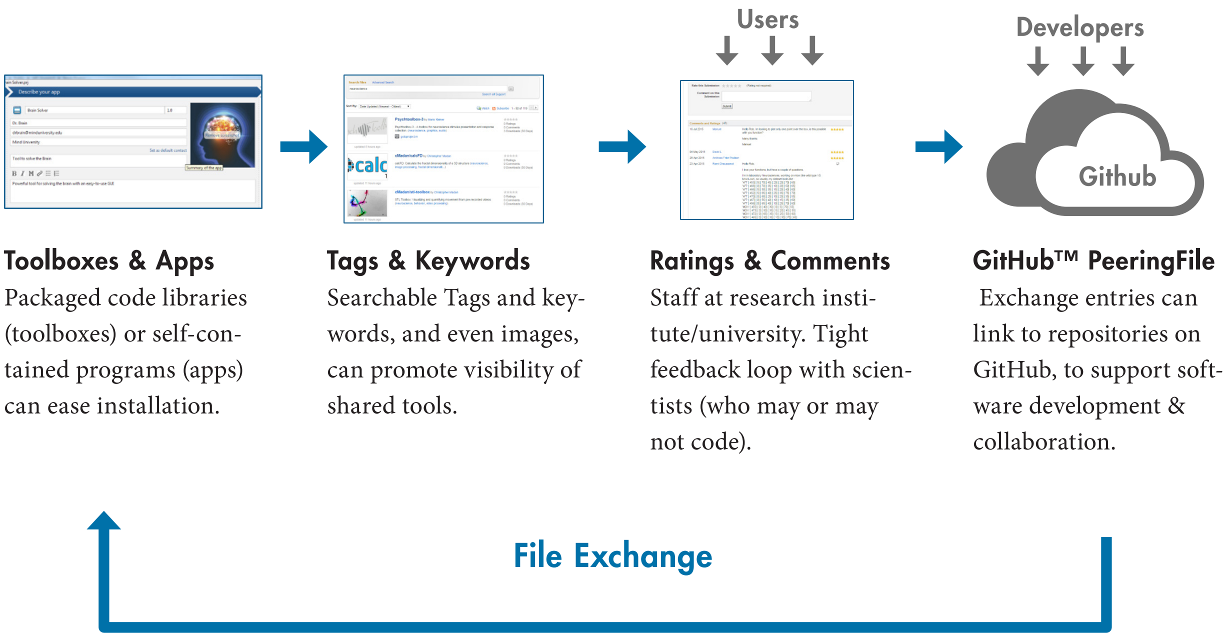
Neuroscience Research Software: Tool Development, Collaboration, and Sharing

Vijay Iyer, Paul Kassebaum, and Lisa Kempler

Introduction

Neuroscientists depend on shared software tools, specialized for their research. Such software must be developed by domain experts or developers closely linked to the science and the scientific community. Yet growing software projects also need software engineering practices, often unfamiliar to scientific developers, to manage complexity, collaboration, and change. A software authoring platform focused on science, with research-level software engineering capabilities, can promote robust tools and resilient tool communities driven by domain experts.

Community Tool Cycle



Toolboxes & Apps
Packaged code libraries (toolboxes) or self-contained programs (apps) can ease installation.

Tags & Keywords
Searchable Tags and keywords, and even images, can promote visibility of shared tools.

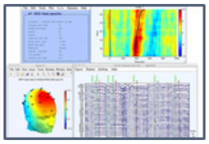
Ratings & Comments
Staff at research institute/university. Tight feedback loop with scientists (who may or may not code).

GitHub™ PeeringFile
Exchange entries can link to repositories on GitHub, to support software development & collaboration.

Community Tool Examples — Highlights from File Exchange

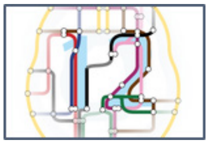
Brain Mapping

BrainStorm
Open source application for MEG/EEG data analysis



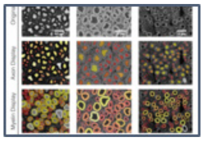
EEGLAB
Widely used toolbox for processing electrophysiological data

FieldTrip
The MATLAB software toolbox for MEG and EEG analysis

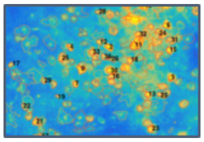


SPM
Free and open source software for the analysis of brain imaging data sequences

