

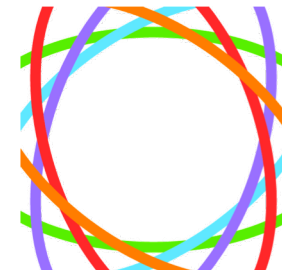
Tools and Informatics for niQC: overview

Pradeep Reddy Raamana

crossinvalidation.com

github.com/raamana

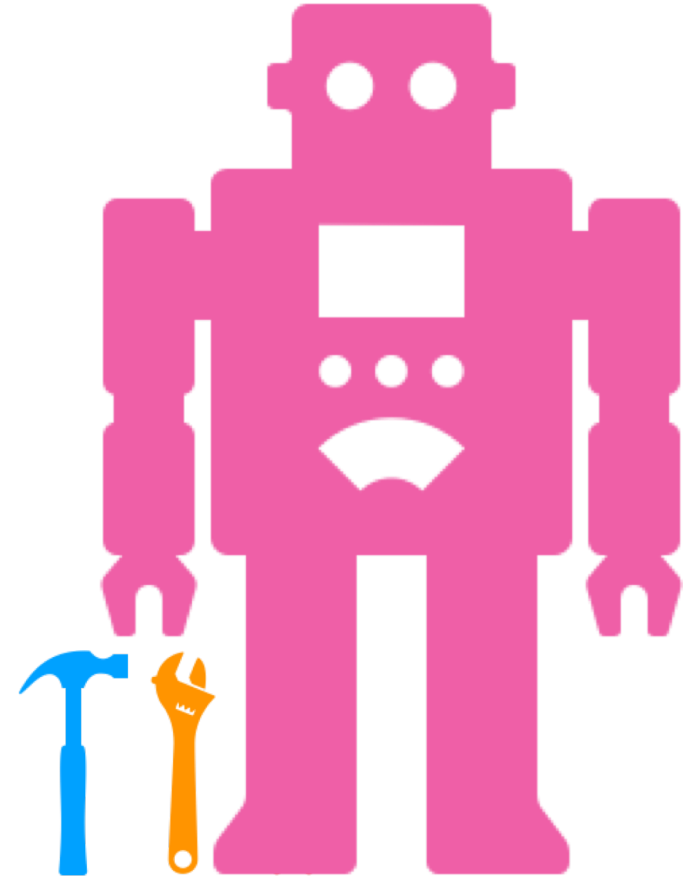
follow [@raamana_](https://twitter.com/raamana_)



ONTARIO
BRAIN
INSTITUTE

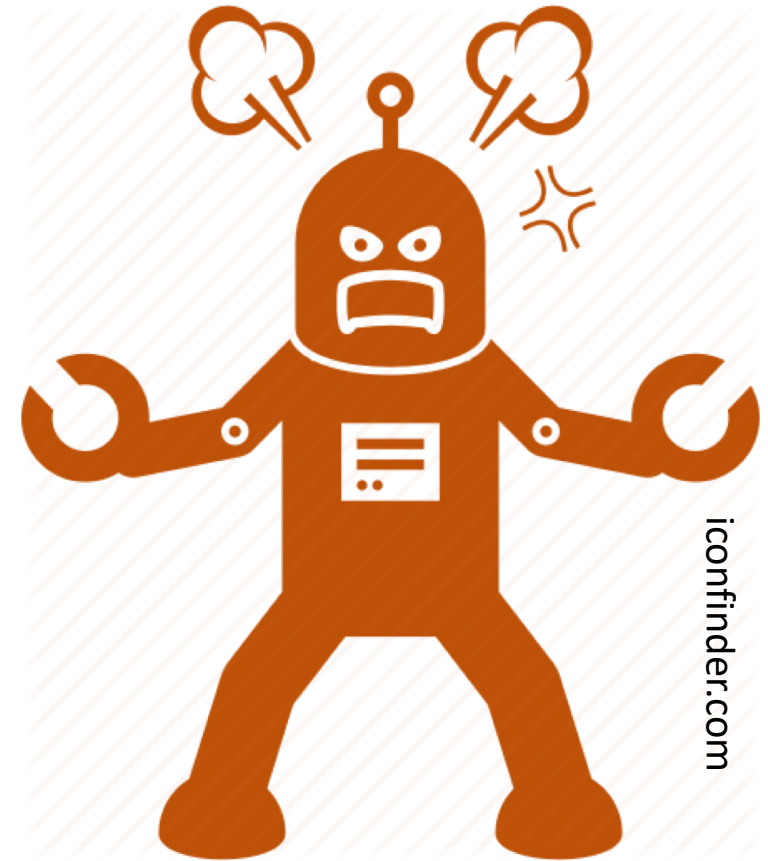
Importance of tools

- Manual QC does not scale!
 - Time-consuming
 - Costly
 - Error-prone
 - Even for [relatively] small samples
- Improving reproducibility
- As well as harmonization



Dangers of automation!

- Tools can sometimes be black boxes
 - users don't understand what's happening
 - or unable to change the process or parts
- There is only so much that can be automated
 - Not sufficiently accurate!
 - Can't help with subtle issues



Summary of available tools

- We can't cover them all in detail
- Will break them down by task
 - Visual inspection
 - Modality-wise tasks
 - Automatic, semi-automatic, manual
- Slides for each tool, and a dynamic collection of tools → niQC website

incf.github.io/niQC

Summary of use-cases, by modality

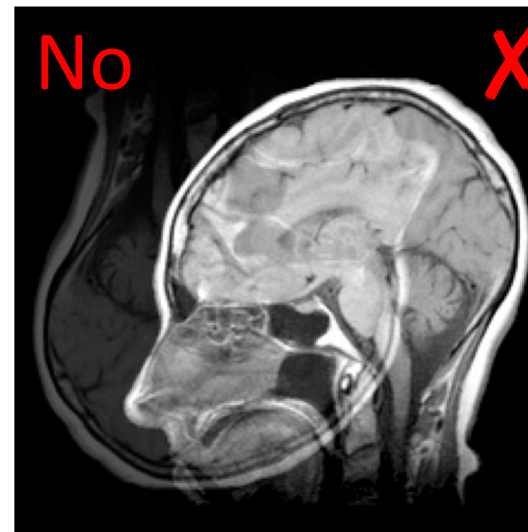
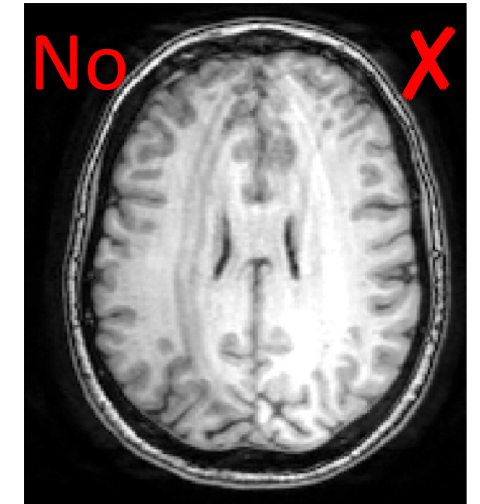
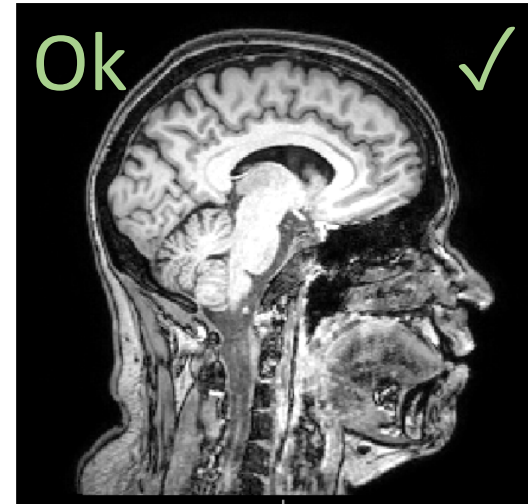
- Multimodal
 - visual aspects of QC for many modalities: **VisualQC** (shameless plug, sorry 😊)
 - Alignment checks : **VisualQC**
 - Stroke/lesion specific QC: **PALS**
- T1w MRI
 - visual QC: various artefacts : **VisualQC**,
 - auto QC: usable or not! : **mriqc**, **QoalaT**,
 - Freesurfer parcellation accuracy: **ENIGMA**, **mindcontrol**, **VisualQC**, **qcApp**,
 - Volumetric segmentation accuracy:
- Functional MRI
 - visual QC : **afni_proc**, **dashQC**, **mriqc**, **VisualQC**
 - generate and visualize image quality metrics (IQMs): **dashQC**, **mriqc**
 - alignment: **dashQC**

Summary of use-cases, per modality

- Diffusion MRI
 - Correction, processing: [eddyqc](#), [ExploreDTI](#), [DTIprep](#)
 - visual QC : [VisualQC](#)
- Real-time QC of fMRI
 - various aspects: [rtQC](#),
- Arterial Spin Labeling
 - various: [ExploreASL](#)
- Scanner and Hardware QC
 - various: [uniQC](#)
- Crowd-sourcing
 - visual QC: [braindr](#),
 - IQMs : web database by [mriqc](#)

T1w Anatomical MRI

- Purpose
 - detect artefacts and rate their severity – comprehensive!
 - Classify as **acceptable or not**, for analysis
 - Manual/Visual
 - Automatic
- What they can not do
 - can not correct artefacts*



* with some exceptions

Artefacts in T1w MRI

VisualQC

ground truth!

VisualQC T1 MRI : /Users/Reddy/dev/visualqc/example_datasets orig.mgz

id_001 (1/2)

useful stats, including alerts for outliers

zero intensities

0.1 0.3 0.5 0.7 0.9

- Pass
- Motion
- Ringing
- Ghosting
- Contrast
- blurry
- Bright
- Dark
- Orient/FOV
- Weird

Notes:

Next

Quit

highly extensible for related visual inspection tasks

I'm tired!

I'm not sure – let's talk to colleagues!

