
Faculty Speed Talks

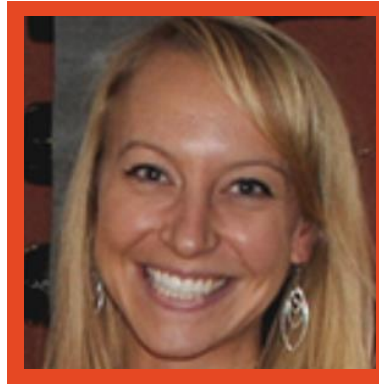
Department of Mathematical and Statistical Sciences



Dr. Yu



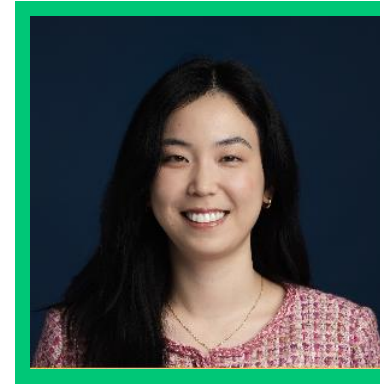
Dr. Clough



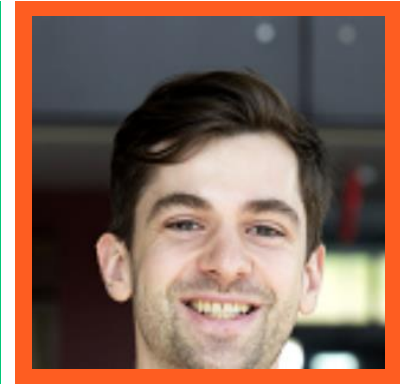
Dr. Hamilton



Dr. Cirkovic



Dr. Choi



Dr. Ongie

MSSC Colloquium, Fall 2026

Dr. Yu

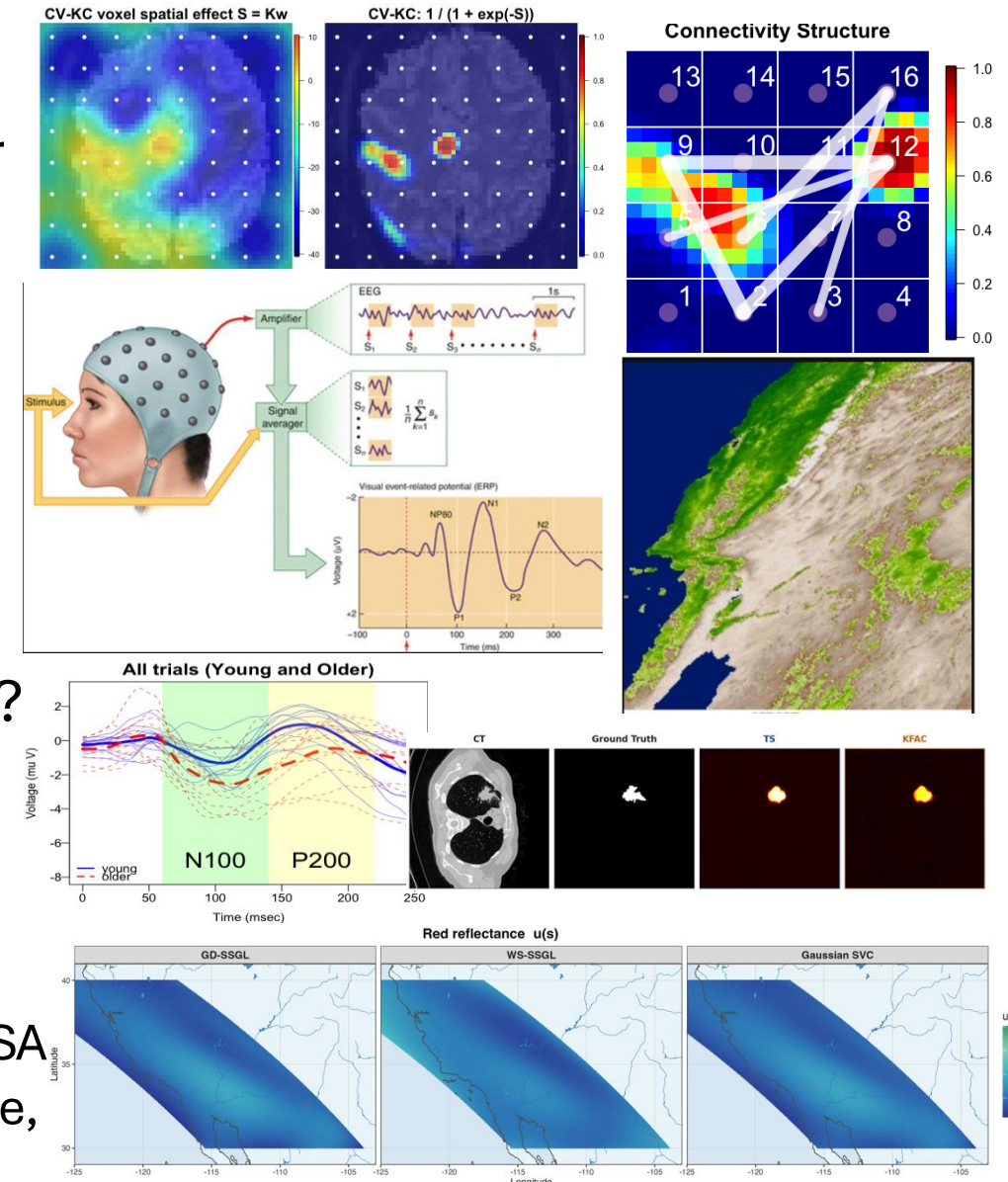
Bayesian methods + Multiscale Modeling



Bayesian Space-Time Modeling and Variable Selection

- Which brain areas get activated
- Which brain regions are connected each other
- When the brain signals reach their peak
- X-ray image classification and CT 3D image segmentation
- Which predictors have spatial effects on the response variable?
 - Is the effect constant or spatially dependent?
- Which parts have a constant effect? Which parts are spatially varying?
- How the effects change over time?

Applications: CV-fMRI, EEG/ERP, infectious disease, NASA environmental remote sensing, skin conductance response, X-rays, CT scans



Current Focus: Multiscale Modeling

Multiscale Spatiotemporal Negative Binomial (MSSTNB)

