

Characterizing the Stability of Neuroimaging Analyses Through Perturbations in Experimental Design

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M.S.E. Johns Hopkins University,
B.Eng Carleton University



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Overview

- Re-introduction to broad thesis topic
- Progress to date
- Next steps
- Timeline for graduation

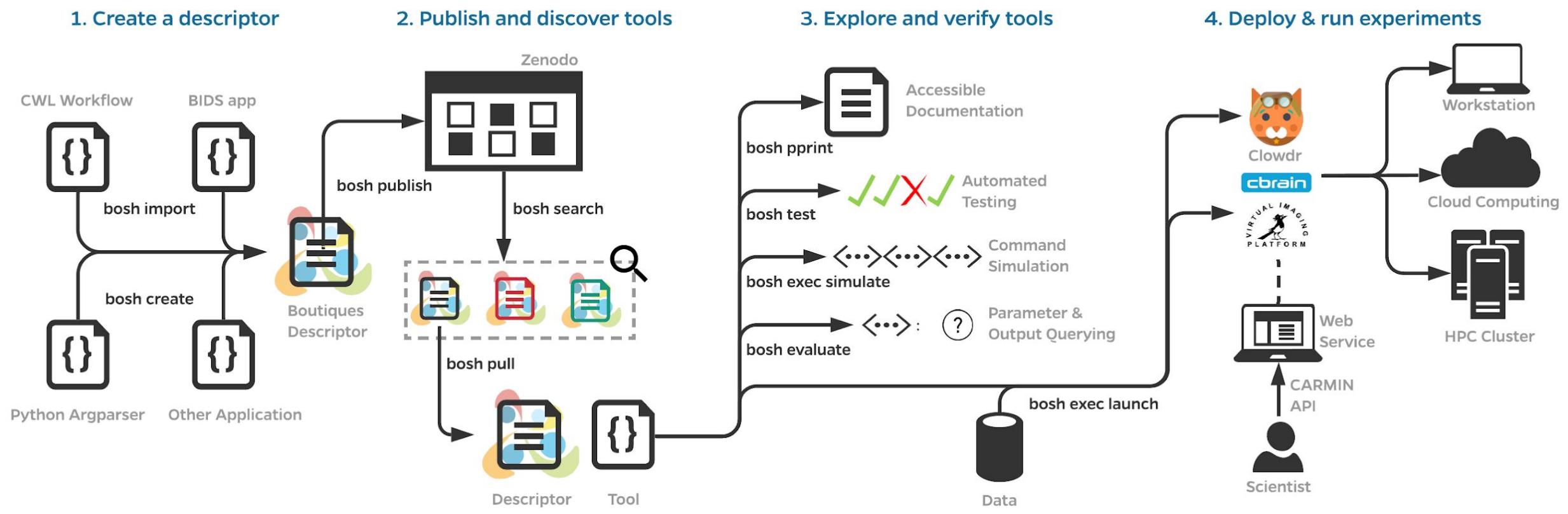
Thesis Objective

To explore and evaluate the effect that minor perturbations have on neuroimaging pipelines, thereby shedding light on the state of stability in neuroimaging and possible paths forward.

Chapter 1: Facilitating FAIR Tool Creation, Consumption, and Deployment

Complete

Boutiques & Clowndr Enable FAIR Tooling

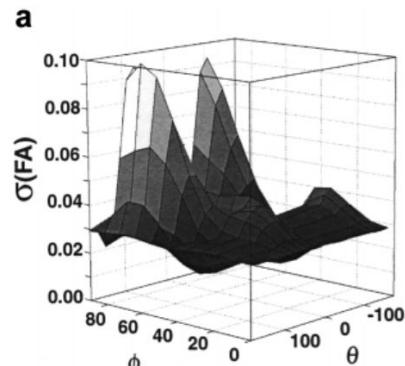


(Kiar, 2019)

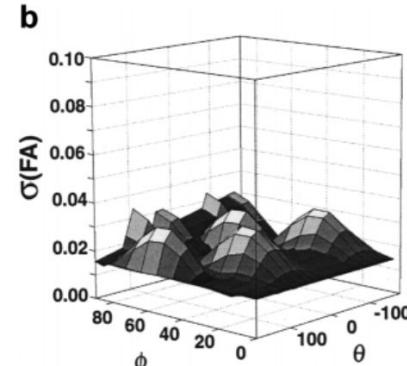
Chapter 2: Comparing Methods for Identifying Instabilities in Pipelines

Complete

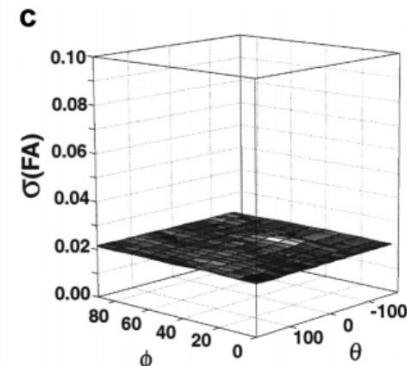
Identifying Instabilities in Neuroimaging



Scheme 1, Tetrahedral

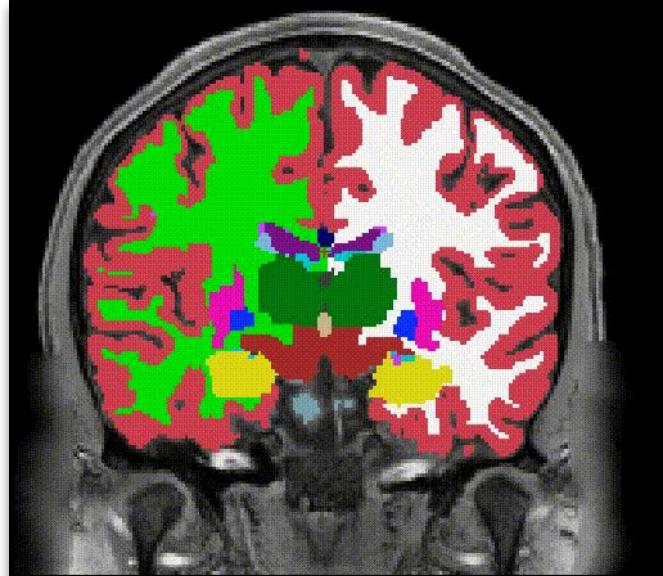


Scheme 10, Jones (N=6)