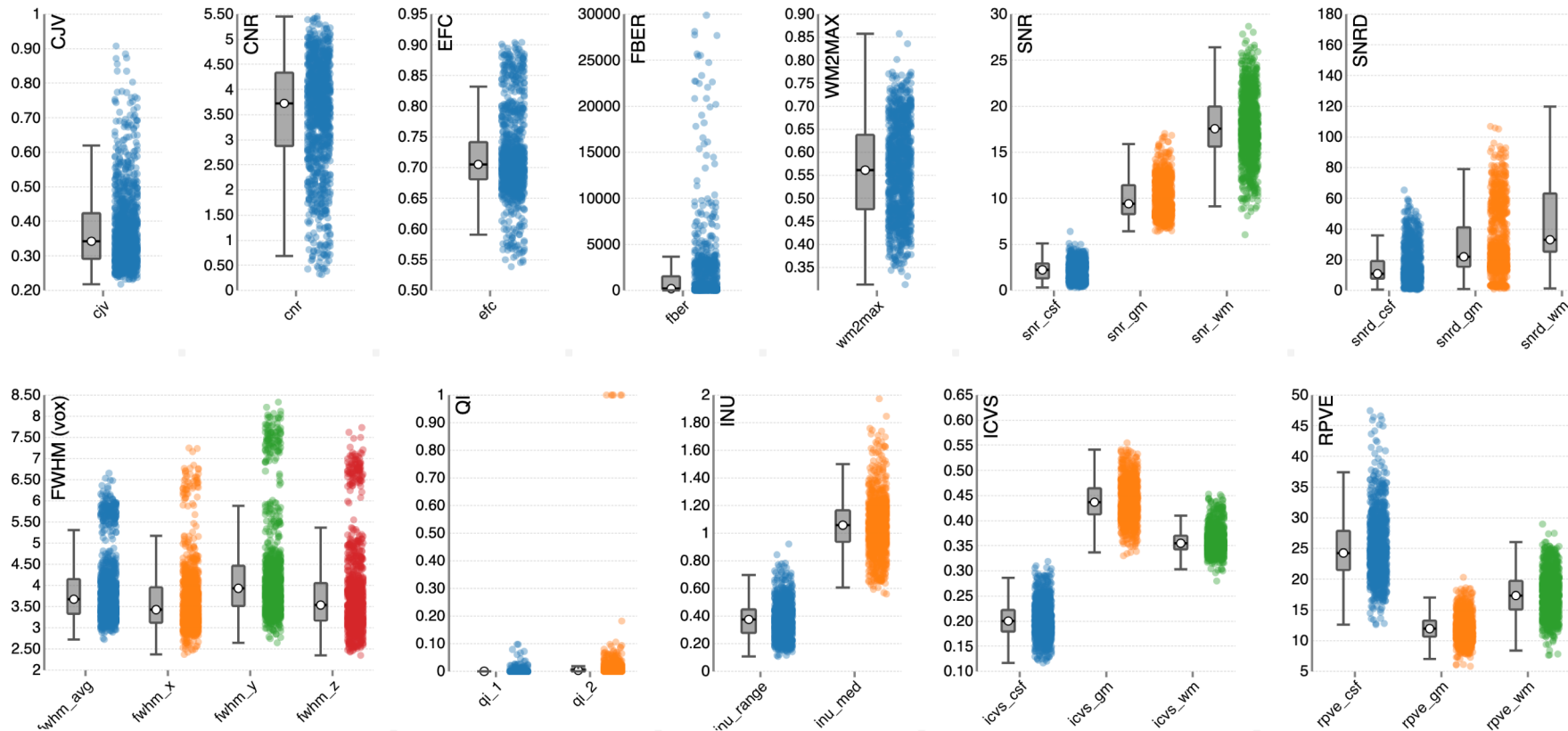
MRIQC: automatic prediction of quality and visual reporting of MRI scans



MRIQC: group T1w report

Summary

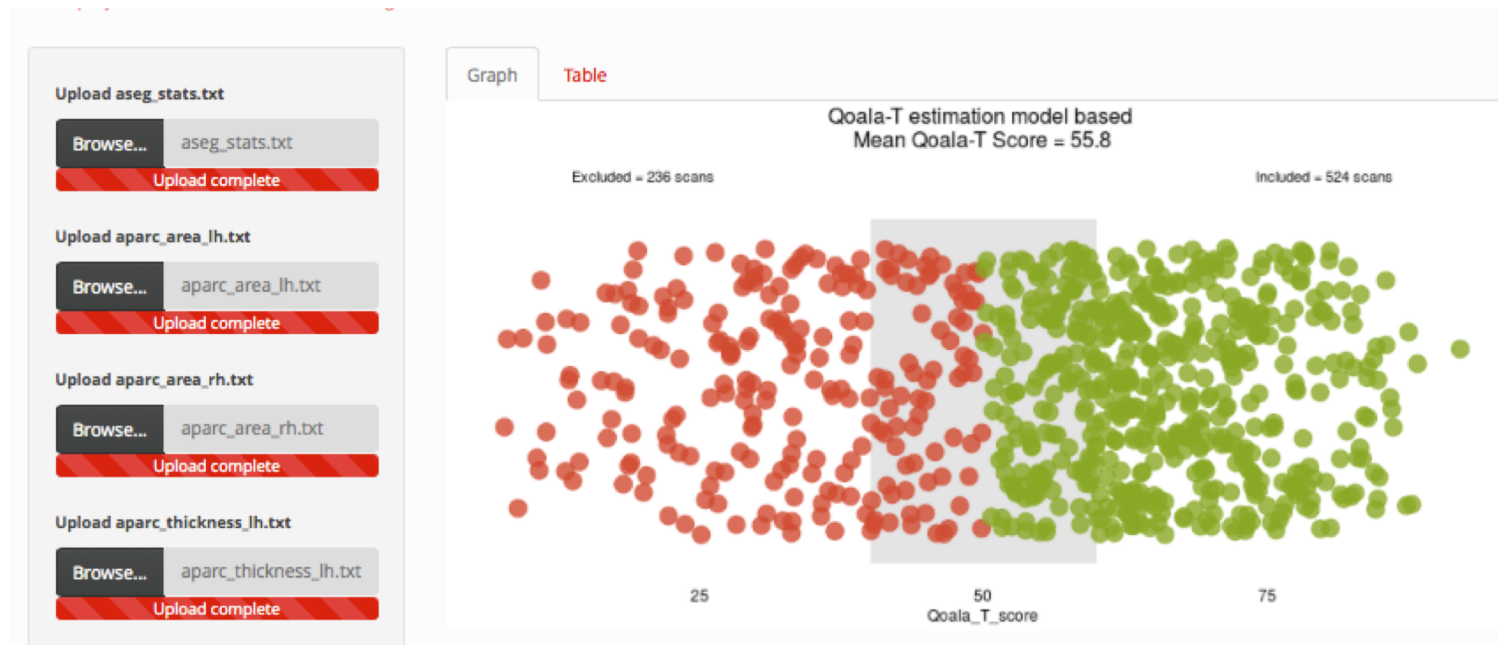
- Date and time: 2018-06-12, 17:28.
- MRIQC version: 0.10.6.



- Auto-classify bad scans (low quality and acquisition issues).
- This pipeline derives from, and is heavily influenced by, the [PCP Quality Assessment Protocol](#).
- Great batch processing capabilities
- Integrates with BIDS format, and is easy to use to openneuro, or as a command line app
- Contact: Oscar Esteban

QoalaT

- Computes quality scores of T1w mri
- Based on Freesurfer outputs
- Semi-automated effort to reduce QC burden



- OA paper: [10.1016/j.neuroimage.2019.01.014](https://doi.org/10.1016/j.neuroimage.2019.01.014)
- Code : <https://github.com/Qoala-T/QC>
- Online app: https://qoala-t.shinyapps.io/qoala-t_app

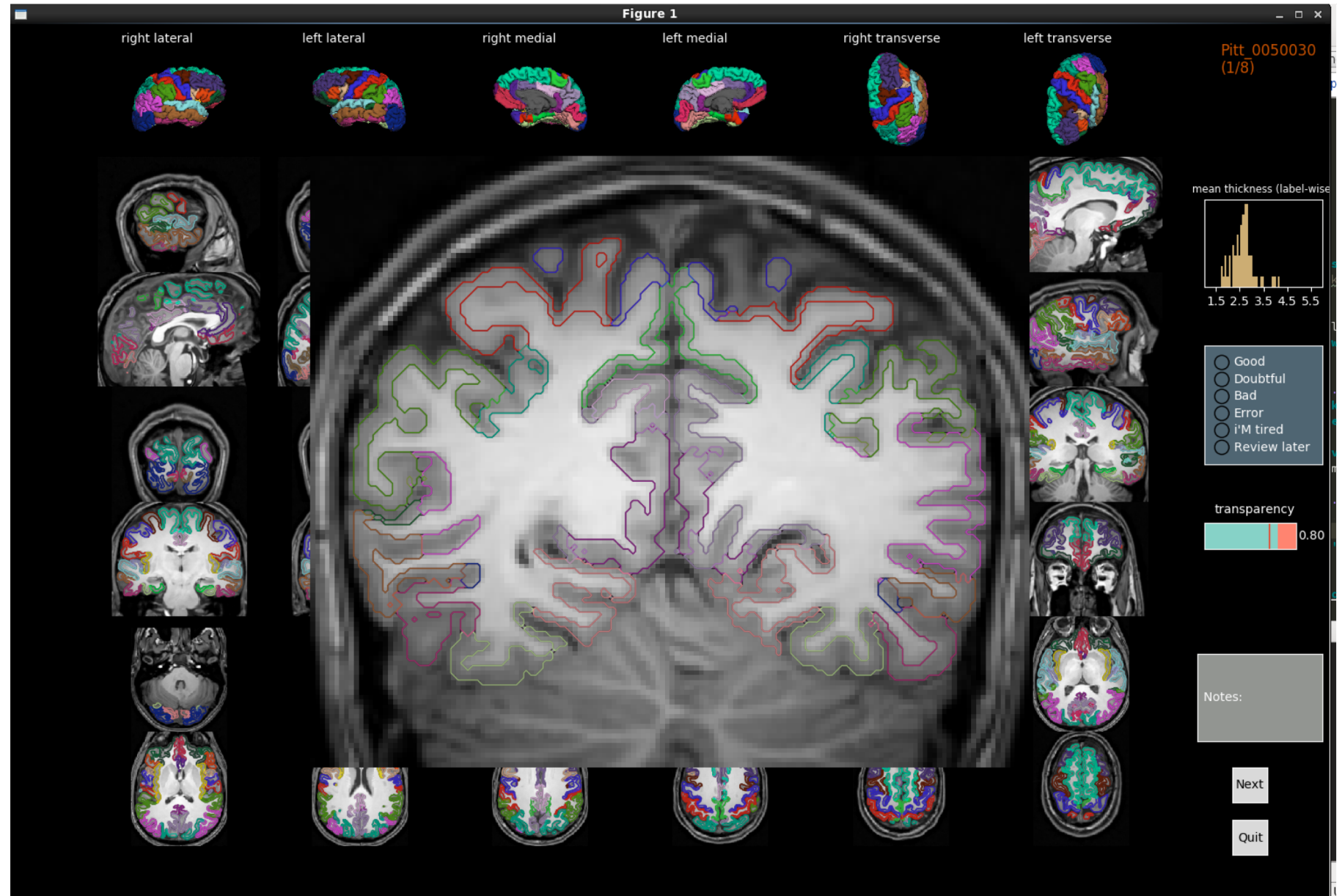
VisualQC _Freesurfer

Focus on
generating ground
truth assessment of
quality

Excellent workflow

Less false positives

outlier detection!





ABOUT ENIGMA PUBLICATIONS WORKING GROUPS RESEARCH PRESS ENIGMAVis
PROTOCOLS EVENTS TRAINING JOIN ENIGMA JOIN OUR MAILING LIST!