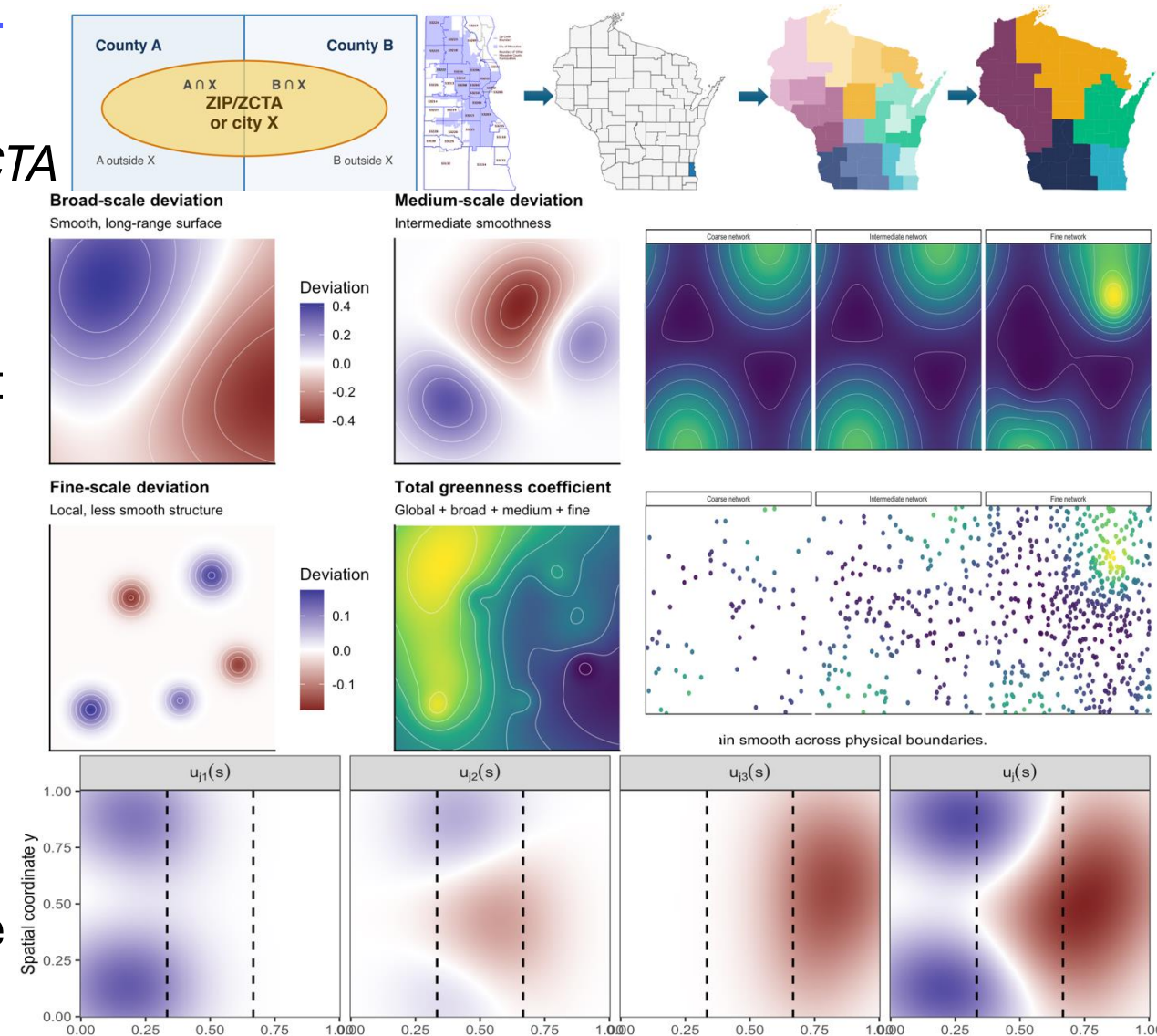
- **Mixed support: coherent** inference at *zip/ZCTA* and *county level* that are **not necessarily nested**.
- **Support-aligned multiscale covariates** that contribute *how coarse-level counts are allocated to finer areas*.

TA-GD-SSGL

- Spatial coefficient surface = global effect + multiresolution deviation effects

DRT-GD-SSGL

- What new effect information appears when the spatial data become finer?



Helpful Skills

Math: Probability, Linear Algebra

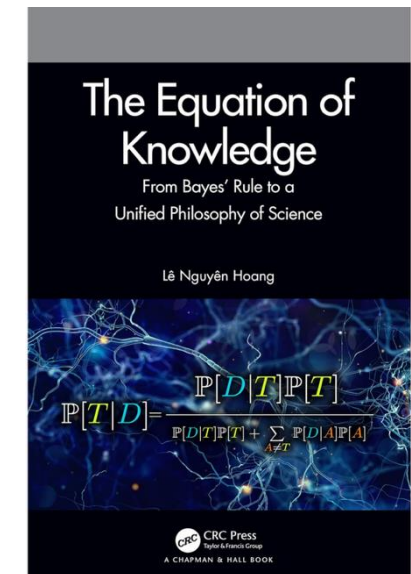
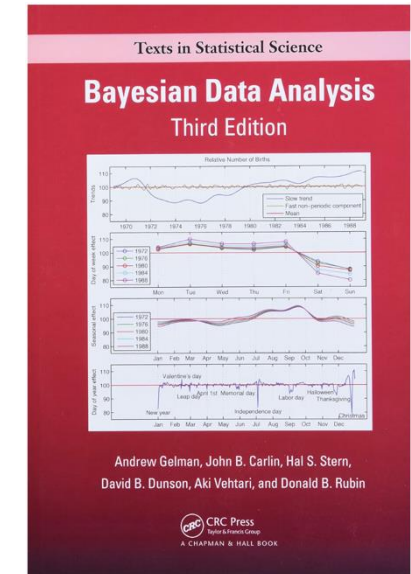
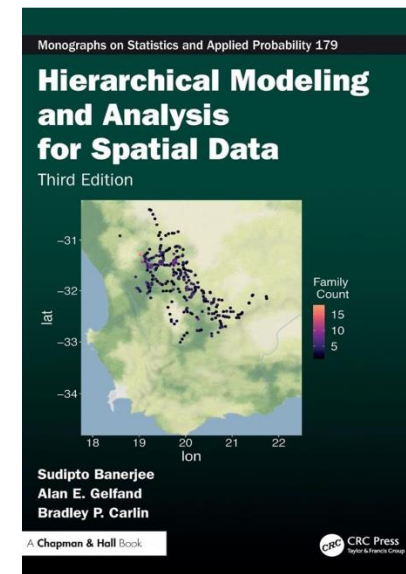
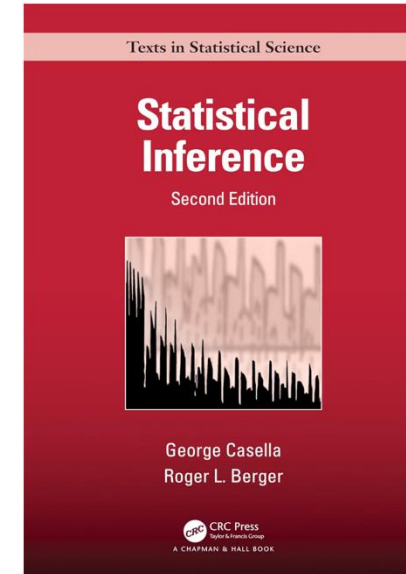
Stats: Classical & Bayesian Inference, Spatial Statistics, Time Series Analysis, Gaussian Processes, Shrinkage, Variable Selection

Machine/Deep Learning: CNN (V-Net)

Algorithms: MCMC, EM, Variational, Laplace

Tools: R, Rcpp, Python, PyTorch, parallel computing

Willingness to learn and communicate



Dr. Clough

Imaging and Lung Injury

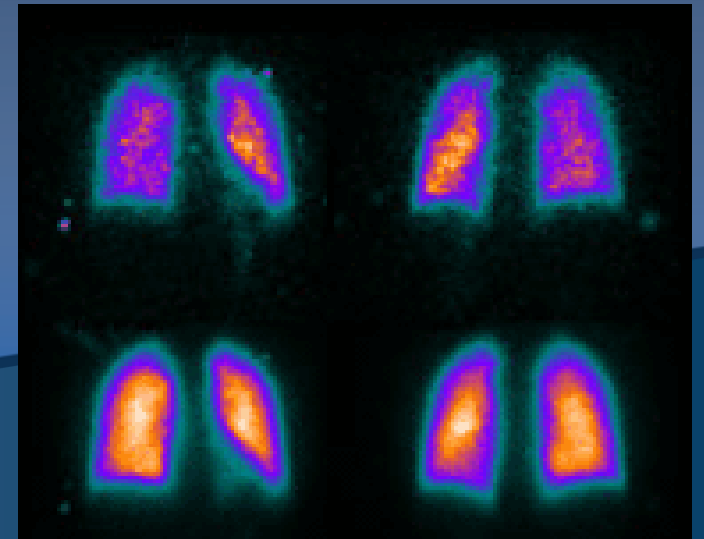


Single Photon Emission Computed Tomography (SPECT)

SPECT is a portable, expensive, noninvasive imaging system that requires ionizing radiation

- Detect emitted gamma rays externally.
- *Reconstruct data to obtain 4D maps of distribution.*
- Use mathematical modeling to quantify kinetic parameters indicative of disease/injury.