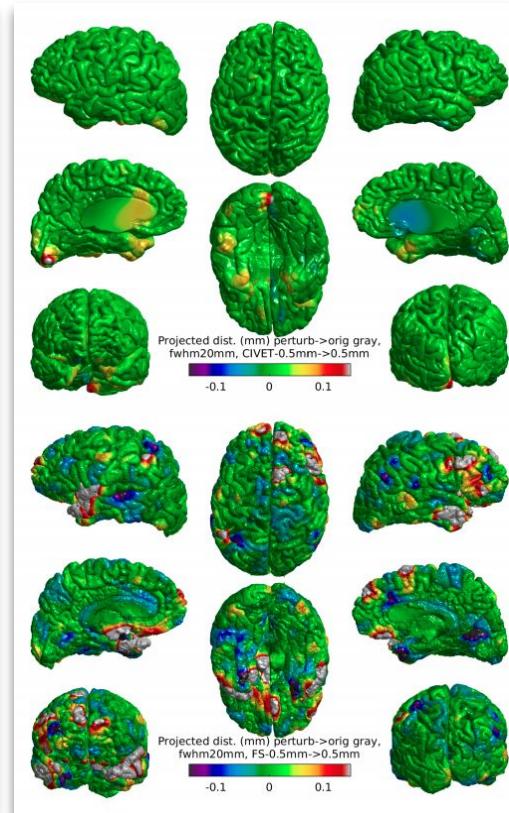
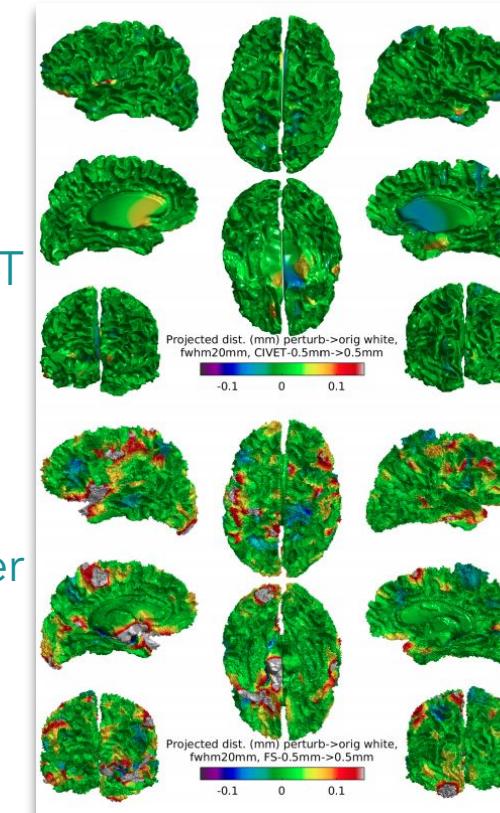
Scheme 8, Jones (N=30)

(Skare, 2000)



(Scaria, 2017)

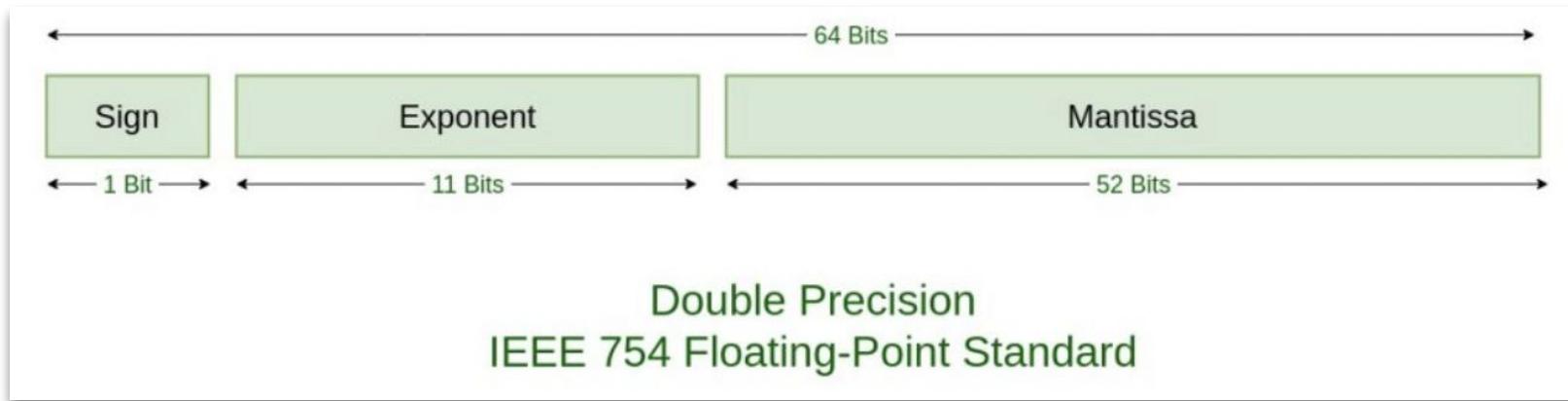
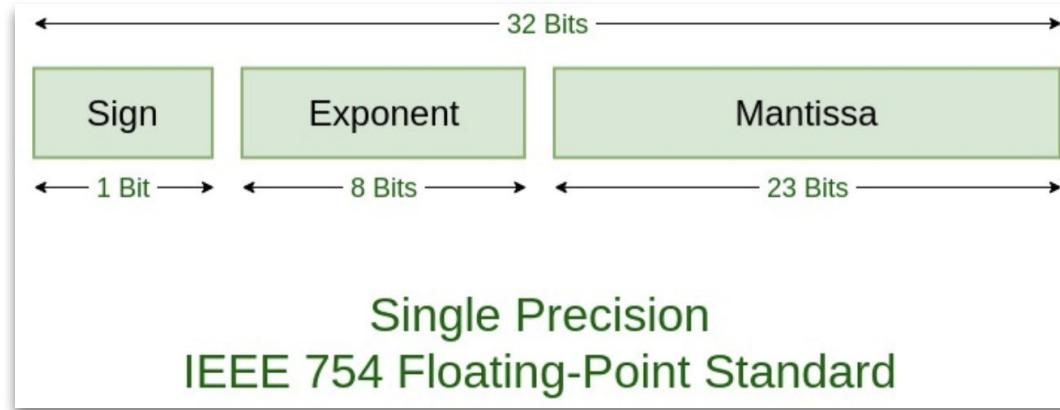
CIVET



Freesurfer

(Lewis, 2017)

Floating Point Representations are Finite



<https://www.geeksforgeeks.org/ieee-standard-754-floating-point-numbers/>

Floating Point Arithmetic is Inexact

E.g. addition is non associative for the following with 8-digits

$$\begin{aligned} (11111113. \oplus -11111111.) \oplus 7.5111111 &= 2.0000000 \oplus 7.5111111 = 9.5111111; \\ 11111113. \oplus (-11111111. \oplus 7.5111111) &= 11111113. \oplus -11111103. = 10.000000. \end{aligned}$$

(Parker, 1997)

Monte Carlo Arithmetic (MCA)

Inexact quantities become random variables

$$\tilde{x} = \text{inexact}(x, s, \xi) = x + 2^{e-s} \xi \quad \text{where } e \text{ is the order of magnitude of } x$$

$$t\text{-digit_precision}(x) = \begin{cases} x & \text{if } x \text{ can be expressed exactly with } t \text{ digits} \\ \text{inexact}(x, t, \xi) & \text{otherwise.} \end{cases}$$

(Parker, 1997)



Verificarlo v0.2.3

build passing DOI [10.5281/zenodo.3370928](https://doi.org/10.5281/zenodo.3370928)

A tool for automatic Montecarlo Arithmetic analysis.