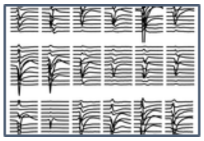
Cellular Neuroscience



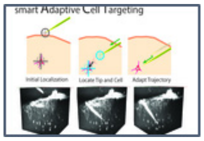
AxonSeg
GUI that performs axon and myelin segmentation on histology images



Deconvolution...
Source extraction and deconvolution from calcium imaging data

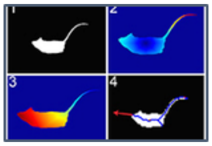


Kilosort
Automated system for neuronal patch clamp recordings in awake behaving mice

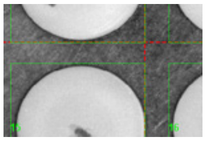


smartACT
Adaptive pipette positioning for 2p-targeted experiment

Behavior & Psychophysics



Autotyping Toolbox
Automated analysis of common behavior tasks in neuroscience



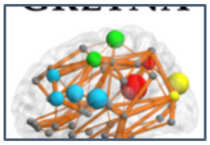
gVision
Image acquisition for behavioral neuroscience

MonkeyLogic
A toolbox for the design and execution of psychophysical tasks with high temporal precision

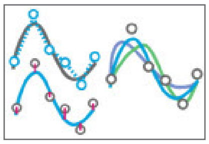
Psychophysics Toolbox
A toolbox for neuroscience stimulus presentation and response collection

Analysis & Theory

Chronux
Open-source software package for the analysis of neural data



GRETNA
A Graph-theoretical Network Analysis Toolkit in MATLAB



VBA-toolbox
Variational Bayesian Analysis (VBA)

Other

DataJoint
A high-level relational database interface for scientific computing

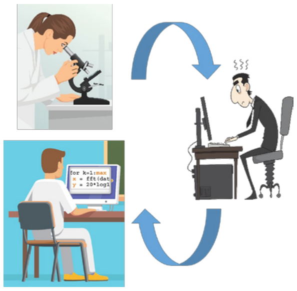
MathWorks®

Science-focused Platform

Who are scientific programmers?

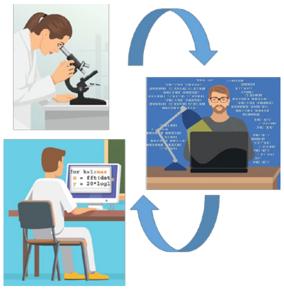
Scientist Coder

Practicing scientist who also codes. Switches hats frequently.



Research Software Engineer

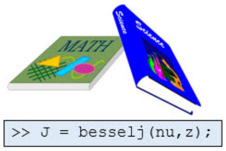
Staff at research institute/university. Tight feedback loop with scientists (who may or may not code).



Scientific Software Service Provider

Company/contractor focused on science applications. Tight feedback loop with scientists (who may or may not code).

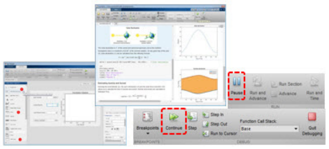
Platform support for scientific programmers



```
>> J = besselj(nu,z);
```

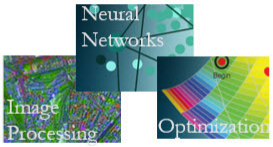
Designed for Math and Science

Language designed to look and read like math and science textbooks and online curricula.



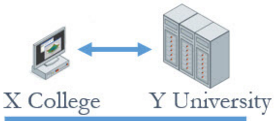
Development by & for Scientists

App design tools, exploratory programming workflows, interactive debugging tools.



Scientific Libraries

Tested, integrated, and documented libraries for many scientific functions.



	MATLAB	MDCS
User brings license	✓*	✓
Center provides access	✓*	✓

* Ask for details

Cluster Resource Sharing

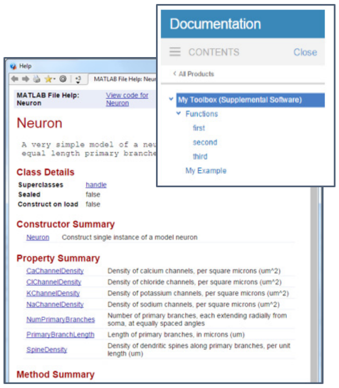
Run scientific code on shared cluster resources for academic uses.

MathWorks®

Research Software Engineering

Documentation

Produce a formal interface for other coders via formatted documentation auto-generated from comments in code.