Structural image processing protocols

Anyone is welcome to use these protocols for their projects! If you use the protocols on this site for projects outside of ENIGMA, please include a reference to the ENIGMA main page (<http://enigma.usc.edu/>) so that your readers and reviewers know about it as well. Please also reference the ENIGMA publication if you are using the ENIGMA1 protocols (Stein et al., 2012, Nature Genetics).

ENIGMA-Sulci

This protocol allows you to segment, label, and visually inspect 123 cortical sulci/subject using FreeSurfer, BrainVISA, R and ImageMagick.

📍 [Google Drive containing the protocol & instructions for download here.](#)

ENIGMA Cortical Quality Control Protocol 2.0 (April 2017)

The original ENIGMA Cortical QC protocol was updated in April 2017. While it does not create a departure from the former process and results, it will increase the ease of QC assessment. Thus, the QC 2.0 protocol may be used going forward but does not require any retroactive implementation.

📍 [Step 1: Extract Cortical Measures from FreeSurfer](#)

Focus on
reasonable
assessment

But at scale

Implemented in
ENIGMA
consortium

Great start to help
improve other
workflows like
VisualQC

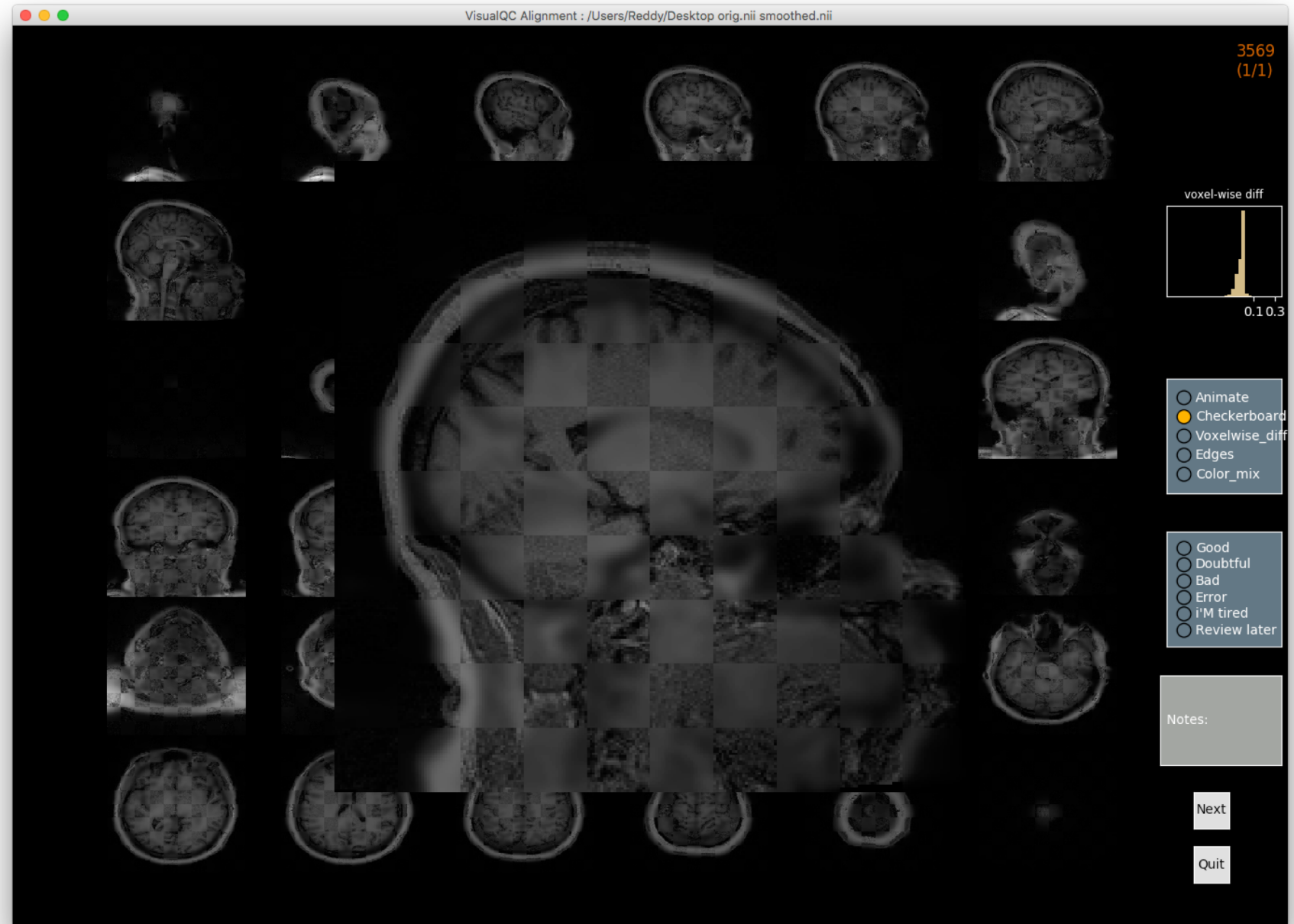
VisualQC _Alignment

Focus on
generating ground
truth assessment of
quality

Excellent workflow

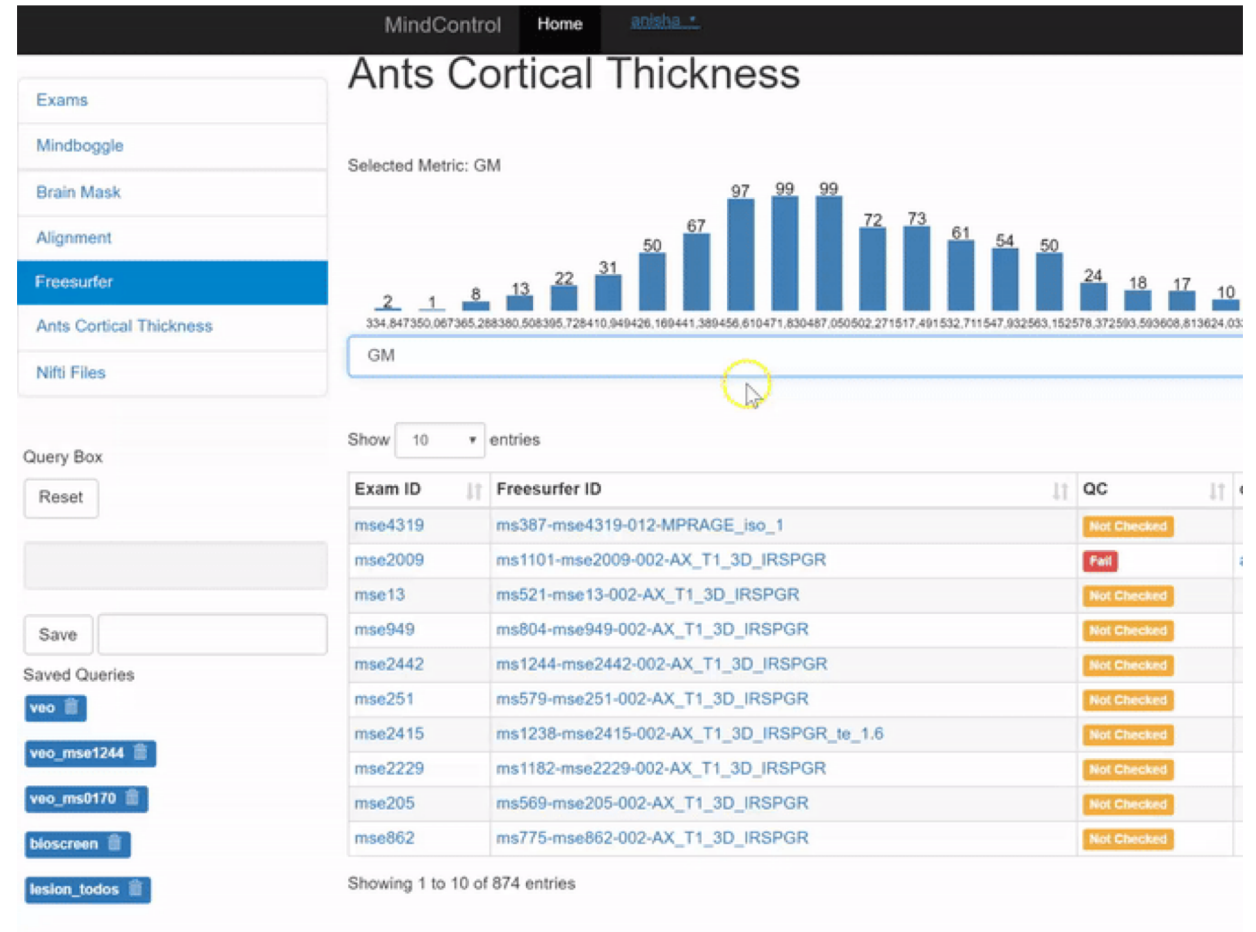
Less false positives

outlier detection!



mindcontrol

- Web app for Freesurfer QC
- Links descriptive QC metrics with an imaging viewer, editor, and annotation toolbox.
- Web-based application enables users to QC on any device, including a tablet
- Great for collaboration