Setup

Compile C/C++/Fortran lib with Verificarlo

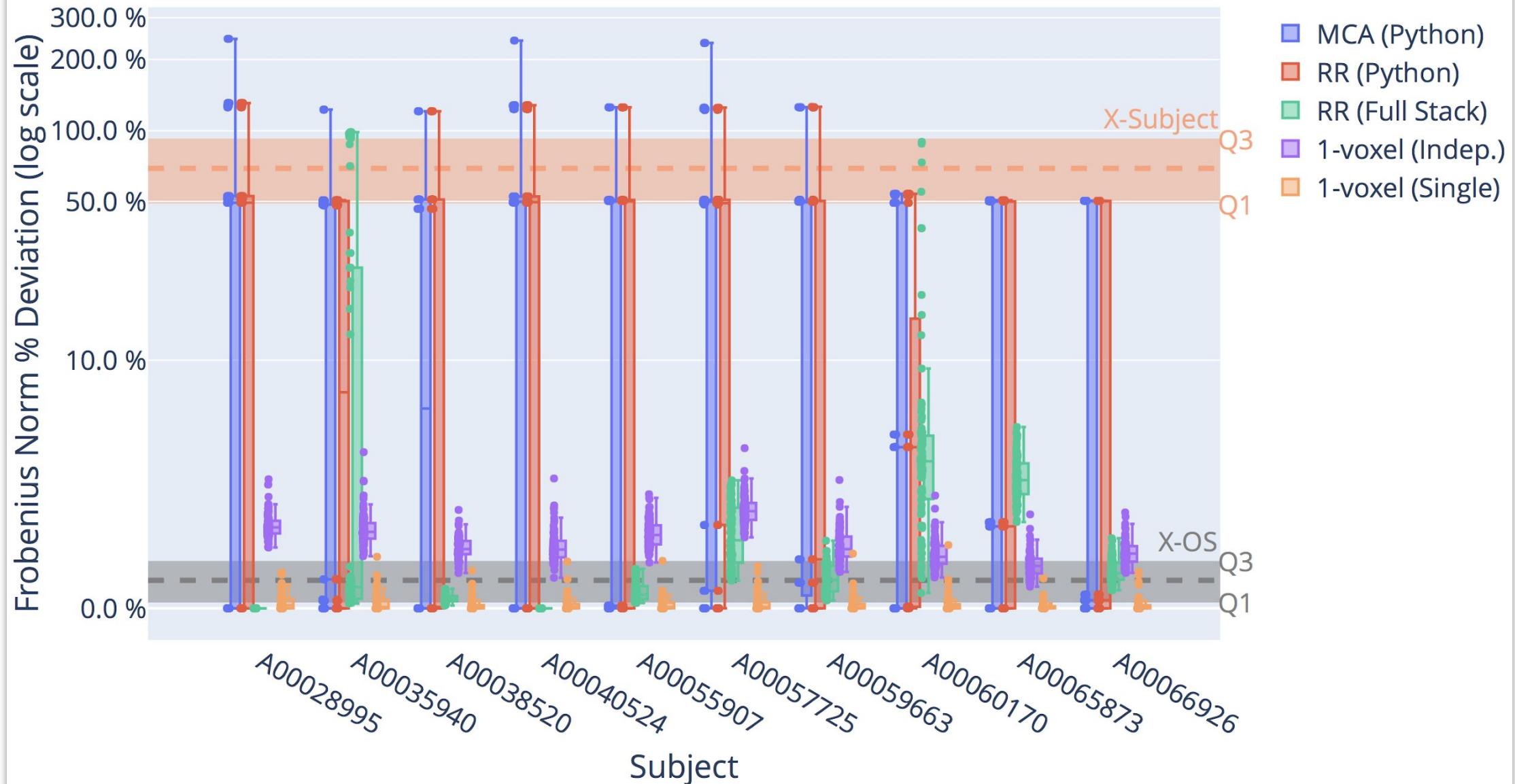
Instrumentation

launch pipeline...

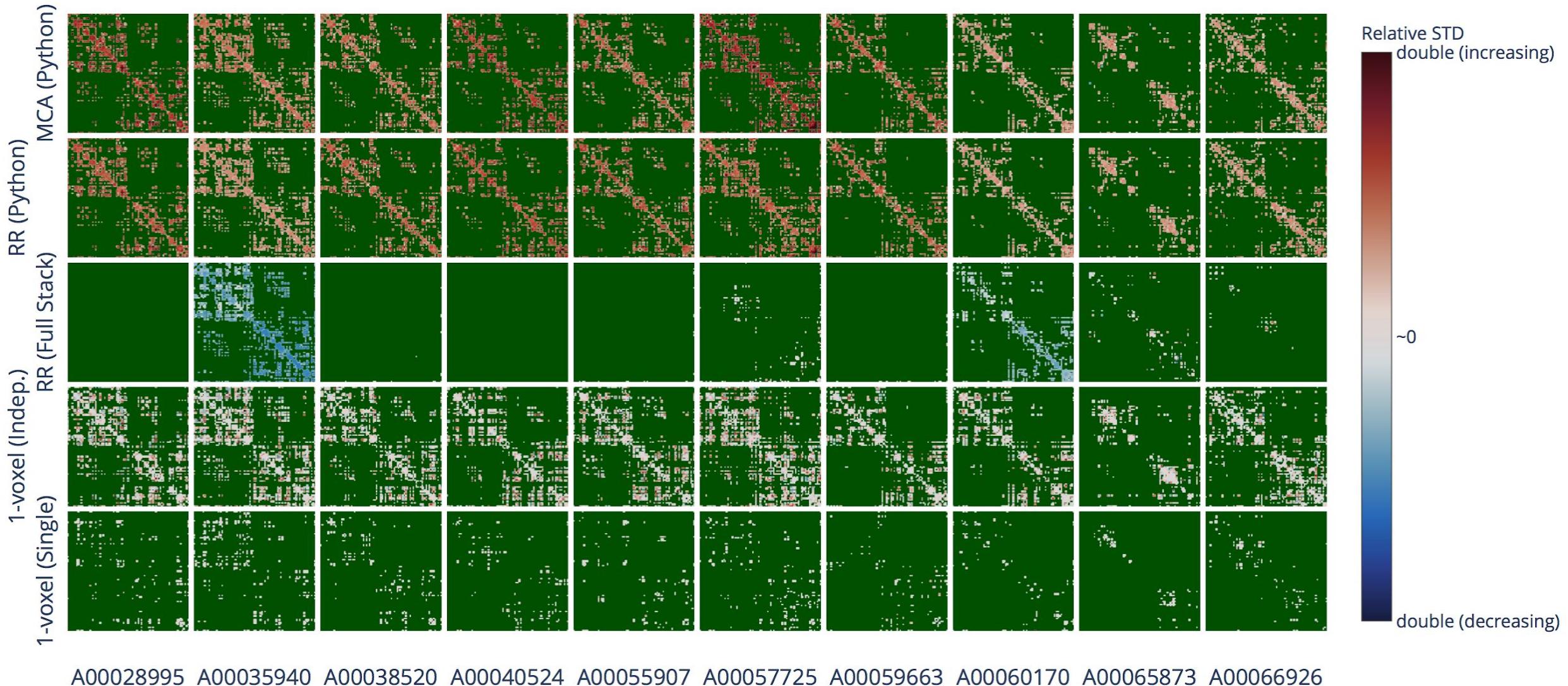
1. if floating point operation:
2. convert {float, double} -> {double, quad}
3. (PB) simulate unrounding/rounding
4. perform operation
5. (RR) simulate unrounding/rounding
6. truncate {double, quad} -> {float, double}
7. endif