Documentation

CONTENTS Close

‹ All Products

My Toolbox (Supplemental Software)
- Functions
  - first
  - second
  - third
- My Example

Help

MATLAB File Help: Neu

MATLAB File Help: Neuron | View code for Neuron

Neuron

```
A very simple model of a neu
equal length primary branche
```

Class Details

Superclasses	handle
Sealed	false
Construct on load	false

Constructor Summary

Neuron	Construct single instance of a model neuron

Property Summary

CaChannelDensity	Density of calcium channels, per square microns (um^2)
ClChannelDensity	Density of chloride channels, per square microns (um^2)
KChannelDensity	Density of potassium channels, per square microns (um^2)
NaChannelDensity	Density of sodium channels, per square microns (um^2)
NumPrimaryBranches	Number of primary branches, each extending radially from soma, at equally spaced angles
PrimaryBranchLength	Length of primary branches, in microns (um)
SpineDensity	Density of dendritic spines along primary branches, per unit length (um)

Method Summary

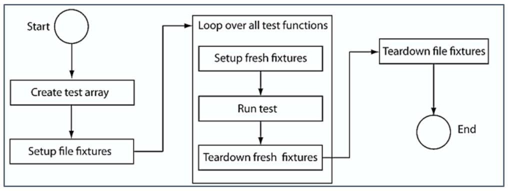
Documentation Generation

Testing Frameworks

Write, run, and analyze tests. A test runner consists of individual (unit) tests which do not alter state. Qualification functions detect various error types.

Type	Action
Verify	Fail & Continue
Assert	Fail & Halt Current Test
Fatal Assert	Fail & Halt Framework
Assume	Filter Current Test

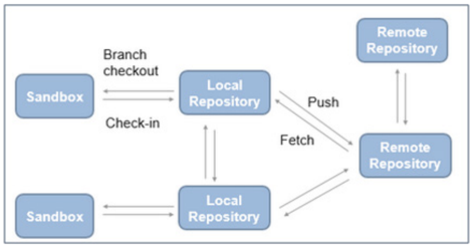
Qualification Functions



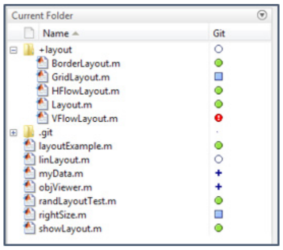
Unit Test Runner

Source Control

Manage and track code changes by one or more contributors using source control systems, either distributed (e.g. Git™) or centralized (e.g. Subversion®)



Source Control Workflow



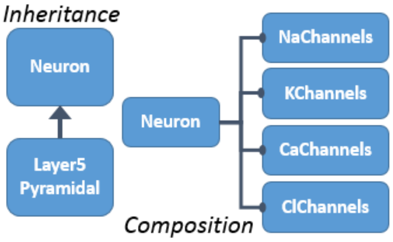
Current Folder

Name	Git
⊟ +layout	○
BorderLayout.m	●
GridLayout.m	■
HFlowLayout.m	●
Layout.m	●
VFlowLayout.m	!
⊞ .git	·
layoutExample.m	●
linLayout.m	○
myData.m	+
objViewer.m	+
randLayoutTest.m	●
rightSize.m	■
showLayout.m	●

Sandbox File Status

Modular Programming

Organize software into modules which can be tested, reused, extended, and combined. Well-designed modules (e.g. OOP classes) promote collaboration & sustainability.

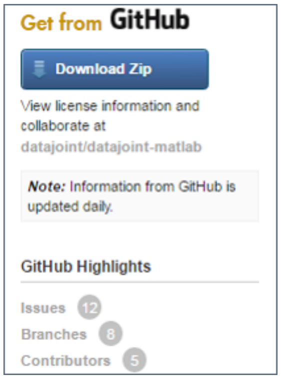


Object-Oriented Programming (OOP)

Team Programming

GitHub Collaborations

GitHub is a widely-used platform for managing software collaborations. It provides web-based interfaces for Git source control, branch and pull request management, issue tracking, wiki capabilities, and more.



Get from **GitHub**

Download Zip

View license information and collaborate at datajoint/datajoint-matlab

Note: Information from GitHub is updated daily.