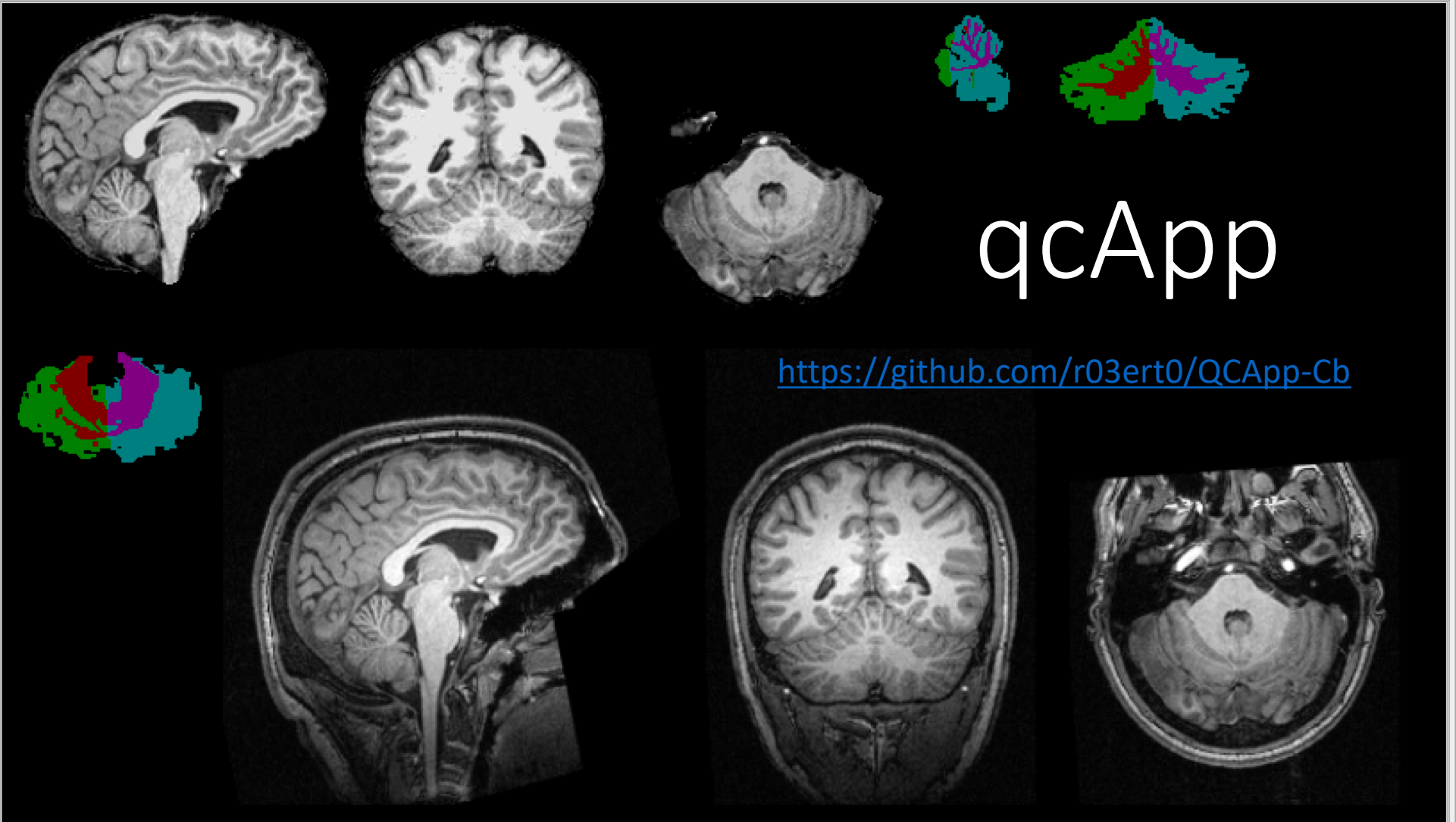


<https://github.com/akeshavan/mindcontrol>

Choose Subjects Directory...

Save QC...

#	QC	Subject	Comments
1	1	0050002	
2	1	0050003	
3	1	0050004	
4	2	0050005	little holes in segm...
5	1	0050006	
6	2	0050007	Holes in segmenta...
7	1	0050008	
8	1	0050009	artefacts in right h...
9	1	0050010	
10	1	0050011	
11	1	0050012	
12	1	0050013	
13	1	0050014	
14	1	0050015	
15	2	0050016	holes in segmentat...
16	2	0050017	bad quality image
17	1	0050019	
18	2	0050020	holes in segmentat...
19	1	0050022	
20	1	0050023	
21	1	0050024	
22	1	0050025	
23	1	0050026	lines artefacts in i...
24	1	0050027	
25	1	0050028	
26	1	0050029	
27	1	0050030	
28	1	0050031	
29	1	0050032	
30	1	0050033	
31	1	0050034	
32	2	0050035	artefact in midsagi...
33	1	0050036	bad quality image
34	1	0050037	
35	1	0050038	
36	1	0050039	
37	2	0050040	little holes in segm...
38	2	0050041	holes in segmentat...
39	2	0050042	holes in segmentat...
40	1	0050043	
41	1	0050044	little holes in segm...
42	1	0050045	
43	1	0050046	
44	1	0050047	
45	2	0050048	bad quality image ...
46	1	0050049	