... re-run pipeline N times

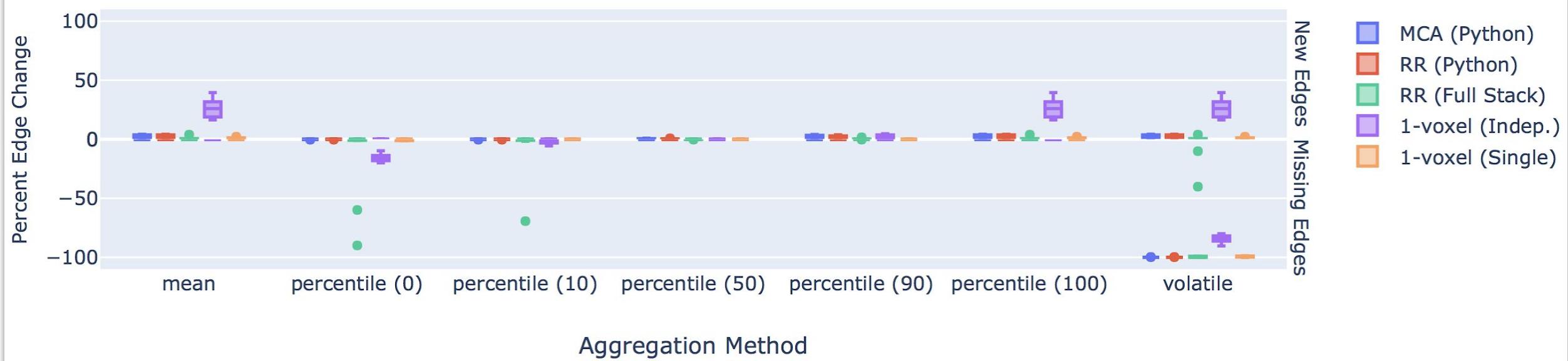
Differences in Perturbed Structural Connectomes



Structural Differences Across Perturbation Modes and Subjects



Deviations in Aggregated Edge Count from Reference



Chapter 3: Evaluating Analytical Impact of Instabilities

In Progress

Chapter 4: Improving Pipeline Stability Through Statistical Aggregation

In Progress

Chapter 5: Informing Tool Selection Based on the Stability of Pipelines

ToDo

Thesis Outline

Chapter 1: Facilitating FAIR Tool Creation, Consumption, and Deployment

Chapter 2: Comparing Methods for Identifying Instabilities in Pipelines

Chapter 3: Evaluating Analytical Impact of Instabilities

Chapter 4: Improving Pipeline Stability Through Statistical Aggregation

Chapter 5: Informing Tool Selection Based on the Stability of Pipelines



Timeline

Ph.D. Start (September, 2017)



Ch. {1, 2, 3, 4, 5}

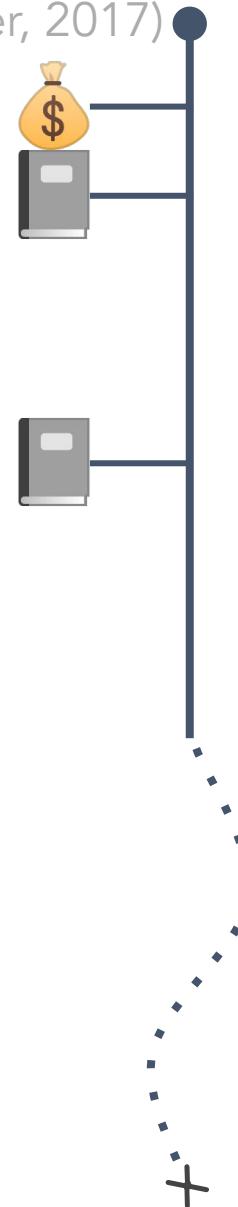


Ph.D. Start (September, 2017)

NSERC CGS-D (March, 2018)

Boutiques (2nd author; March, 2018)

Clowdr (March, 2019)



The screenshot shows the GigaScience journal homepage with a green header. The main content area displays the article 'Boutiques: a flexible framework to integrate command-line applications in computing platforms' by Tristan Glatard et al. The article is from Volume 7, Issue 5, May 2018, with a DOI of <https://doi.org/10.1093/gigascience/giy016>. It was published on 23 March 2018.

The screenshot shows the frontiers in Neuroinformatics journal homepage with a dark header. The main content area displays the article 'A Serverless Tool for Platform Agnostic Computational Experiment Management' by Gregory Kiar et al. The article is from Front. Neuroinform., 05 March 2019, with a DOI of <https://doi.org/10.3389/fninf.2019.00012>. It has 1,631 total views. The article is categorized under TECHNOLOGY REPORT ARTICLE.

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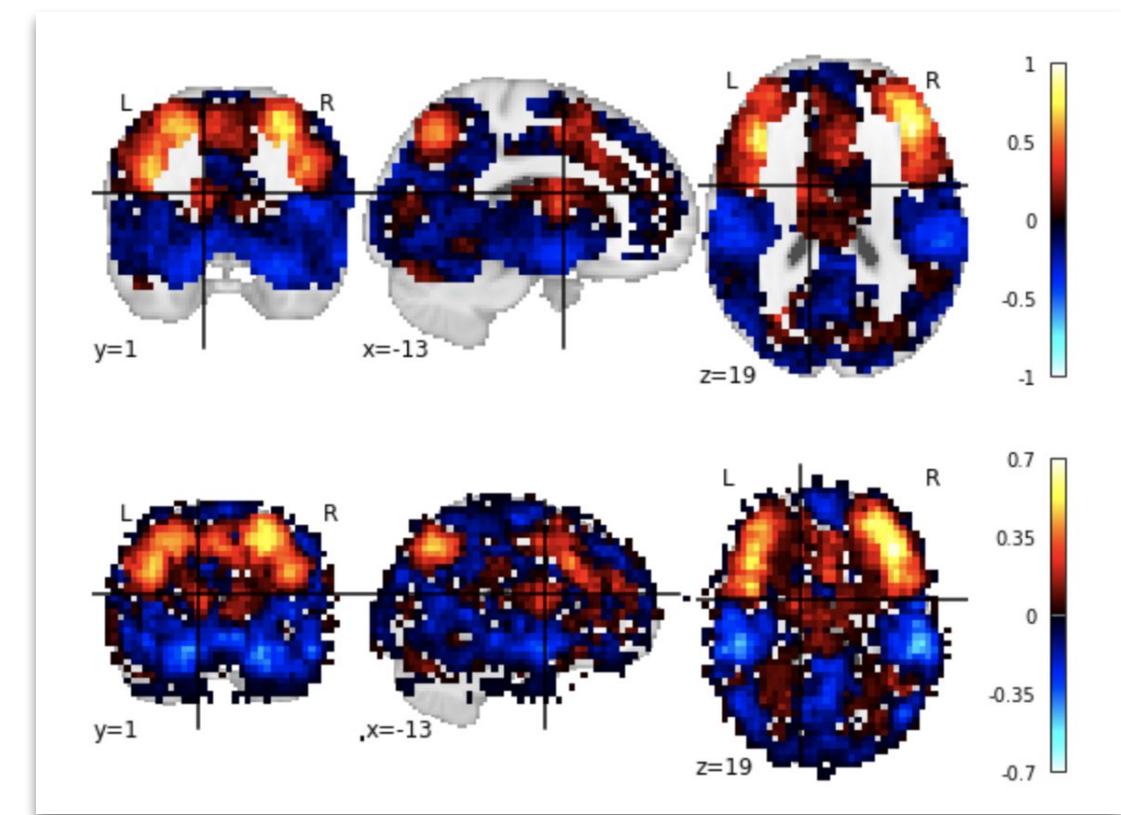
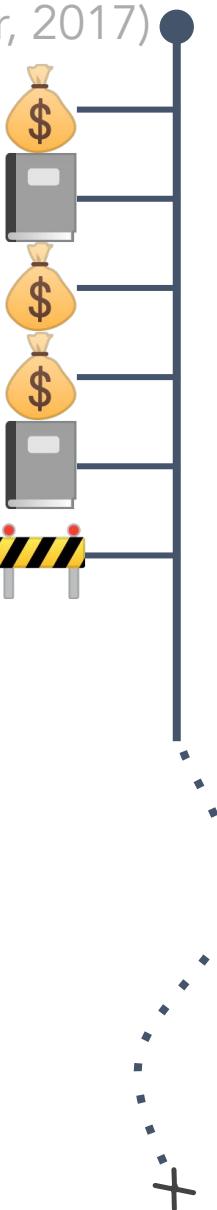
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NSERC MS-FSS (December, 2018)