Objective: Detect, grade and predict acute lung injury in patients in the ICU.

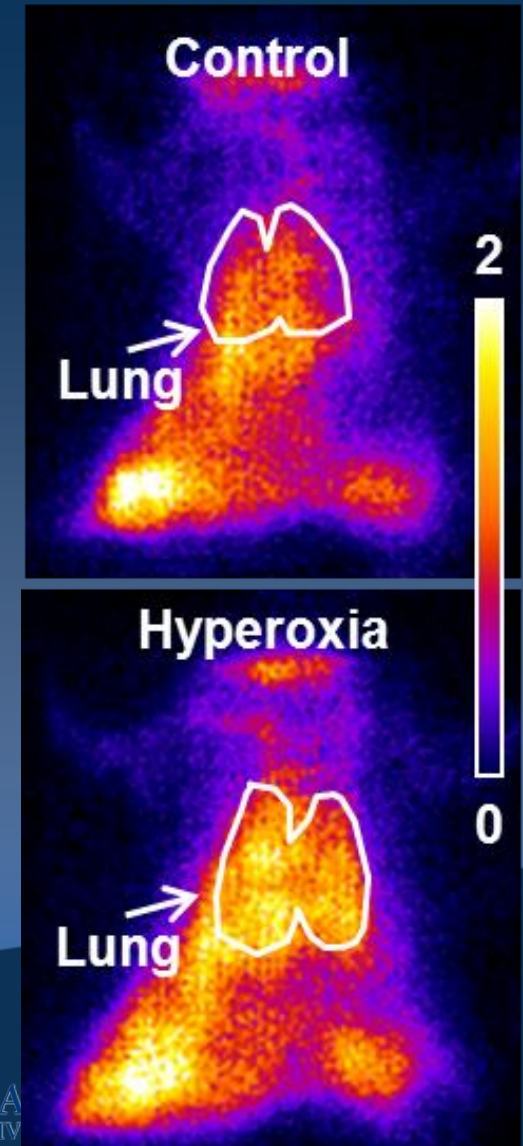


Research Focus: Development of fast algorithms that reliably recover images and relevant physiological information from SPECT data.

- Include a priori info
- Develop fast acquisition protocols
- Use iterative recon algorithms
- Utilize 4D data
- Develop appropriate pharmacokinetic models of the tracer
- Identify pathways for targeted therapy
- Predict disease progression



HMPAO Images



Helpful Tools and Techniques:

- Math: Integral equations, (linear Fourier transforms), convex optimization, regularization methods.
- Prob/Stat: Shallow learning, parameter identification, pharmacokinetic modeling
- Computing: HPC, GPU computing, data acquisition hardware and software
- Biomed Eng: Animal experiments, build imaging equipment

Further Reading:

- Pharmacokinetics of ^{99m}Tc -HMPAO in isolated perfused rat lungs. *J Appl Physiol* 2019
- Protection by inhaled hydrogen therapy in a rat model of acute lung injury can be tracked in vivo using molecular imaging. *Shock* 2017
- Biomarkers for radiation pneumonitis using noninvasive molecular imaging. *J Nucl Med* 2016



Dr. Hamilton

*Inverse Problems and
Electrical Impedance Tomography*



Inverse Problems & Imaging

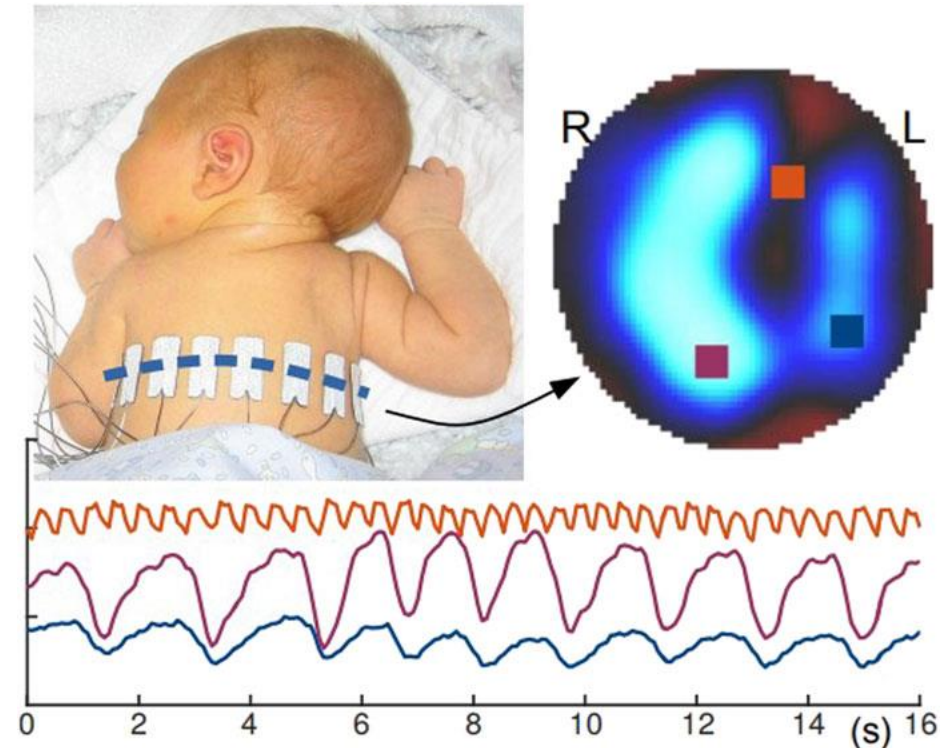
Electrical Impedance Tomography (EIT)

EIT is a portable, inexpensive, non-invasive imaging system that requires no ionizing radiation.

- Attach electrodes to the **surface** of the domain.
- Apply (harmless) current and measure the resulting voltage.
- Recover the internal conductivity (and permittivity) by solving a PDE

$$\nabla \cdot \sigma(x) \nabla u(x) = 0, \quad x \in \Omega \subset \mathbb{R}^n$$

Applications include: breast cancer detection and tumor classification, monitoring lung function in ICU patients, kidney reflux, **stroke classification and monitoring, etc.**