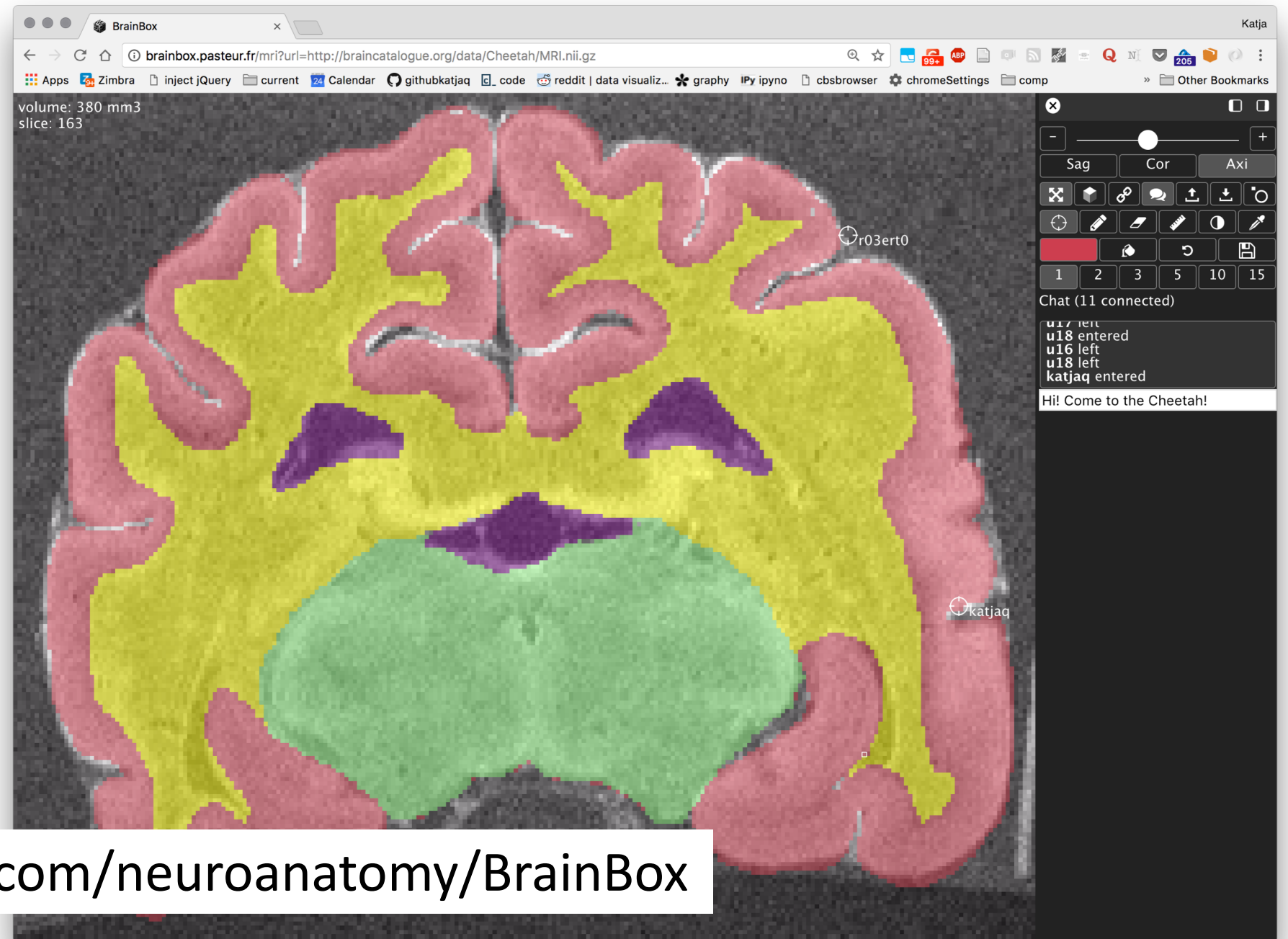


<https://github.com/r03ert0/QCApp-Cb>

ICV	SS	GM	WM	Cbl
		●	●	●
●				

BrainBox

- Web app for collaborative curation of neuroimaging data



<https://github.com/neuroanatomy/BrainBox>

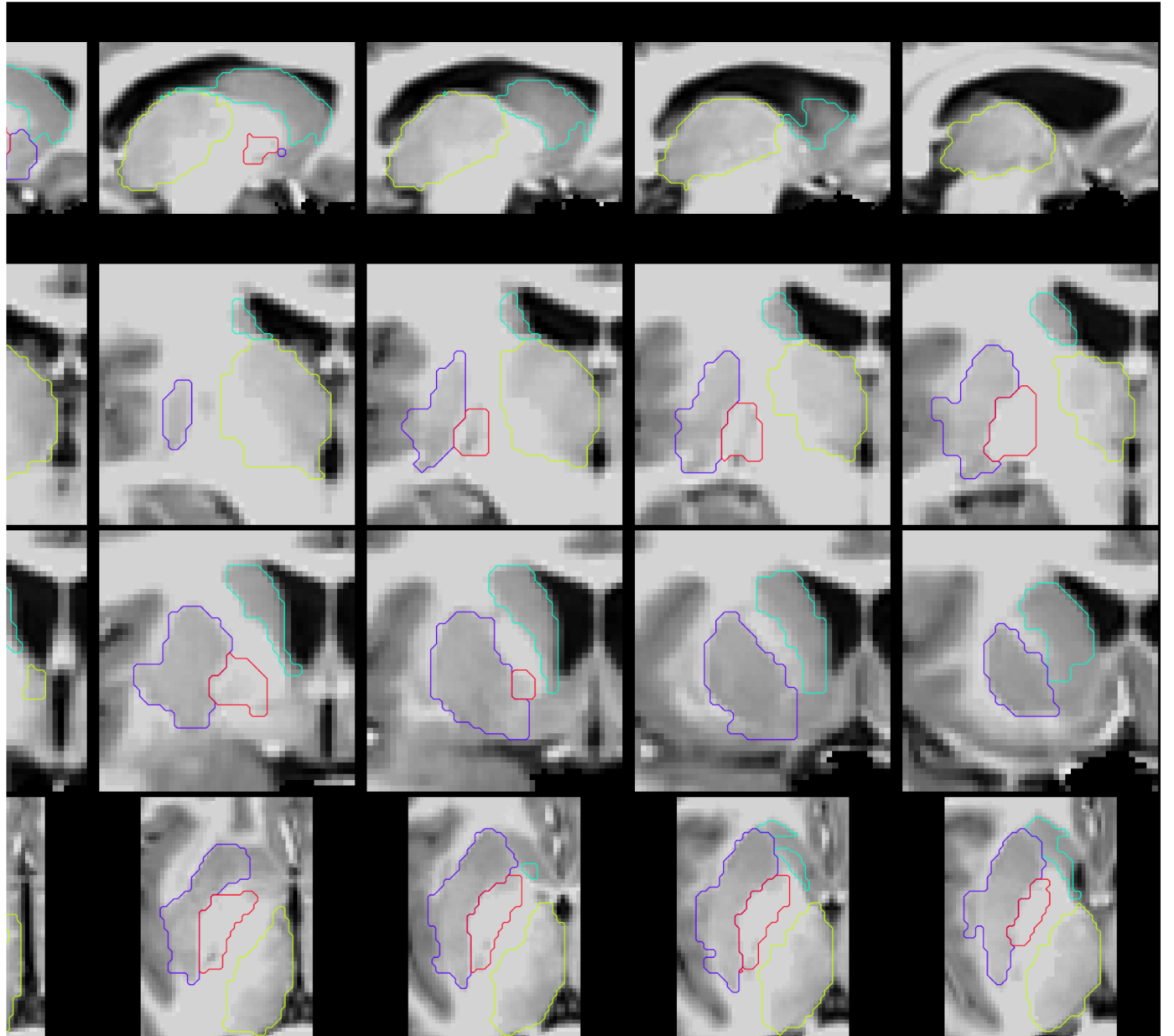
VisualQC _Segmentation

Focus on generating ground truth assessment of quality

Excellent workflow

Less false positives

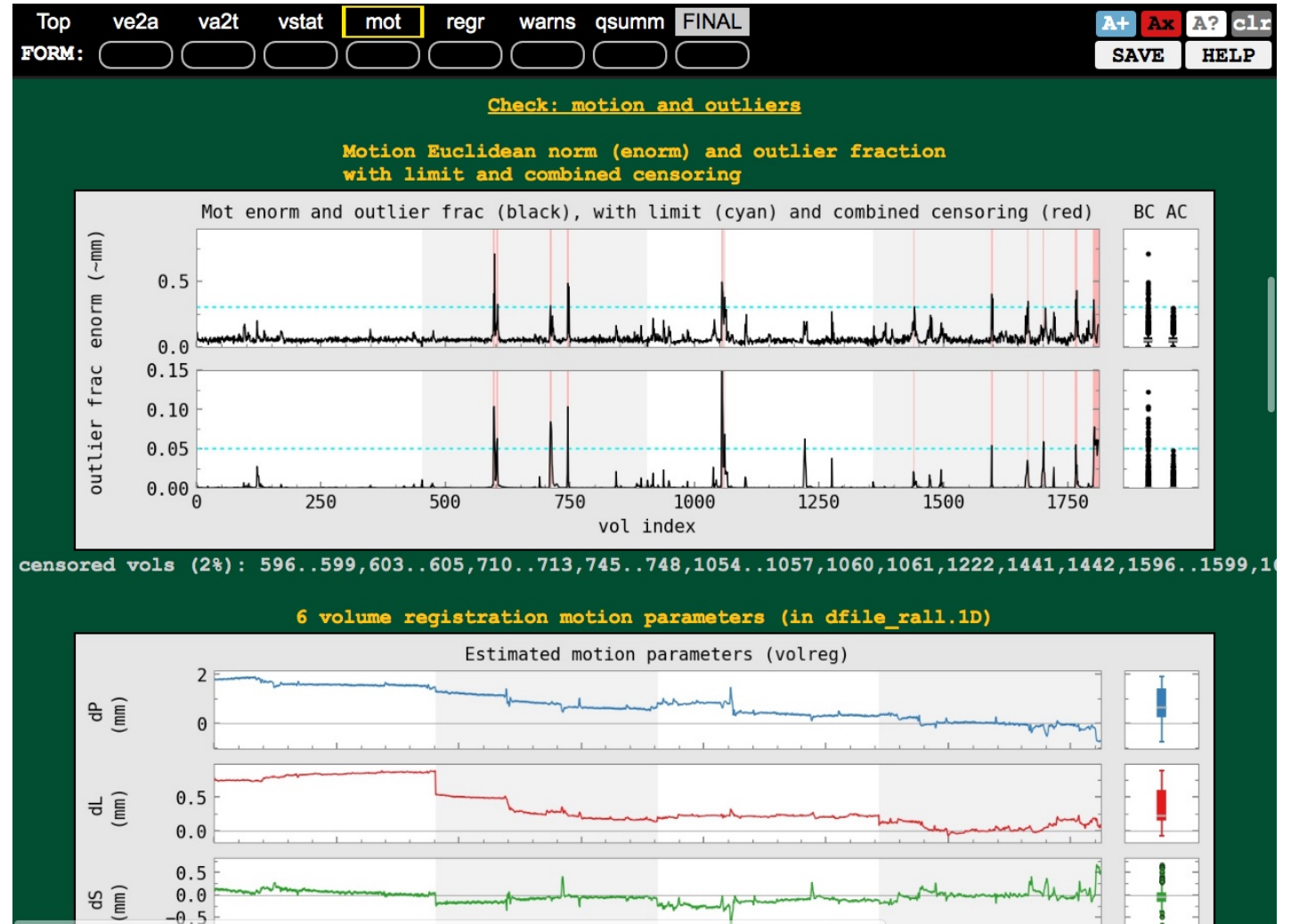
outlier detection!



afni_proc.py

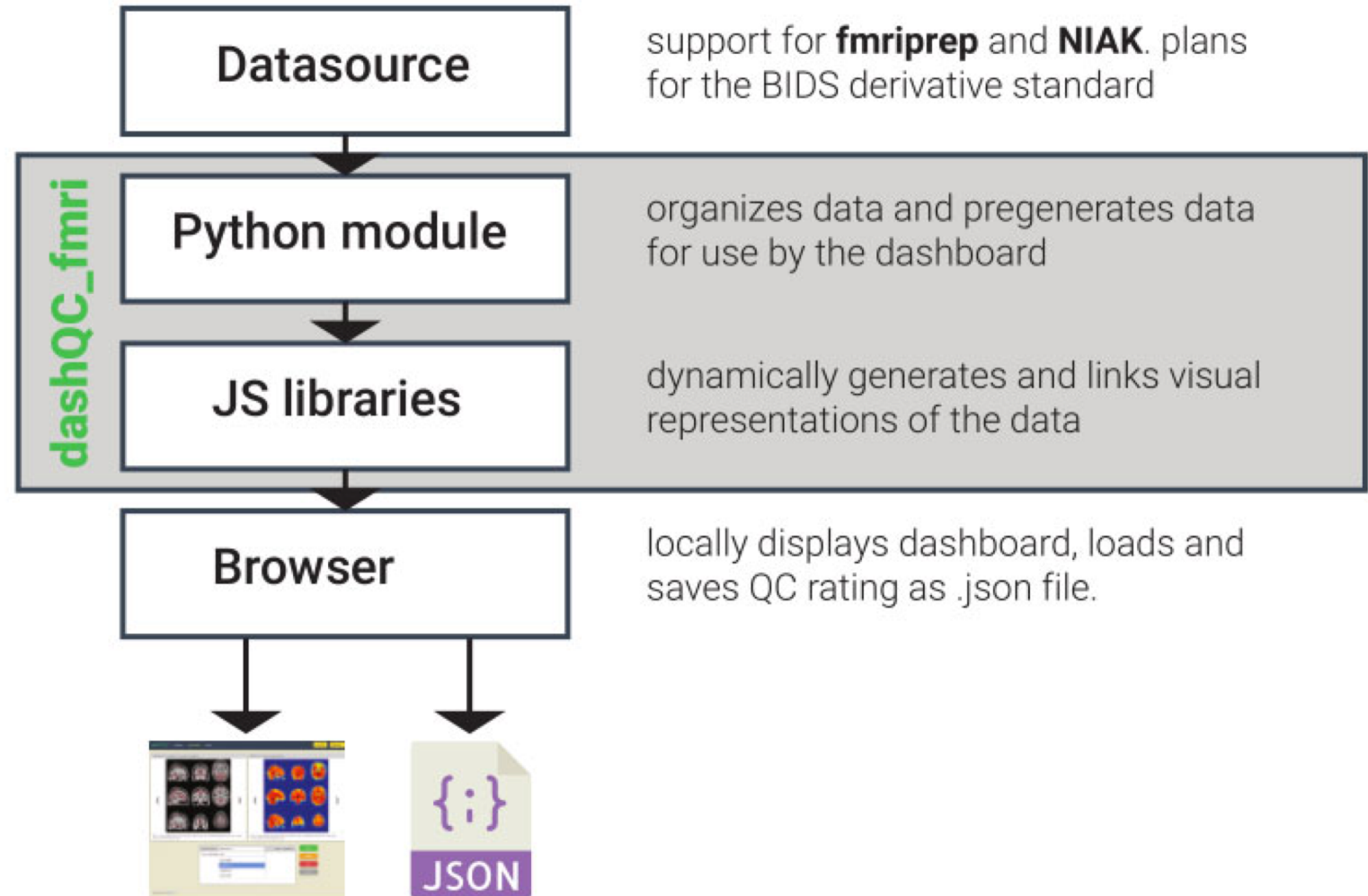
- Automated generation of QC images collected onto a Web page
- Across a dataset also
- Script in the AFNI land

<https://afni.nimh.nih.gov/>



dashQC

- fMRI QC
- Visualize IQMs
- Check alignment



<https://dashqc-fmri.readthedocs.io/en/latest/>

MRIQC: automatic prediction of quality and visual reporting of MRI scans



Oscar Esteban¹, Krzysztof Gorgolewski¹, Russell Poldrack¹ - ¹Dept. of Psychology, Stanford University, US

QA - ASSESSMENT

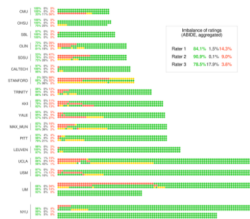
- Find systematic errors in acquisition
- Maximize quality of ongoing studies

QC - CONTROL

- Find subpar images
- Prevent biasing analysis

VISUAL INSPECTION

... is **time consuming**, and prone to inter- and intra- **rater variabilities**



Site	Rater 1	Rater 2
LEUVEN	95%	95%
UCLA	95%	95%
USM	95%	95%
UM	95%	95%
NYU	95%	95%

AUTOMATED PREDICTION

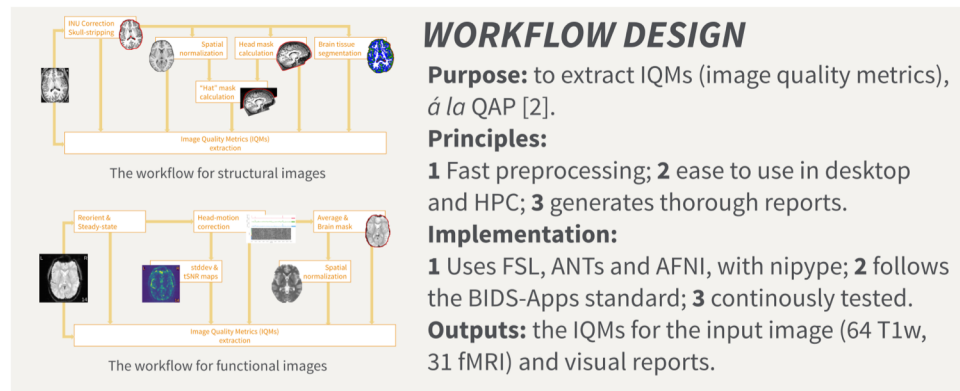
Data: 1098 rs-fMRI scans from ABIDE [1], manual QA ratings (accept/reject) of two experts [2] (reject fractions - rater 1: 4.64%; rater 2: 5.83%).

Methods: nested cross-validation (scikit-learn) with AUC (area under the curve) scoring. Stratified 6-Fold split and grid search in the inner loop. Outer loop uses a stratified 5-Fold. Run permutation (5000 rep.) testing.