GitHub Highlights

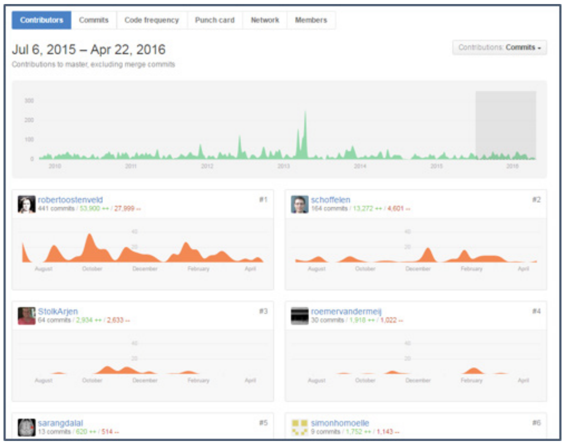
Issues 12

Branches 8

Contributors 5

Case Study — Fieldtrip

Many contributors: >15 in past year, 30 all-time. Collaborate effectively, across labs and borders, using GitHub issues and pull requests.



Jul 6, 2015 – Apr 22, 2016

Contributions to master, excluding merge commits

robertoostenveld #1
441 commits / 53,900 ++ / 27,999 --

schoffelen #2
164 commits / 13,272 ++ / 4,601 --

StolkArjen #3
64 commits / 2,934 ++ / 2,633 --

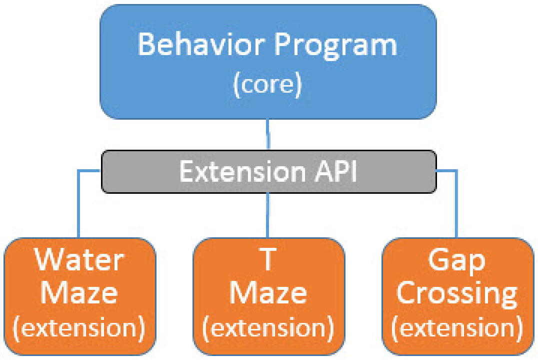
roemervandermeij #4
30 commits / 1,918 ++ / 1,022 --

sarangdalal #5
13 commits / 620 ++ / 514 --

simonhomoelle #6
9 commits / 1,752 ++ / 1,143 --

Extensible Design

Code modularity can expand team programming to include loosely coupled outside contributors. Many successful projects employ an "extension" architecture & process to extend the core program's functionality.


Behavior Program (core)

Extension API

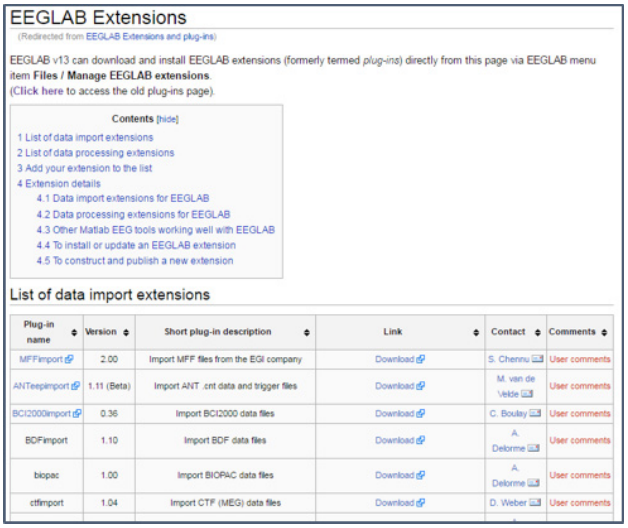
Water Maze (extension)

T Maze (extension)

Gap Crossing (extension)

Case Study — EEGLAB

Over 60 extensions are listed, version tracked, and quality checked by project managers.



EEGLAB Extensions

(Redirected from EEGLAB Extensions and plug-ins)

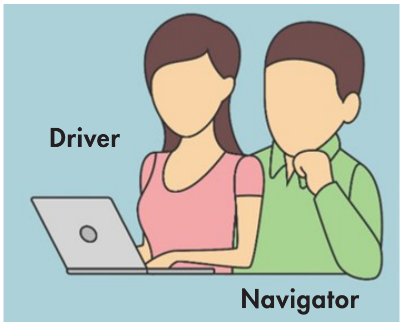
EEGLAB v13 can download and install EEGLAB extensions (formerly termed *plug-ins*) directly from this page via EEGLAB menu item **Files / Manage EEGLAB extensions**.
(**Click here** to access the old plug-ins page).