Mitacs Globalink (February, 2019)

Clowdr (March, 2019)

DL Aggregation Method (April, 2019)



Ch. {1, 2, 3, 4, 5}

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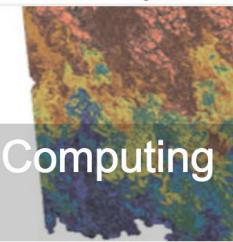
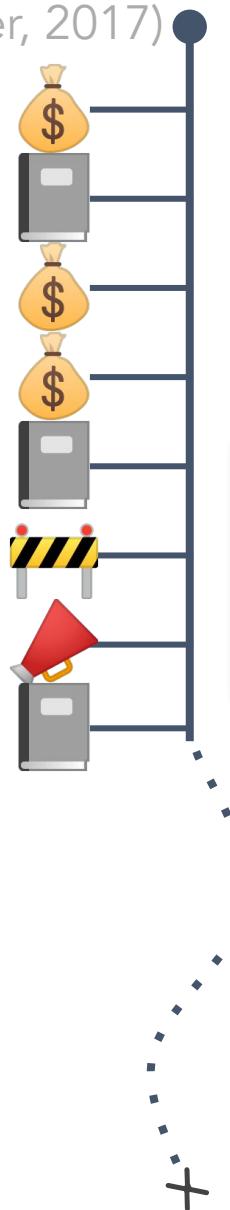
Mitacs Globalink (February, 2019)

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DL Aggregation Method (April, 2019)

Exploring Perturbations (Nov, 2019)

Exploring Perturbations (Dec, 2019)



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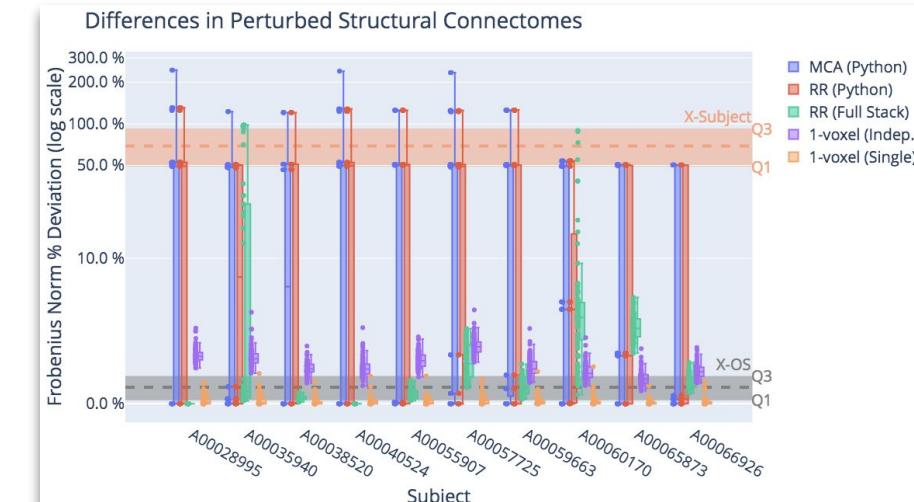
arXiv.org > q-bio > arXiv:1908.10922

Quantitative Biology > Neurons and Cognition

Comparing Perturbation Models for Evaluating Stability of Neuroimaging Pipelines

Gregory Kiar, Pablo de Oliveira Castro, Pierre Rioux, Eric Petit, Shawn T. Brown, Alan C. Evans, Tristan Glatard

(Submitted on 28 Aug 2019 (v1), last revised 17 Oct 2019 (this version, v2))



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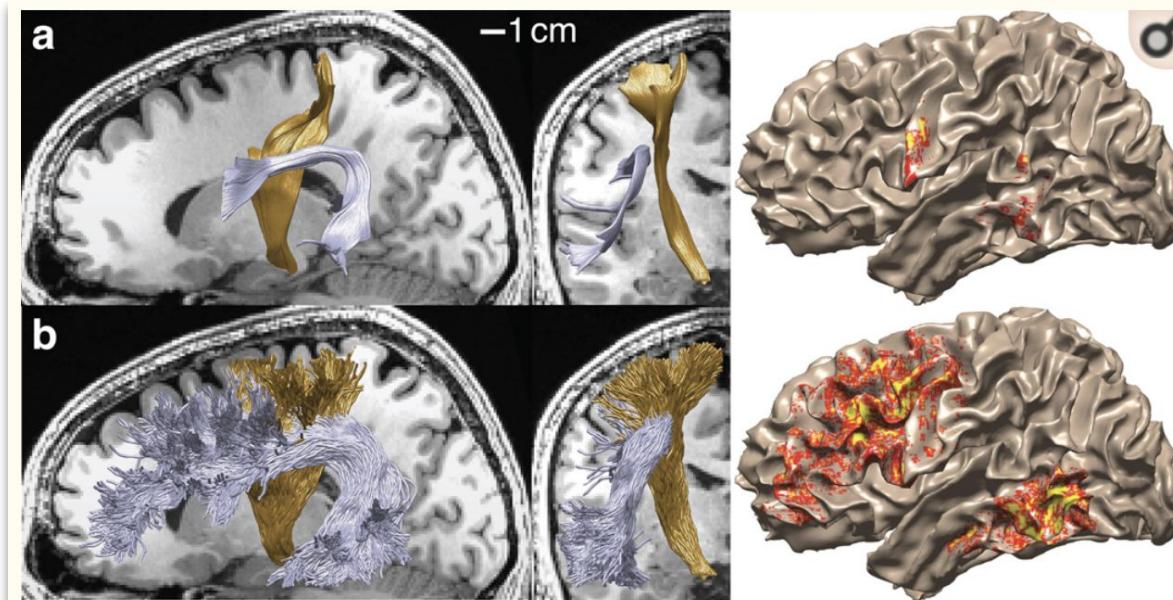
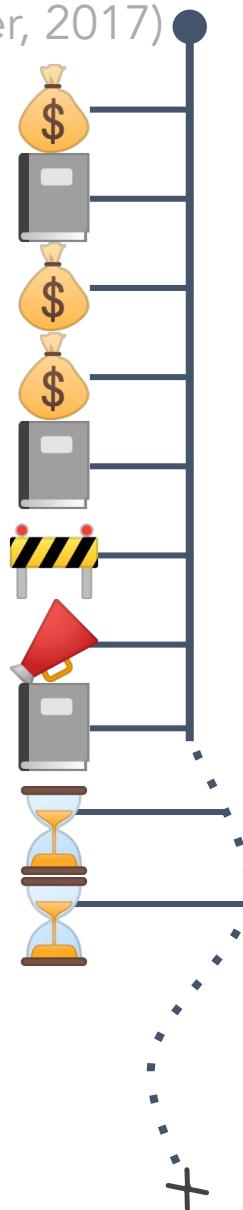
DL Aggregation Method (April, 2019)