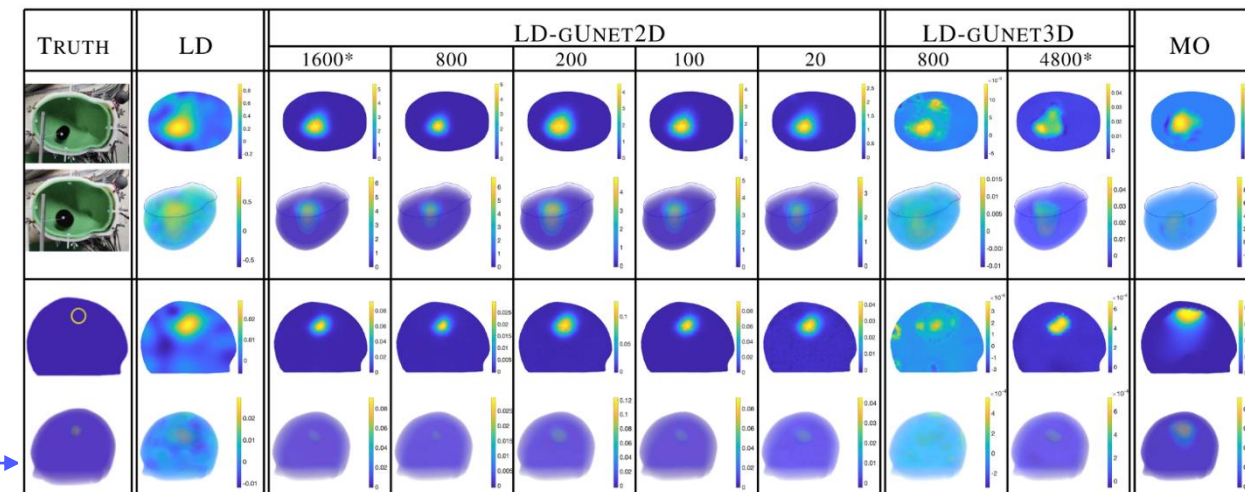
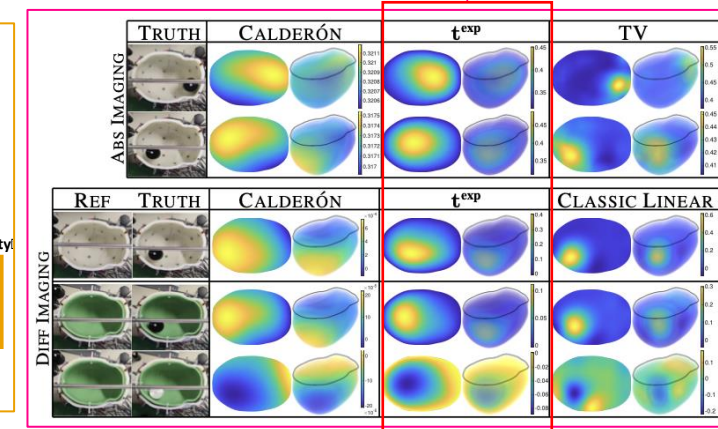
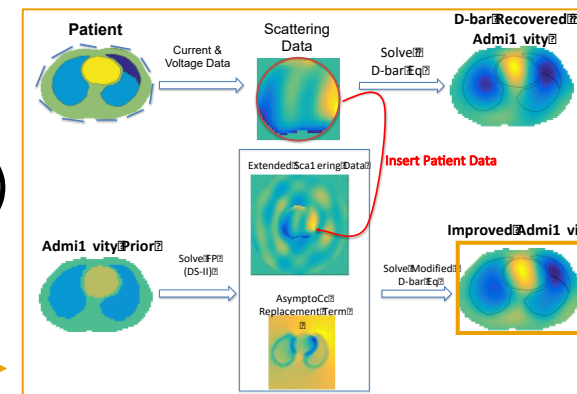


Research Focus

Development of **fast** algorithms that reliably recover **informative images** from **practical** EIT data.

[H, Muller, Kolehmainen, Toivanen, IEEE TBME 2025]

- Real-time image reconstruction
- Complex Geometrical Optics (CGOs)
 - 15-360x faster than optimization
- Including anatomical atlases
- 3D data (stroke and breast imaging)
- Deep learning (CNNs + GNNs)
 - Model-based learning + U-nets
 - Generalizability***



[Toivanen, Kolehmainen, Paldanius, Hanninen, Hauptmann, H, IEEE TBME 2026]

Helpful Skills

Math: PDEs, linear algebra, numerical analysis, inverse scattering theory (nonlinear Fourier transforms), regularization methods, functional analysis, graph theory.

Prob/Stat: Deep learning, CNNs, graph networks, Bayesian inversion.

Computing: HPC, GPU computing, programming with python, Matlab, C, etc.

An **inquisitive** mind + can-do attitude.

Further Reading (with links)

[Foundational Work in EIT](#): Isaacson et al. 2004, IEEE TMI

Network Papers: [Deep D-bar](#), [Beltrami-Net](#), [GCNM Model-based Learning](#), [Graph U-nets](#), [3D Stroke Monitoring](#)

A priori D-bar: [Full boundary](#), [partial boundary](#).

3D CGO Papers: Simulations [2020](#), Experimental [2022](#), Partial boundary data [2026](#)

[Linear and Nonlinear Inverse Problems with Practical Applications](#) by Mueller & Siltanen

Dr. Cirkovic

*Network Science, Random Graphs,
Extreme value theory, computational
statistics*



Heavy-tailed behavior...

in networks...

$$P(D > i) \approx Ci^{-\alpha}, \quad \alpha > 0,$$

where D is the degree of a “typical” node.

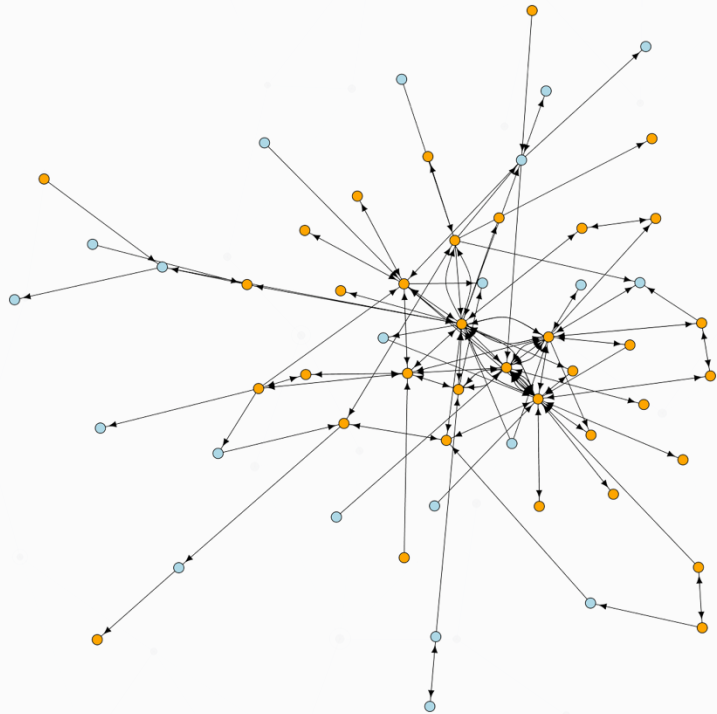


Figure: Preferential attachment with reciprocity.

and more recently... in text!

$$P(F > i) \approx Ci^{-\alpha}, \quad \alpha > 0,$$

where F is the frequency of a “typical” word.

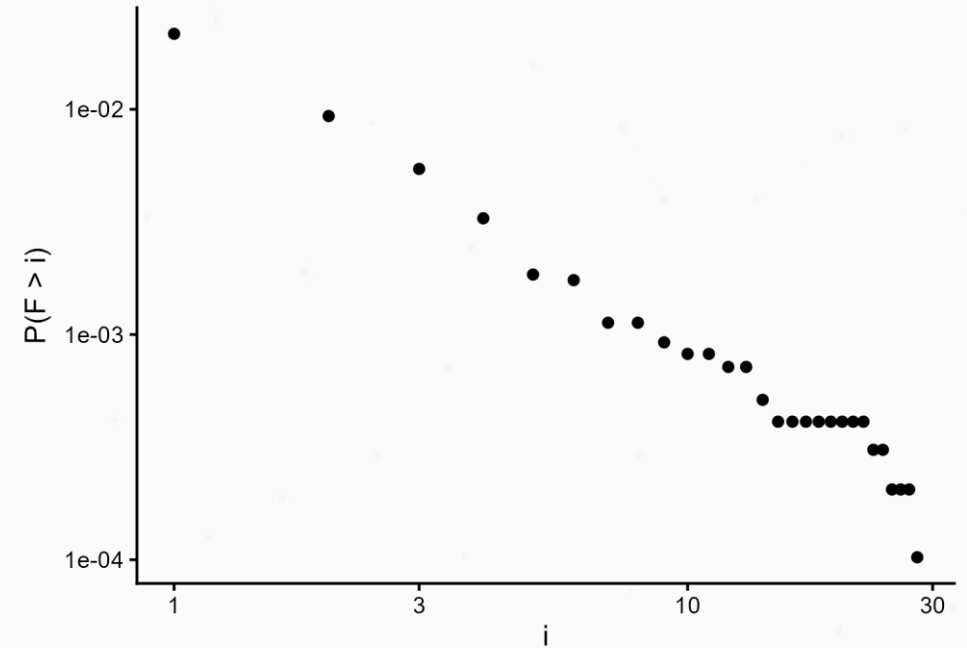


Figure: How often “windows” appears in forum posts.