Models: SVC (support vector machines classifier) and RFC (random-forests classifier). Preprocessing: with and without site-wise standardization.

Table 1. Cross-validation results. The best performing classifier was RFC-zs, with the following hyperparameters (estimator/minimum samples per split/maximum depth): rater 1 (1/82/5); and rater 2 (1/12/7). The reported score is roc_auc (area under the curve of the receiver-operator characteristic).

	RFC-zs	SVC-lin-zs	SVC-rbf-zs	RFC-zs	SVC-lin-zs	SVC-rbf-zs
Rater 1	0.94 (p<0.01)	0.82 (p<0.01)	0.82 (p<0.01)	0.88 (p<0.01)	0.89 (p<0.01)	0.88 (p<0.01)
Rater 2	0.72 (p<0.01)	0.66 (p<0.01)	0.63 (p<0.01)	0.65 (p<0.01)	0.57 (p<0.01)	0.48 (p<0.65)



WORKFLOW DESIGN

Purpose: to extract IQMs (image quality metrics), *à la* QAP [2].
Principles:
 1 Fast preprocessing; 2 ease to use in desktop and HPC; 3 generates thorough reports.
Implementation:
 1 Uses FSL, ANTs and AFNI, with nipype; 2 follows the BIDS-Apps standard; 3 continuously tested.
Outputs: the IQMs for the input image (64 T1w, 31 fMRI) and visual reports.

GROUP & INDIVIDUAL VISUAL REPORTS

Group and individual reports
 MRIQC speeds up manual assessment with the combination of group and individual reports.

The fMRI summary plot
 Individual reports consist of several sections that help evaluate different quality aspects. One section is the fMRI summary plot that shows the estimated head motion, DVARS, spikes, etc. Other visual elements to aid inspection are mosaic views of volumes.

Quality Assessment
 We modified our reconstruction protocol after discovering signal leakage from the eyes using MRIQC.

- Auto-classify bad scans (low quality and acquisition issues).
- This pipeline derives from, and is heavily influenced by, the [PCP Quality Assessment Protocol](#).
- Great batch processing capabilities
- Integrates with BIDS format, and is easy to use to openneuro, or as a command line app
- Those using fMRIPrep will feel at home
- Contact: Oscar Esteban

[1] Di Martino A, et al. (2016) Autism Brain Imaging Data Exchange I (ABIDE I)
 [2] Craddock C, and Bellec P (2015), <http://preprocessed-connectomesproject.org/>.

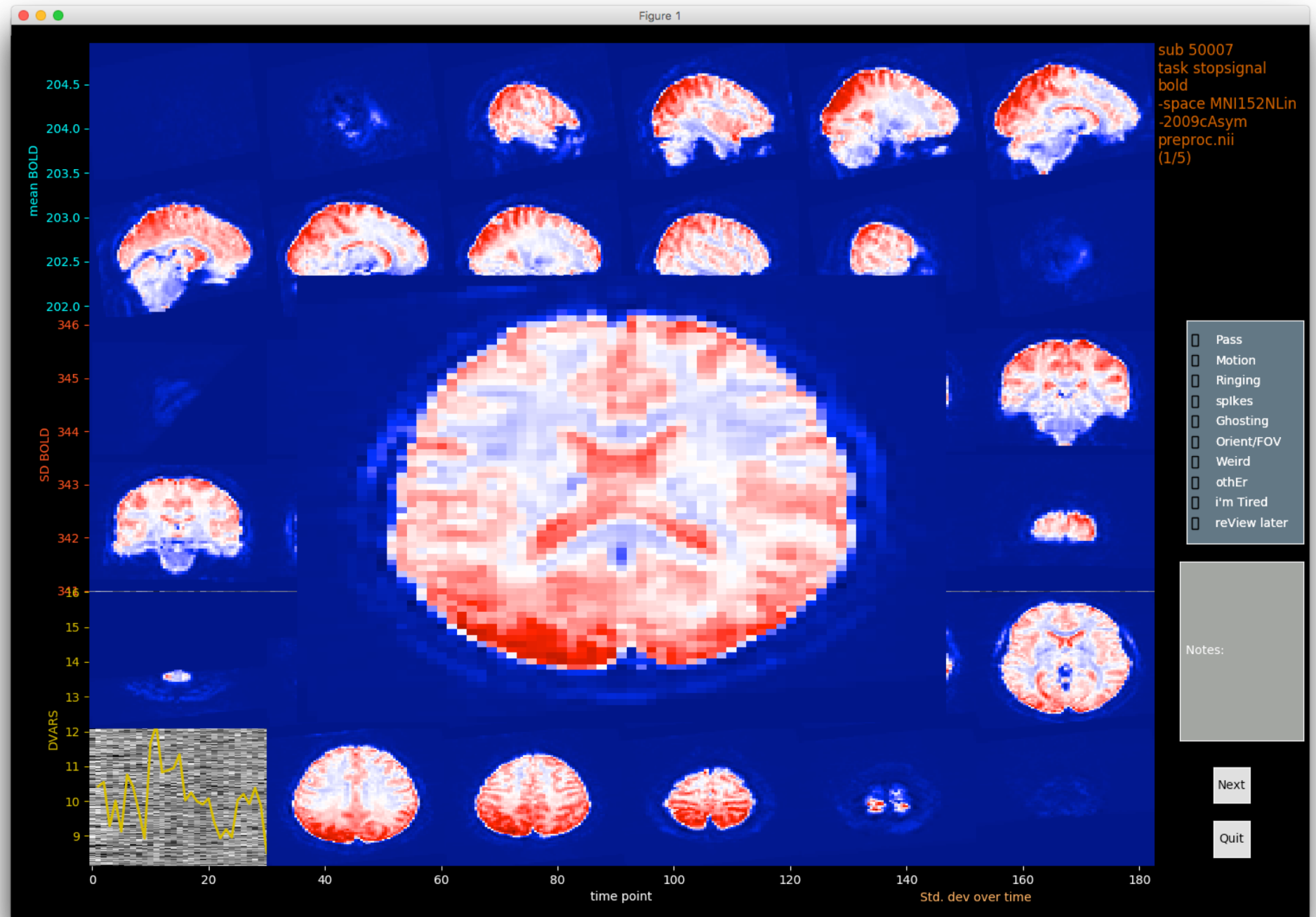
VisualQC _FuncMRI

Focus on
generating ground
truth assessment of
quality

Excellent workflow

Less false positives

outlier detection!



eddyqc

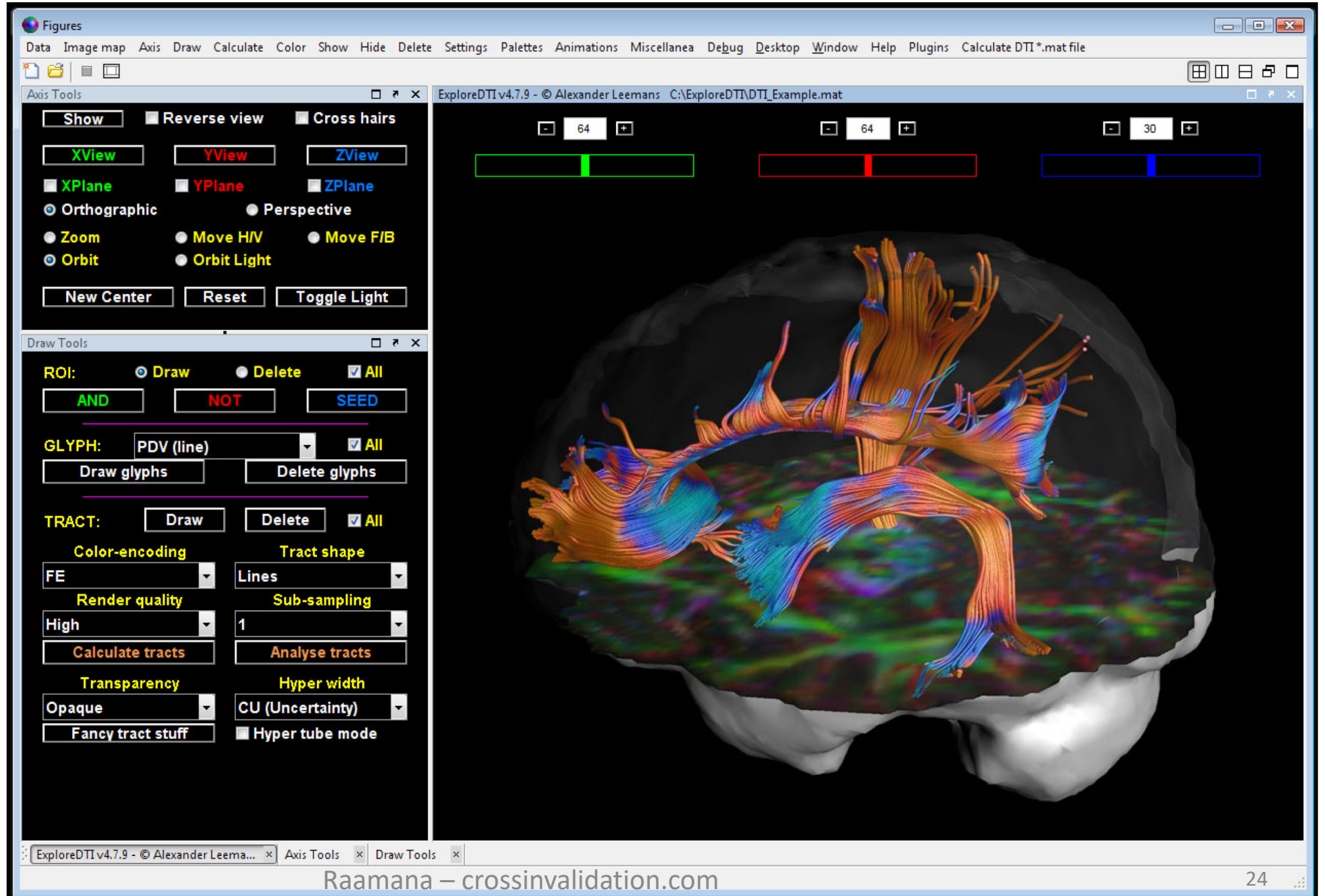
<https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/eddyqc>

- Allows to assess dMRI data both at the single subject and group levels
- QC metrics are derived through different stages of FSL's pre-processing tools (TOPUP and EDDY).
- Classify as good or bad quality datasets
- Identify subsets of the data that may need careful visual inspection.

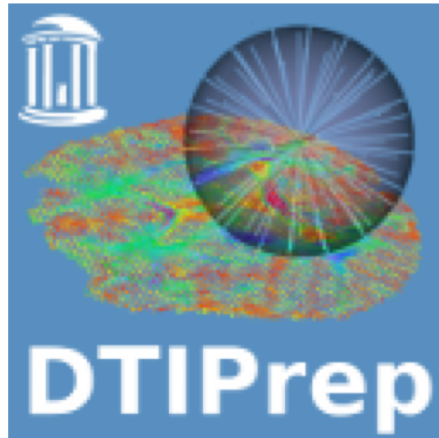


ExploreDTI

for exploratory
diffusion (tensor)
MRI and fiber
tractography.