Exploring Perturbations (Nov, 2019)

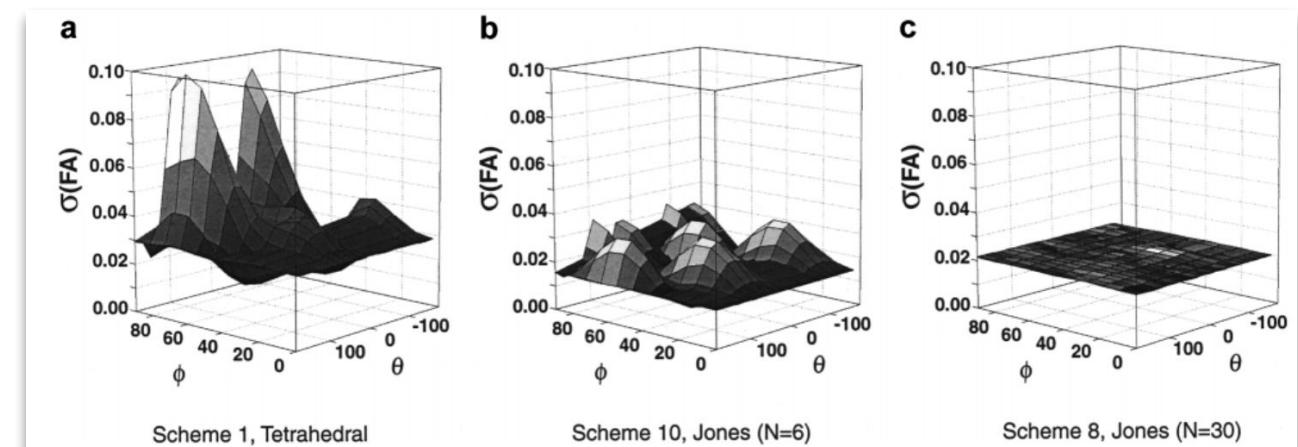
Exploring Perturbations (Dec, 2019)

Exploring Analytic Impact (2019)

Relative Algorithmic Stability (2020)



(Pestilli, 2015)



(Skare, 2000)

Ch. {1, 2, 3, 4, 5}

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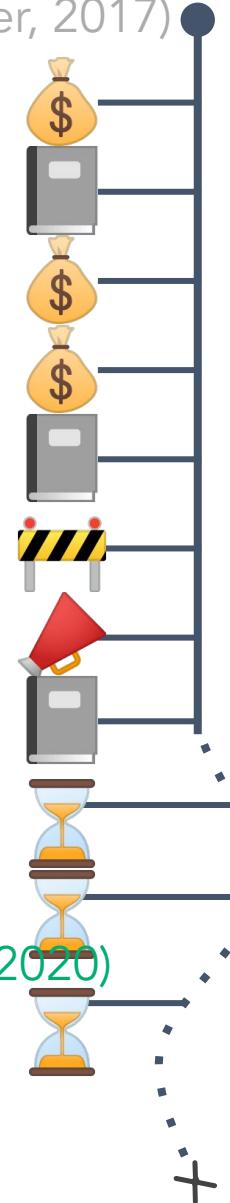
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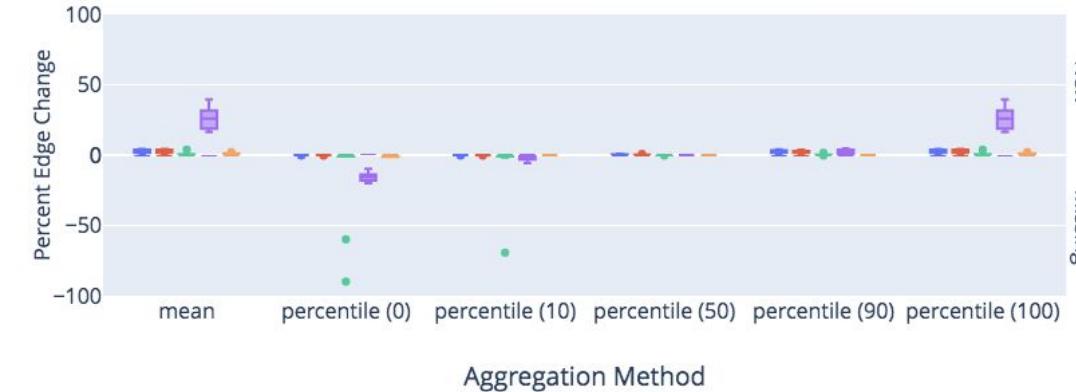
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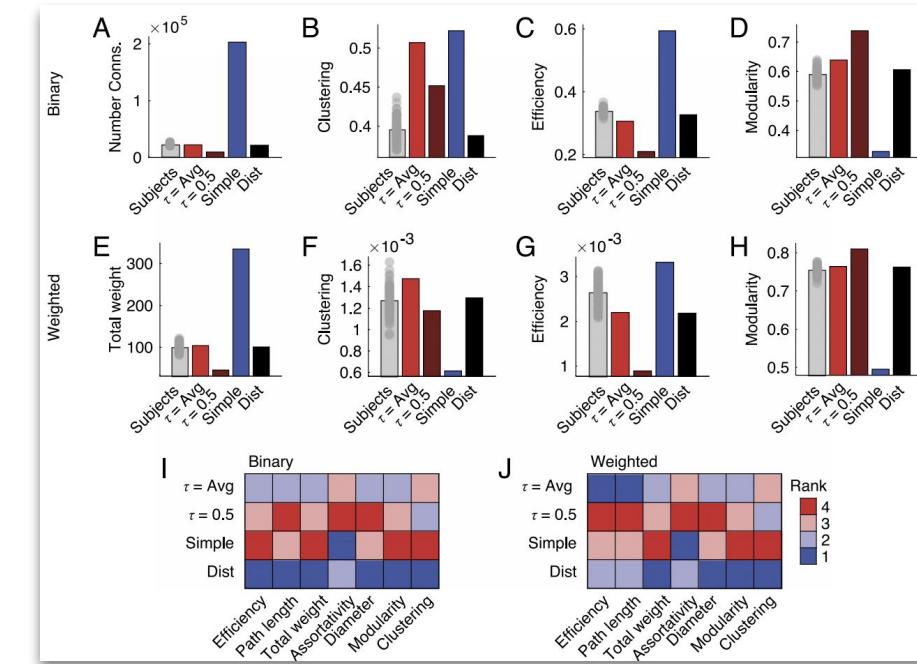
Evaluating Aggregation Methods (2020)