Topic Models

“The different accidents of **life** are not so changeable as the feelings of **human nature**. I had **worked** hard for nearly two years, for the sole purpose of infusing **life** into an inanimate **body**. For this I had **deprived** myself of **rest** and **health**. I had desired it with an **ardour** that far exceeded moderation; but now that I had finished, the beauty of the **dream** vanished, and breathless horror and disgust filled my **heart**. Unable to **endure** the aspect of the **being** I had **created**, I rushed out of the room and continued a long time traversing my **bed**-chamber, unable to compose my **mind** to **sleep**. At length **lassitude** succeeded to the tumult I had before **endured**, and I threw myself on the **bed** in my clothes, endeavouring to seek a few moments of forgetfulness. But it was in **vain**; I **slept**, indeed, but I was disturbed by the wildest **dreams**.”

–Mary Shelley, *Frankenstein*

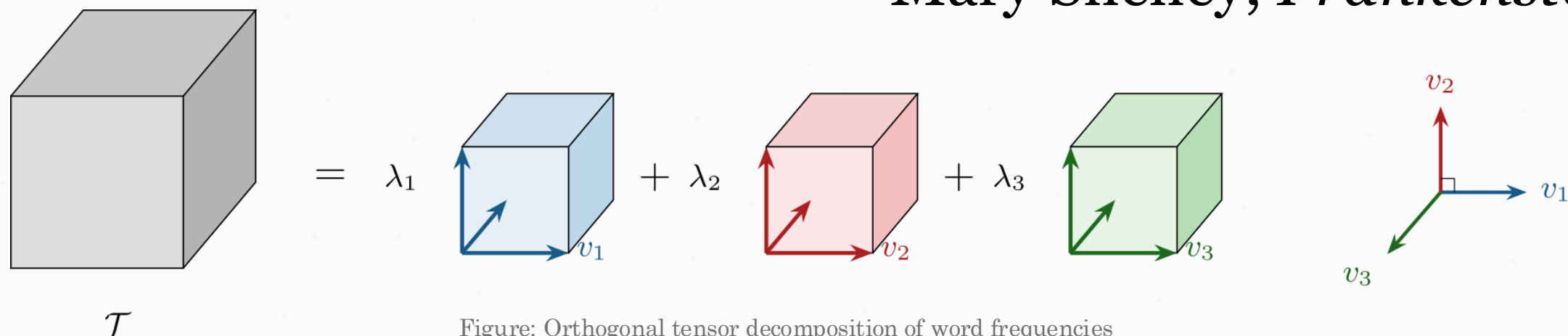


Figure: Orthogonal tensor decomposition of word frequencies

How you can contribute!

Helpful classes/skills

Math:

- Probability (MSSC 6010)
- Linear algebra (MSSC 6040)
- Analysis/Measure theory (optional)

Statistics:

- Multivariate stats (MSSC 6250)
- Bayesian stats (MSSC 5790, optional)
- Time series (MSSC 5760, optional)

Skills:

- Programming in R and/or Python
- Intrinsically motivated

References

Papers/preprints:

- [Preferential attachment with reciprocity](#)
- [Heavy-tailed topic modeling](#)

Some nice review papers:

- [Heavy tails in network data](#)
- [Heavy tails in natural language processing](#)

Dr. Choi

Statistical Genetics

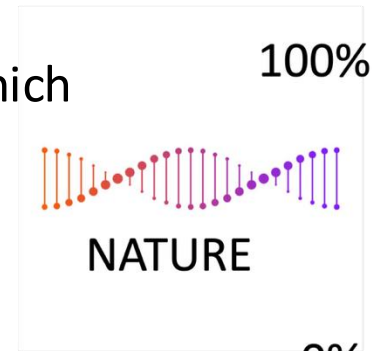


Research Areas in Statistical Genetics

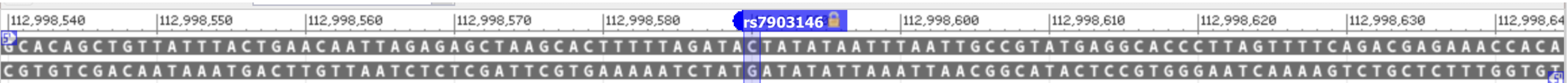
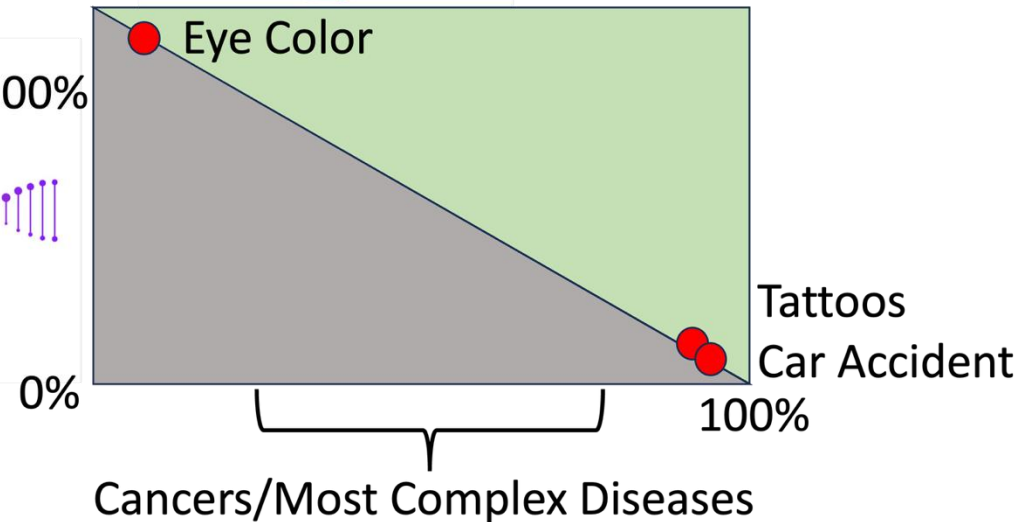
Why genetics?

- Twin studies have shown that many human traits are heritable (e.g. height ~80% heritability)
- Heritability tells us that genes matter, but not which genes are responsible.

How do we move from knowing a trait is heritable to identifying the genetic variants that influence it?



NURTURE



Challenges in genetics:

1. High dimensionality
2. Correlation between genetic variants
3. Rare and weak genetic effects

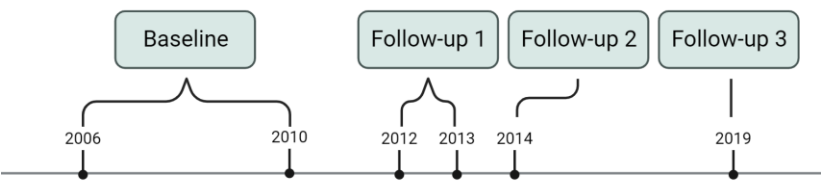
Biobanks: massive repositories that connect genetics with longitudinal health data

a

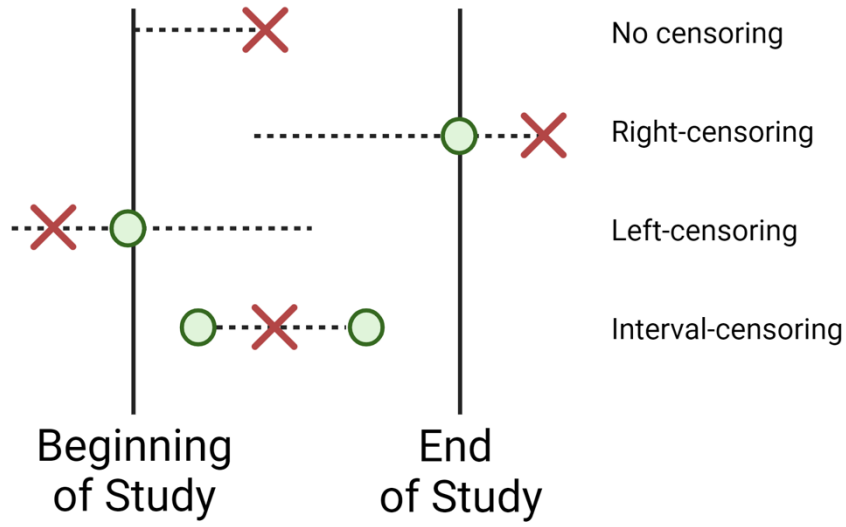


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Biobank	Country	Samples (available WGS)	Ancestry	Cohort
All of Us	United States	245,000	Multi-ethnic	Population-based
UK Biobank	United Kingdom	500,000	European	Population-based
PRECISE-SG100K	Singapore	50,000	Chinese, Malay, Indian	Population-based
NPBBD-Korea	South Korea	25,000	Korean	Population-based, Diseased
Biobank Japan	Japan	14,000	Japanese	Population-based, Diseased