DTIPrep



Applications Places System | Emails | FiberViewer(Aditya) | DTIPrepExt | DTI2013 | DTIPrep | DTIAtlasFiberAnalyzer | DTIAtlasExtension | CreateProjectsScript | 73 °F Tue Jan 29, 15:26

Terminal | NITRC: DWI/DTI Quality Control Tool: DTIPrep: Manage Images - Mozilla Firefox

DTIPrep Tools(Qt4) - /rodent/SherylMoy/20101124_sheryl_BF.SM2/20101124_sheryl_BF.SM2_dwi.nhdr

File View Help

DTIPrep

DWI Protocol Protocol Path QC Results

ImageInfo

Size	256	340	128
Origin	0.000000	0.000000	0.000000
spacing	0.058594	0.070547	0.075000
Space	left-posterior-superior		

Space directions

1.000000	0.000000	0.000000
0.000000	1.000000	0.000000
0.000000	0.000000	1.000000

Measurement Frame

0.000000	1.000000	0.000000
1.000000	0.000000	0.000000
0.000000	0.000000	1.000000

Diffusion

Tag	Value
DWMRI_b-value	1600
DWMRI_gradient_0000	0.000000 0.000000 0.000000
DWMRI_gradient_0001	0.000000 0.000000 0.000000
DWMRI_gradient_0002	0.000000 0.000000 0.000000
DWMRI_gradient_0003	0.217400 -0.487000 -0.845900
DWMRI_gradient_0004	-0.957500 -0.073000 0.278900
DWMRI_gradient_0005	-0.672300 -0.738900 0.045100
DWMRI_gradient_0006	-0.082900 -0.451000 0.888600
DWMRI_gradient_0007	-0.002700 -0.940200 -0.340700
DWMRI_gradient_0008	0.661500 -0.372700 0.650800
DWMRI_gradient_0009	-0.494500 0.842100 -0.215000
DWMRI_gradient_0010	0.872200 -0.419100 -0.252000
DWMRI_gradient_0011	0.903000 0.181100 0.389700
DWMRI_gradient_0012	-0.292000 -0.816600 0.497900
DWMRI_gradient_0013	-0.258400 -0.023000 -0.965800

Sphere Radius: 1.00
Sphere Opacity: 0.00

MPR 3D view

Image2DView 1
S DWI 0
S Axial 64
S None 1.00 W/L Vis I> I>

Image2DView 2
S DWI 0
S SagRI 128
S None 1.00 W/L Vis I> I>

Image2DView 3
S DWI 0
S Coran 170
S None 1.00 W/L Vis I> I>

Dicom2Nrrd DTIPrep

Image File: Browse...
Description:
Make Default:
Add

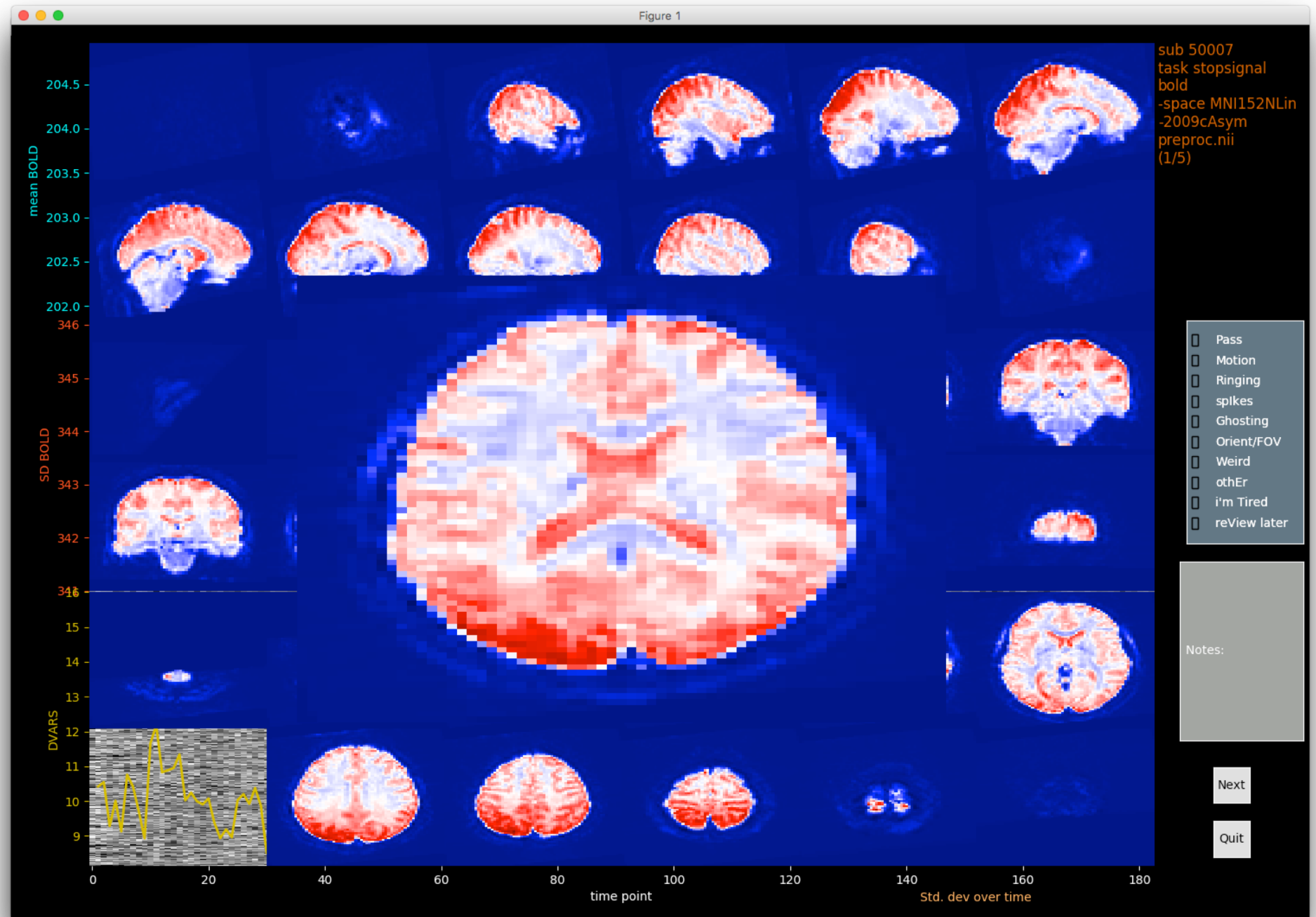
VisualQC _Diffusion

Focus on
generating ground
truth assessment of
quality

Excellent workflow

Less false positives

outlier detection!

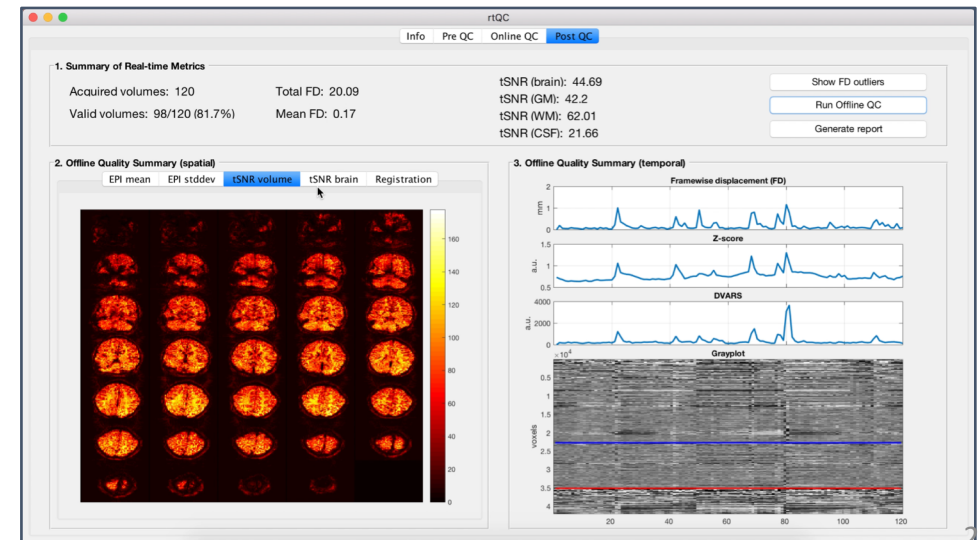
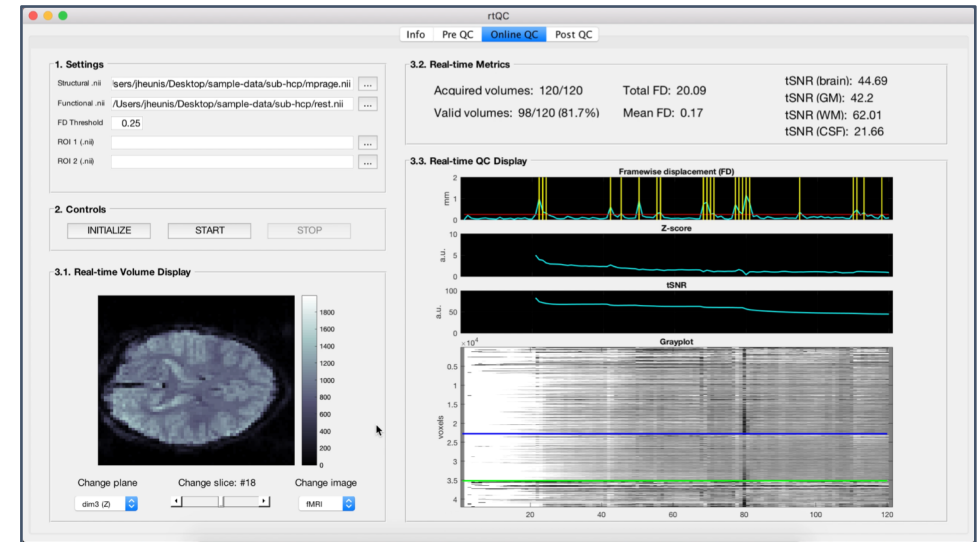


rtQC toolbox: Real-time quality control for fMRI

- Problems it solves so far
 - Easy-to-use QC!
 - Whole-brain and ROI-based QC.
 - Standardized metrics (e.g. tSNR, FD, Z).
 - Real-time visualization.
 - Real-time outlier detection.
 - Offline and real-time data comparisons.
 - ART-like output for integration with any pipeline.
 - Open-source (Matlab-based).
 - Automated QC summary.
 - Automated HTML report.
- Challenges it does not solve yet (coming soon)
 - Further real-time denoising (e.g. from physiological noise).
 - Multi-modal QC (e.g. EEG-fNIRS, etc.).