Deviations in Aggregated Edge Count from Reference



Legend:
█ MCA (Python)
█ RR (Python)
█ RR (Full Stack)
█ 1-voxel (Indep.)
█ 1-voxel (Single)



(Betzel, 2019)

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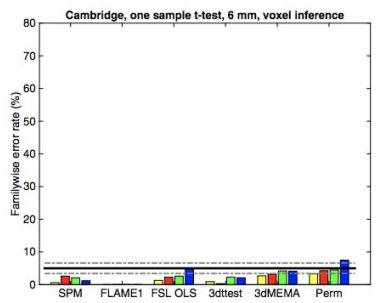
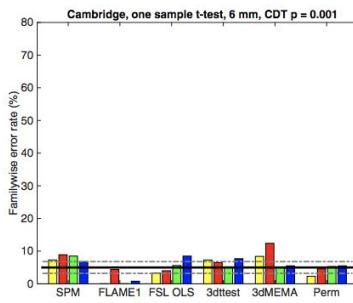
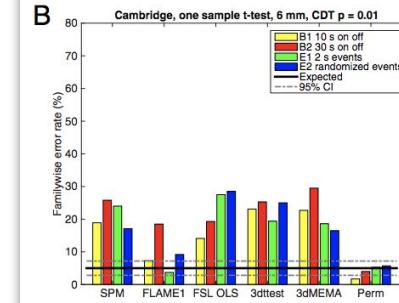
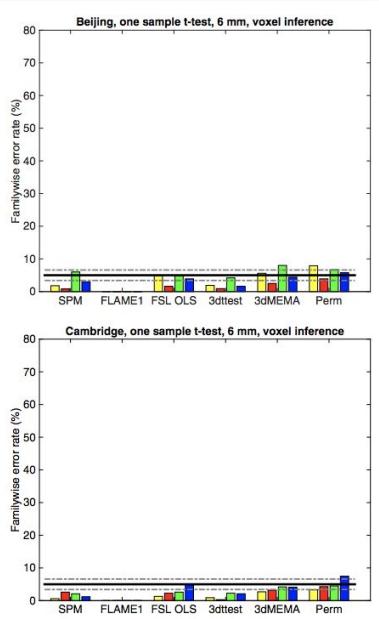
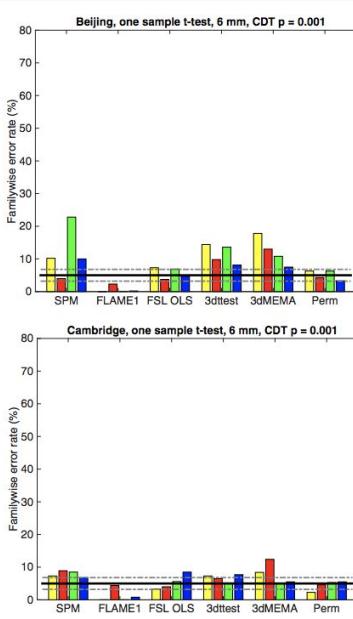
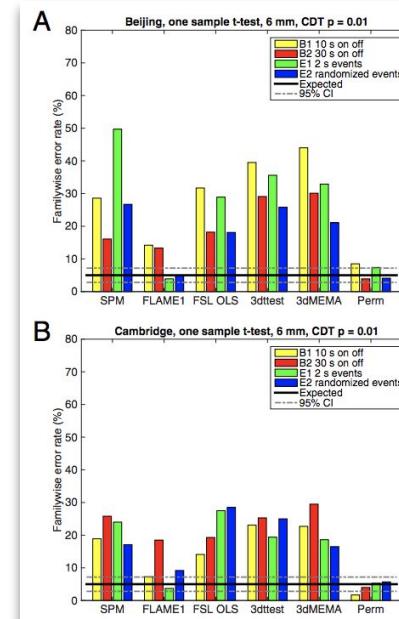
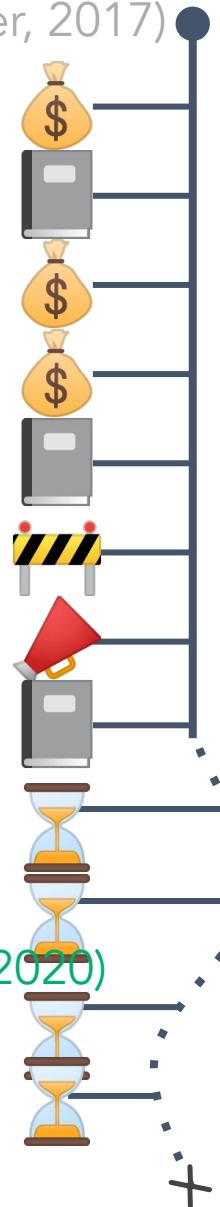
Exploring Perturbations (Dec, 2019)

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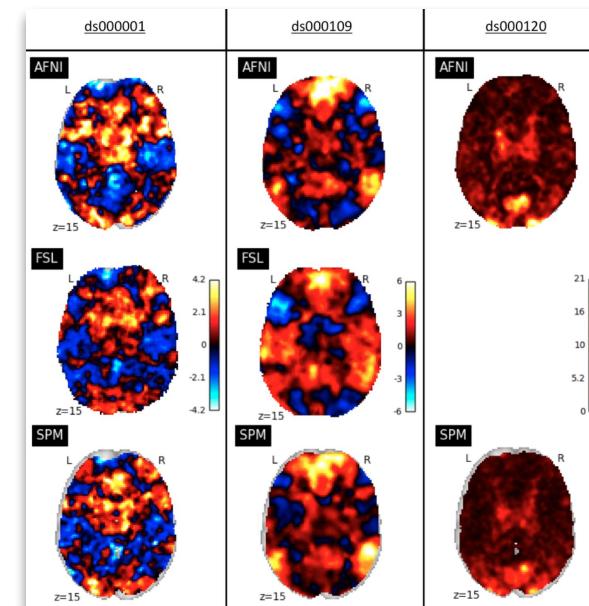
Relative Algorithmic Stability (2020)

Evaluating Aggregation Methods (2020)

Tool Comparison & Ranking (2020)