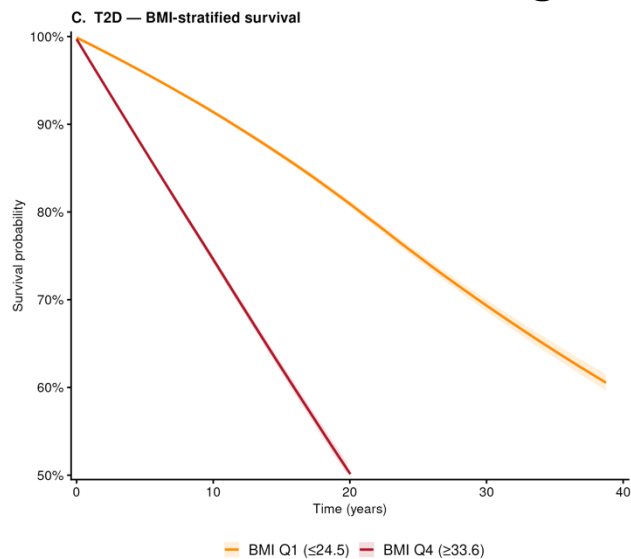
- Disease outcomes from biobanks can be modeled as survival outcomes, but censoring is common.
- Interval-censoring: the outcome occurs between two observed time points.



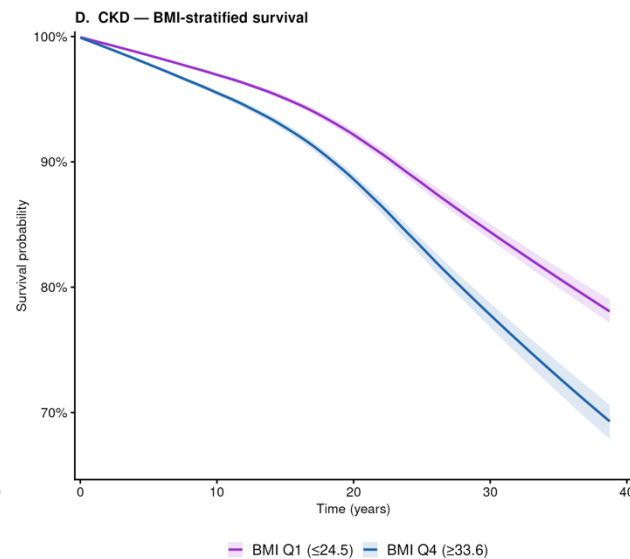
From Identifying Associations to Understanding Mechanisms

Past / Current

- **Genetic Association**
 - Detecting genetic effects across multiple and high-dimensional outcomes
- **Bayesian Survival Modeling**
 - Modeling censored disease onset and heterogeneous genetic effects
- **Bayesian Fine-Mapping**
 - Prioritizing likely causal variants genetic association signals



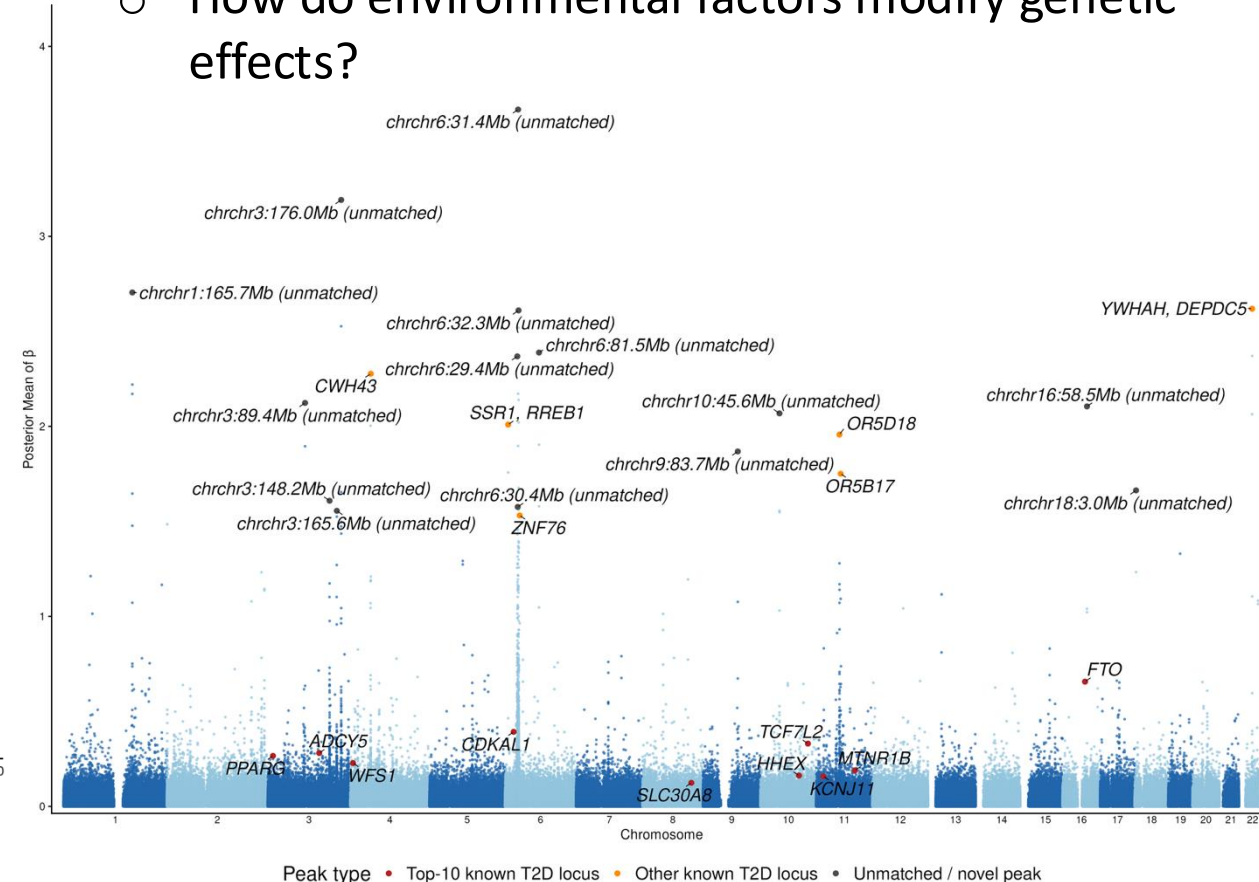
TPBN posterior mean $\pm$ 95% posterior credible interval.
Mean covariate profile at BMI quartiles.



TPBN posterior mean $\pm$ 95% posterior credible interval.
Mean covariate profile at BMI quartiles.

Future Directions

- **Genetic causal inference**
 - Mediation analysis: How do genetic variants influence disease through intermediate traits?
- **Gene x Environment Interactions**
 - How do environmental factors modify genetic effects?