Contents [hide]
1 List of data import extensions
2 List of data processing extensions
3 Add your extension to the list
4 Extension details
4.1 Data import extensions for EEGLAB
4.2 Data processing extensions for EEGLAB
4.3 Other Matlab EEG tools working well with EEGLAB
4.4 To install or update an EEGLAB extension
4.5 To construct and publish a new extension

List of data import extensions

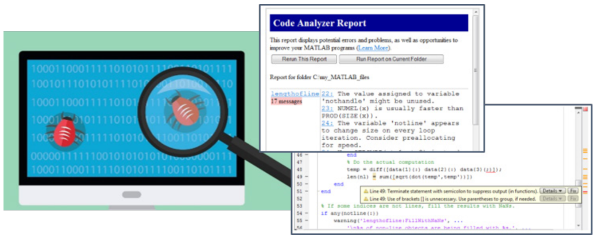
Plug-in name	Version	Short plug-in description	Link	Contact	Comments
MFFimport	2.00	Import MFF files from the EGI company	Download	S. Chennu	User comments
ANTeepimport	1.11 (Beta)	Import ANT .cnt data and trigger files	Download	M. van de Velde	User comments
BCI2000import	0.36	Import BCI2000 data files	Download	C. Boulay	User comments
BDFimport	1.10	Import BDF data files	Download	A. Delorme	User comments
biopac	1.00	Import BIOPAC data files	Download	A. Delorme	User comments
ctfimport	1.04	Import CTF (MEG) data files	Download	D. Weber	User comments

Software Sustainability



Pair Programming

Tool Forums



Code Analyzer Report

This report displays potential errors and problems, as well as opportunities to improve your MATLAB programs (Learn More).

Report for folder C:\my_MATLAB_files

lengthofline 17 messages

22: The value assigned to variable 'nothandle' might be unused.
23: NUMEL(x) is usually faster than PROD(SIZE(x)).
24: The variable 'notline' appears to change size on every loop iteration. Consider preallocating for speed.

```
46 -            end
47              % Do the actual computation
48              temp = diff([data(1)(:) data(2)(:) data(3)(:)]);
49 -            len(nl) = sum([sqrt(dot(temp',temp'))])
50 -        end
51 -    end
52
53   % If some indices are not lines, fill the results with NaNs.
54 - if any(notline(:))
55 -     warning('lengthofline:FillWithNaNs', ...
```

⚠ Line 49: Terminate statement with semicolon to suppress output (in functions).
⚠ Line 49: Use of brackets [] is unnecessary. Use parentheses to group, if needed.

Code Analysis

Workshops

Managing Technical Debt

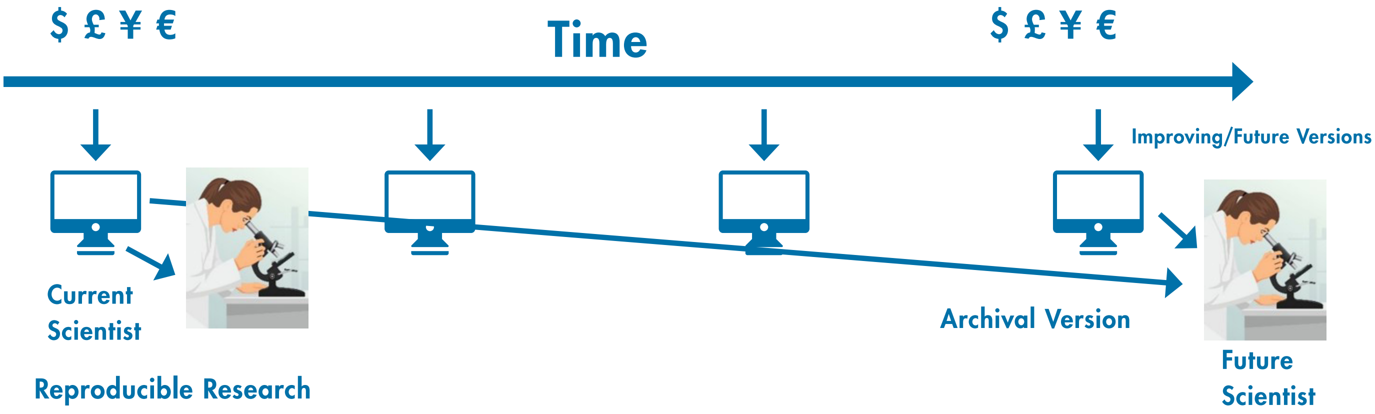
Addressing internal software quality through code analysis and reviews can ensure long-term development sustainability, as project and team evolves.

Resilient Tool Communities

Software tools can adapt to scientific and personnel change when broad communities of developers, scientific leaders, and users are engaged together.

Pathways to Funding

Software tools with sustainable community and development attributes are likely more attractive for project funding.



Reproducible Research

Questions of scientific reproducibility reveal many meanings and levels. Sustainable software can support archival replication and also encourage me-too studies.