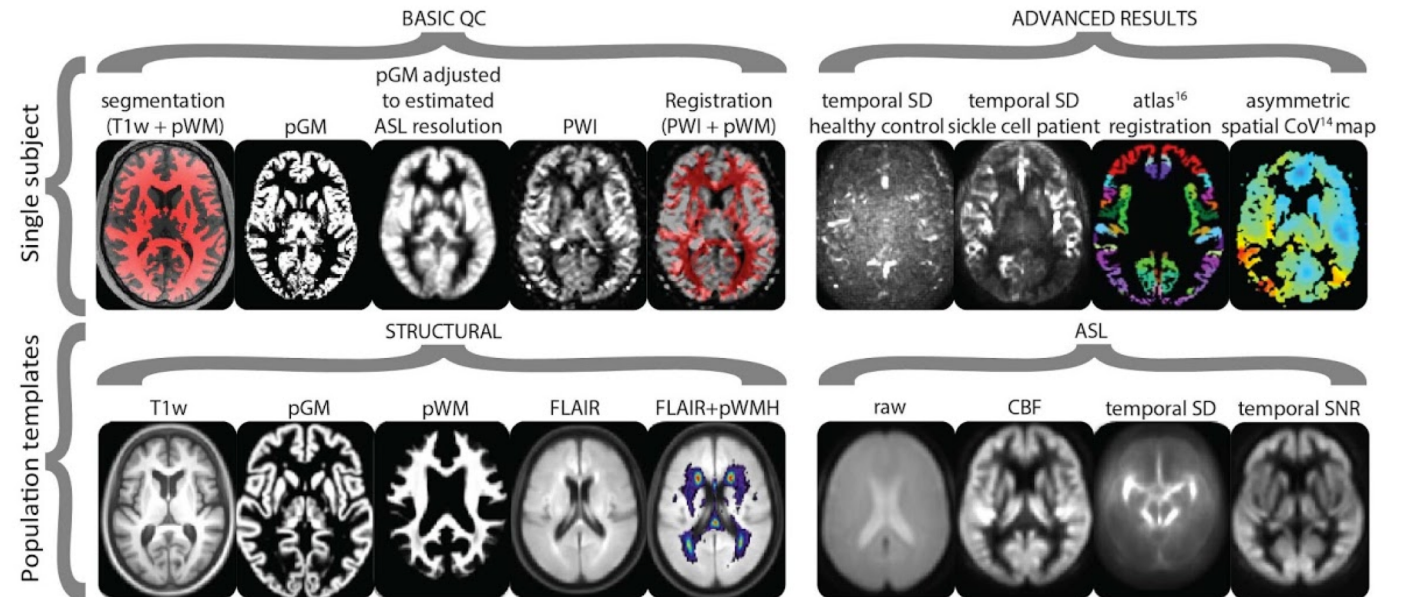
Heunis, S., et al. 2019. rtQC: An open-source toolbox for real-time fMRI quality control. *Proceedings of the annual meeting of the OHBM. 9th - 13th June; 2019; rome; Italy.*

Hellrung, L., et al. 2017. rtQC: An open-source collaborative framework for quality control methods in real-time functional magnetic resonance imaging. *Proceedings of the Real-time functional imaging and neurofeedback conference (rtFIN)'; 29th November -1st December; 2017; Nara; Japan.*



ExploreASL: QC for Arterial Spin Labeling

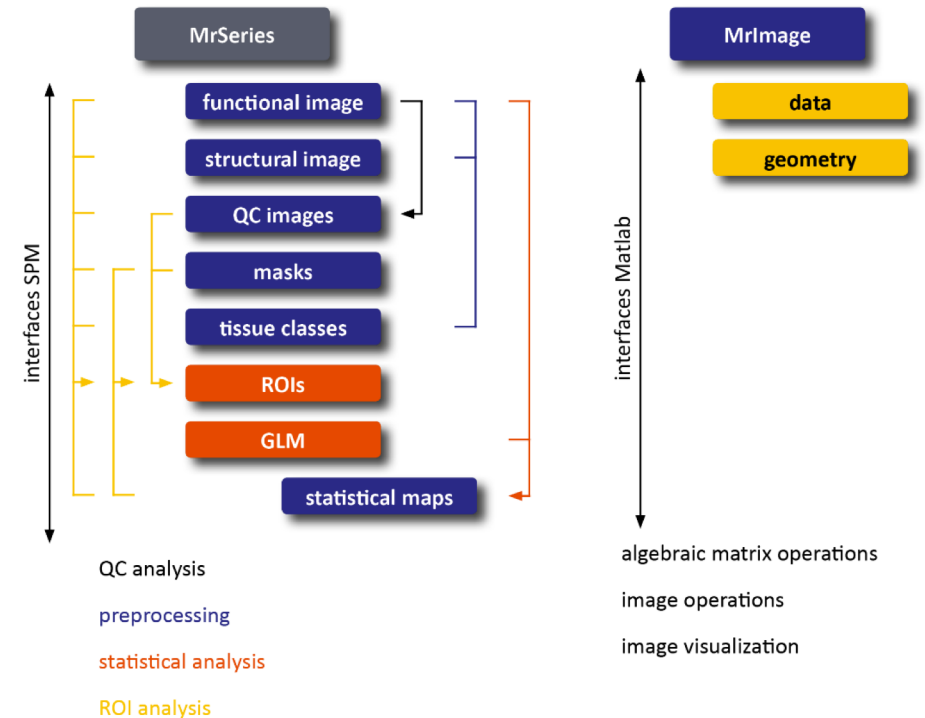
- Image processing and statistics of arterial spin labeling perfusion MR images
- Collaborative framework that facilitates cross-pollination between image processing method developers and clinical investigators



<https://sites.google.com/view/exploreasl>

uniQC: scanner and hardware QC

- Artefact detection needs fast switching between n-dimensional image operations and visualization
 - New fMRI sequences often include non-standard data (multi-echo, VASO) & QC heuristics have to be developed (e.g., Multi-Band slice leakage)
- Integrates with SPM well: makes QC for fMRI specific to the study w/ realistic analysis pipeline (e.g., CNR in ROIs for FX of interest)
- Ideal when num. of dimensions > 4



<https://github.com/CAIsr/uniQC>

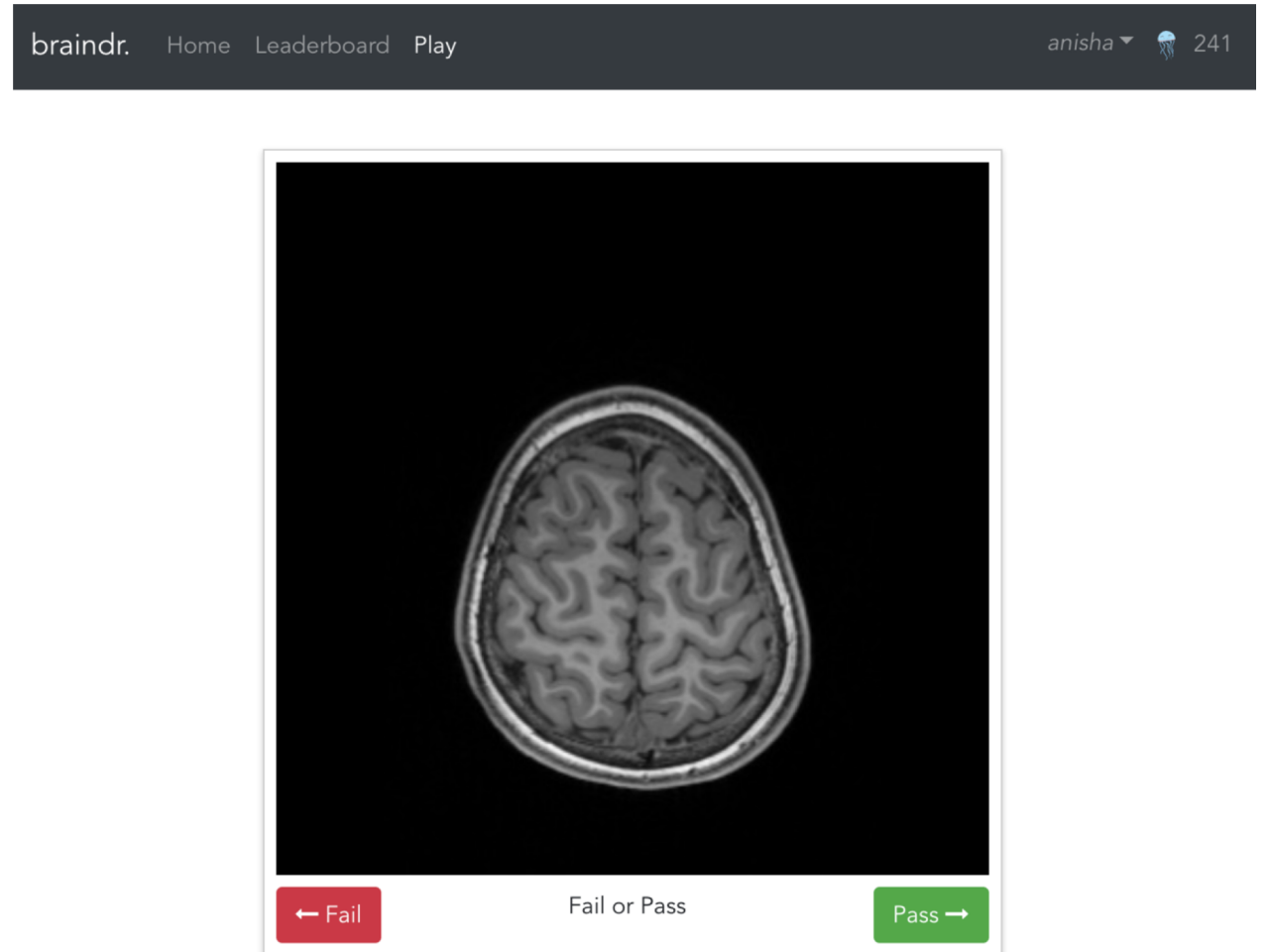
Crowd-sourcing QC

- The scale of neuroimaging studies is growing rapidly!!
- → QC burden grows exponentially
- Relying on QC experts for each of the 50K images is simply infeasible
- Going beyond a single lab!
 - Training



braindr

- Train "citizen scientists" with examples of various artefacts
 - Assess their ability via ground truth from experts
 - Web interface: easy and quick!
 - Gamified for engagement!
 - Multiple ratings for each image
 - High consensus → accurate!
-
- URL: braindr.us



Tips on tool selection – personal advice

- Either for use, or for contribution
- Ask detailed questions on what a tool does
- And more importantly what it doesn't do

- You know your problem best
- Do not compromise on your needs
- But keep an open mind

- Do not reinvent the wheel – it is not worth it!
 - For your own productivity

Thank you.

crossinvalidation.com

github.com/raamana

follow [@raamana_](https://twitter.com/raamana_)

Automatic identification of bad T1w scans

- mriqc via image quality metrics (IQMs)
- QoalaT via Freesurfer based metrics
- Few other research papers also: refer to niQC Zotero collection
 - incf.github.io/niQC