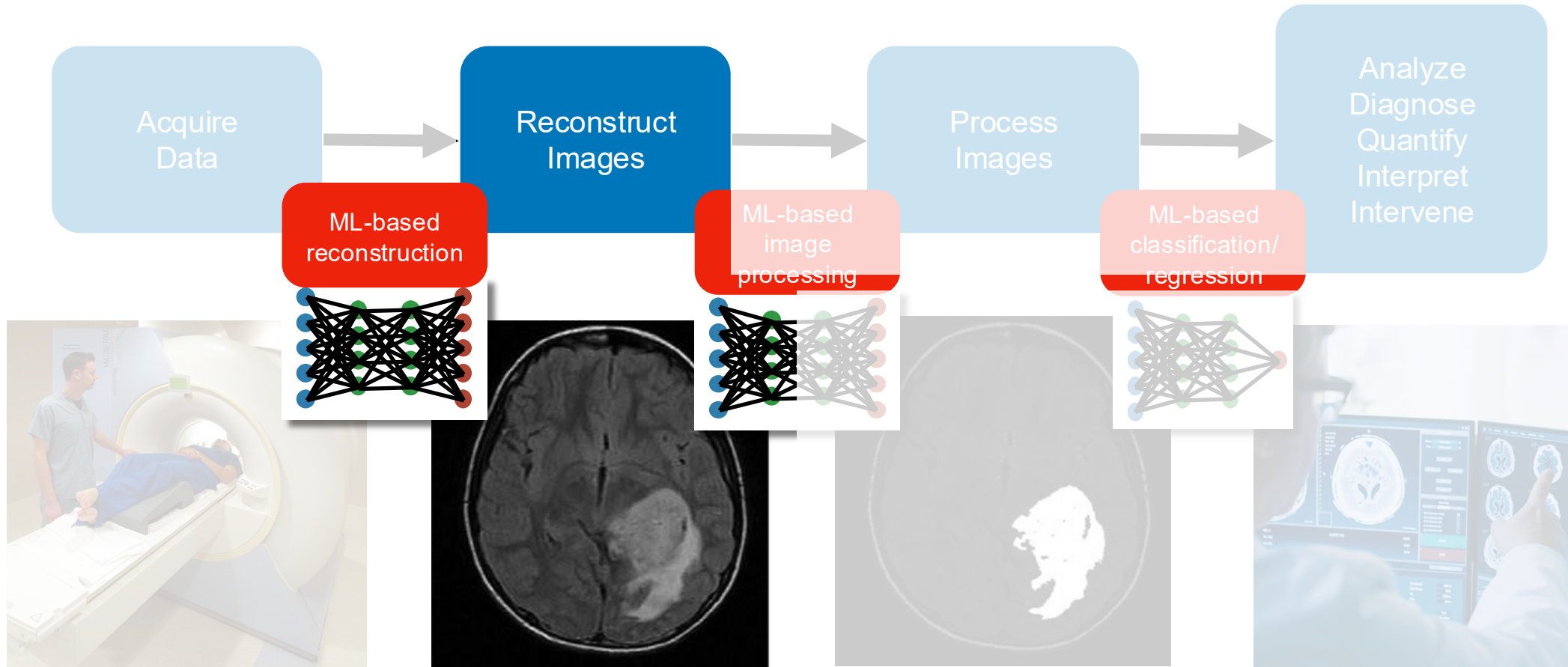
Dr. Ongie

Mathematics of deep learning, applied algebraic geometry in data science and machine learning, machine learning for medical imaging, optimization in computational imaging



AI/ML for Improved Medical Image Reconstruction

(initially) less obvious place: Most obvious place for machine learning is in post-processing



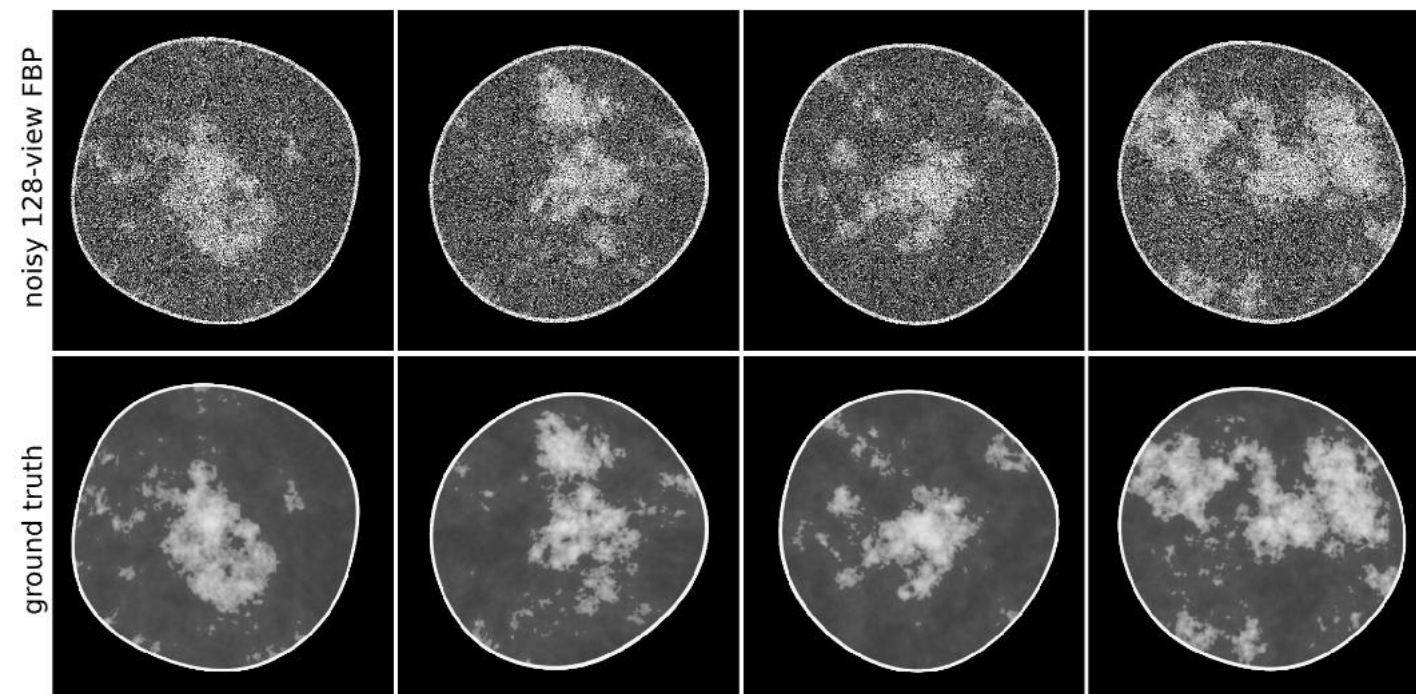
Dr.

Why bother with AI/ML in recon?

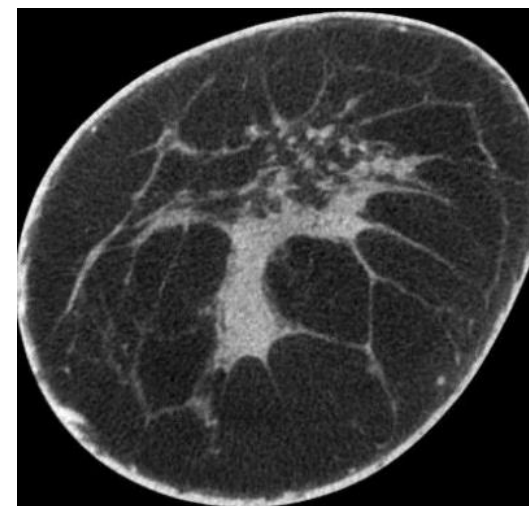
In X-ray Computed Tomography (CT)...