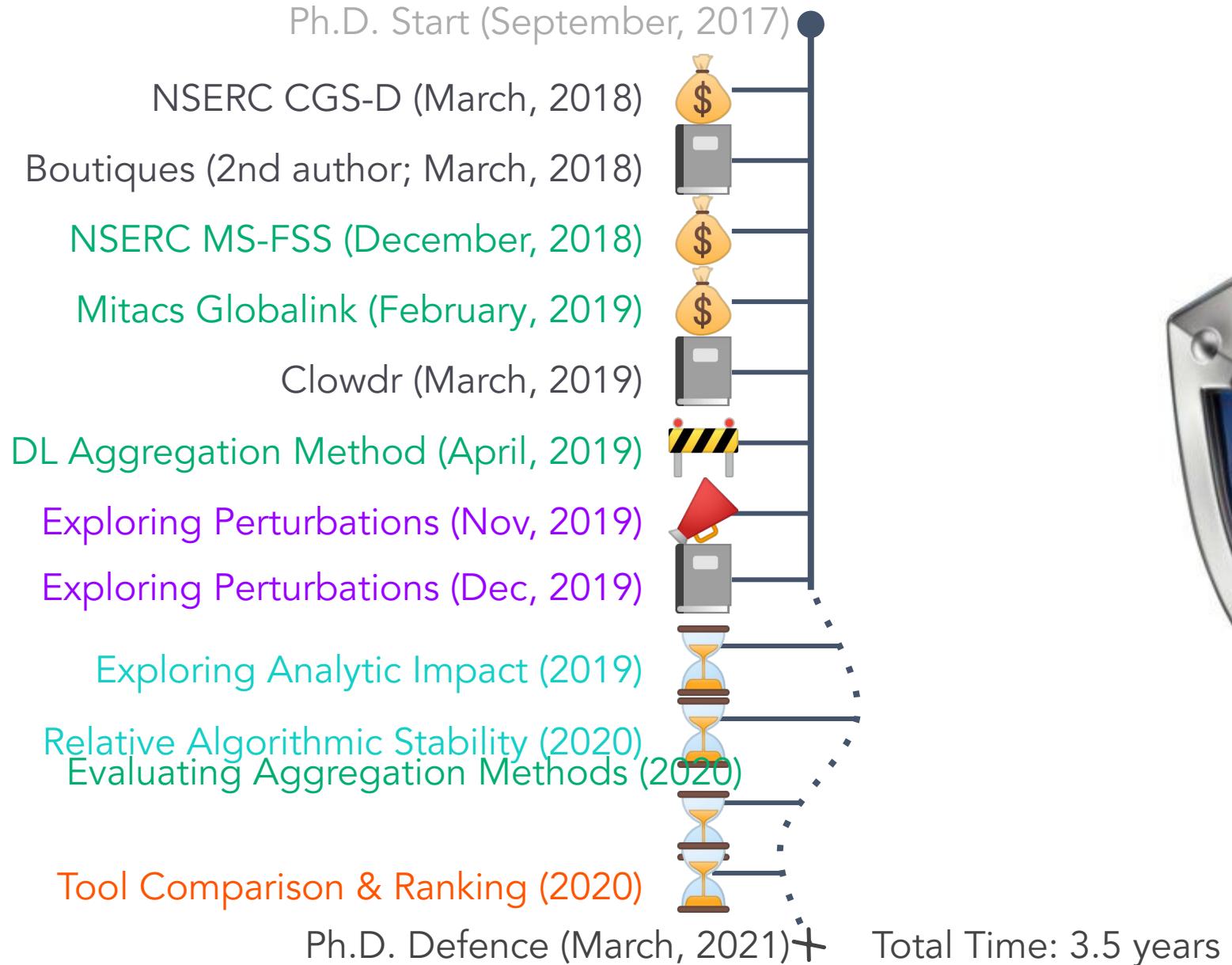


(Eklund, 2016)

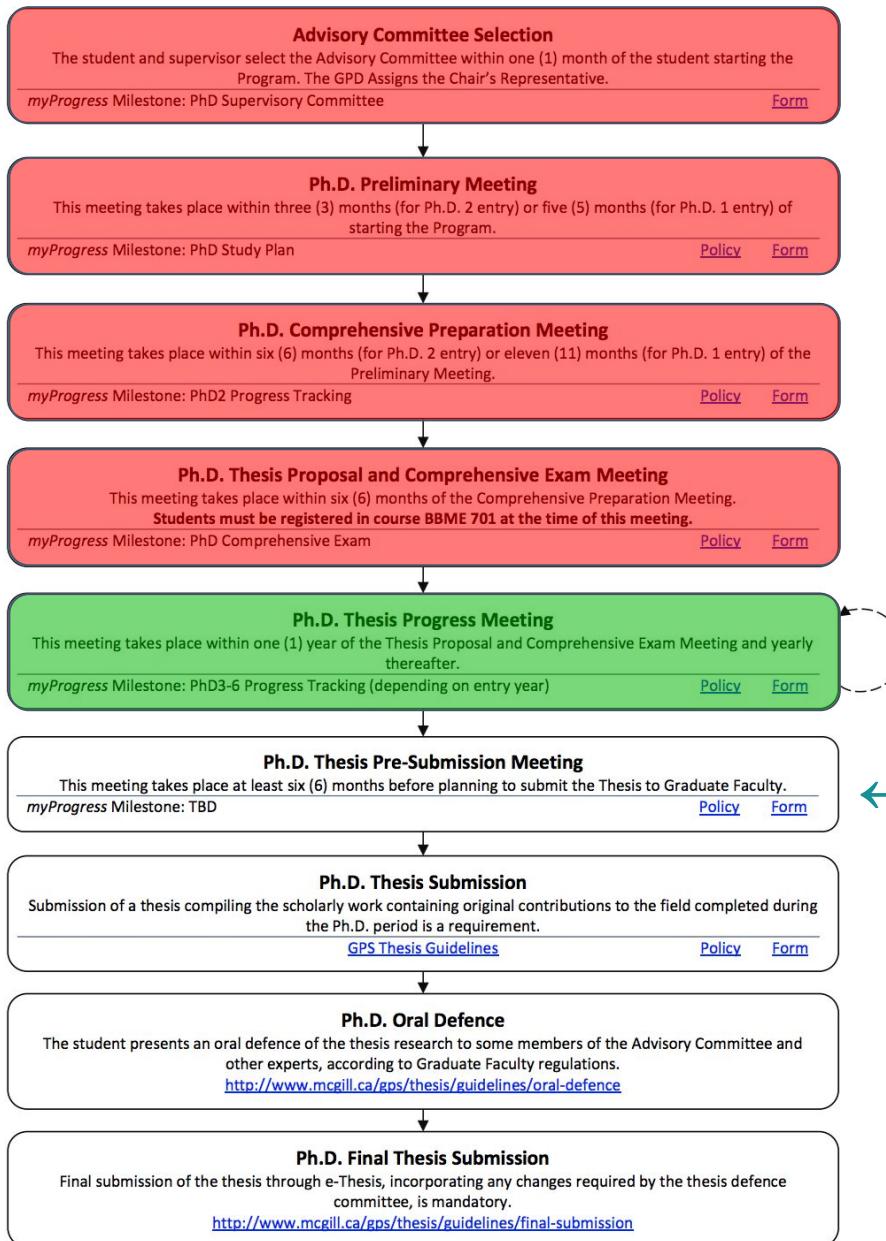


(Bowring, 2019)

Ch. {1, 2, 3, 4, 5}



we are here →



← approval required 6 months pre-defense

i.e. this time next year

All code mentioned in this presentation is publicly available on GitHub.

Thanks!

Find me @



gkiar



g_kiar



greg.kiar@mail.mcgill.ca

Acknowledgements



...



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Questions?