- Uses ionizing radiation — potentially harmful to patient
- Can reduce dose but at the expense of **noise/artifacts**

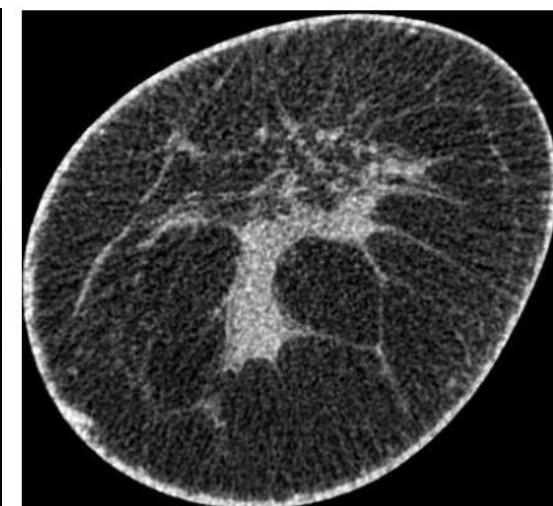
Key idea: learn an image model from data



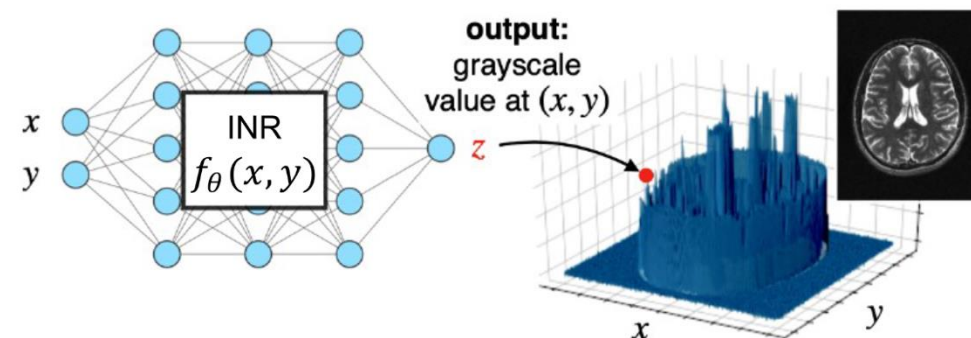
standard dose
breast CT scan



reduced dose
breast CT scan



...or if there is no data,
come up with other models



e.g., image is compressible
as an “INR”

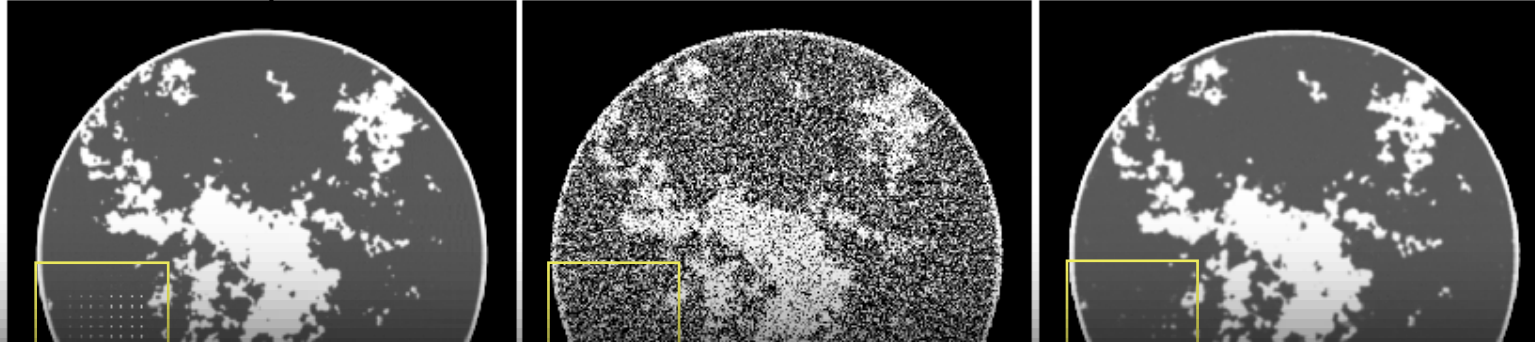
Dr.

One issue with AI/ML recon: Erasure of clinically relevant details

breast CT phantom

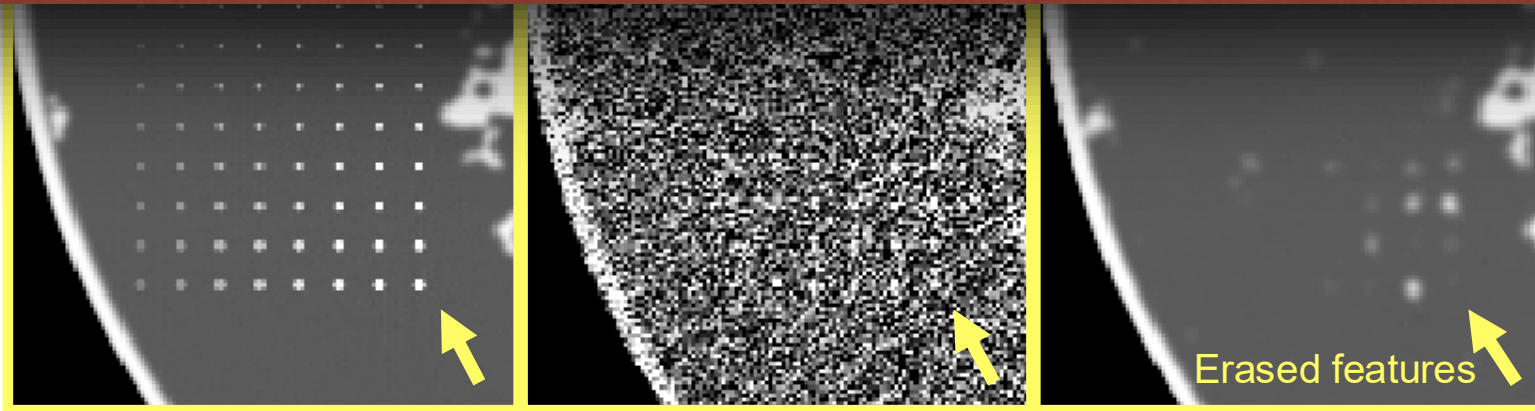
low-dose recon

neural network recon



Key Problem: How do we ensure learning approaches to image reconstruction yield faithful, reliable results, with task-specific improvements?

breast CT
simulation st



Skills

- **Math:** Linear algebra, Optimization, Signal/Image Processing (e.g., FFTs and filtering)
- **Stats/ML:** Basic understanding of machine learning principles, Signal Detection Theory (ROC curves and fun stuff like that)
- **Computing:** Familiarity with Linux/Unix command line environment, Python for machine learning (specifically Numpy and Pytorch).

Contact Info:

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E-mail: gregory.ongie@marquette.edu

Further Reading

Recent Papers:

M. Najaf, G. Ongie. Sampling Theory for Super-Resolution with Implicit Neural Representations. SIAM Journal on Imaging Science. Vol 19, Issue 2, 1037-1076. May 2026.

G. Ongie, M. Murphy, E. Sidky, I.S. Reiser, X. Pan. Enhancing Signal Detectability in Plug-and-Play CT Reconstruction. SPIE Medical Imaging. Feb 2026.

M. Najaf, G. Ongie. Accelerated Optimization of Implicit Neural Representations for CT Reconstruction. IEEE International Symposium on Biomedical Imaging (ISBI), April 2025.

G. Ongie, M. Lantz, E.Y. Sidky, I.S. Reiser, X. Pan. Direct optimization of signal detection metrics in learning-based CT image restoration. SPIE Medical Imaging. Feb 2025.

Review Article:

G. Ongie, A. Jalal, C. Metzler, R. Baraniuk, A. Dimakis, R. Willett. Deep Learning Techniques for Inverse Problems in Imaging. IEEE Journal on Selected Areas in Information Theory. May 2020.

Dr. Ongie