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A tale of two crises: COVID-19 and ML reproducibility

Trustworthy AI for Medical and Health Research Workshop

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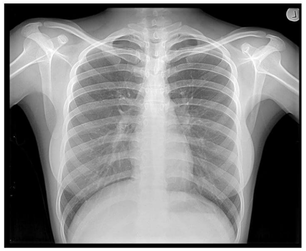
email: mr808@cam.ac.uk

A pandemic of reproducibility issues

ML for COVID-19



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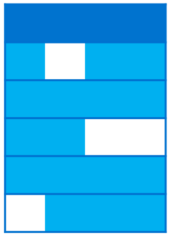
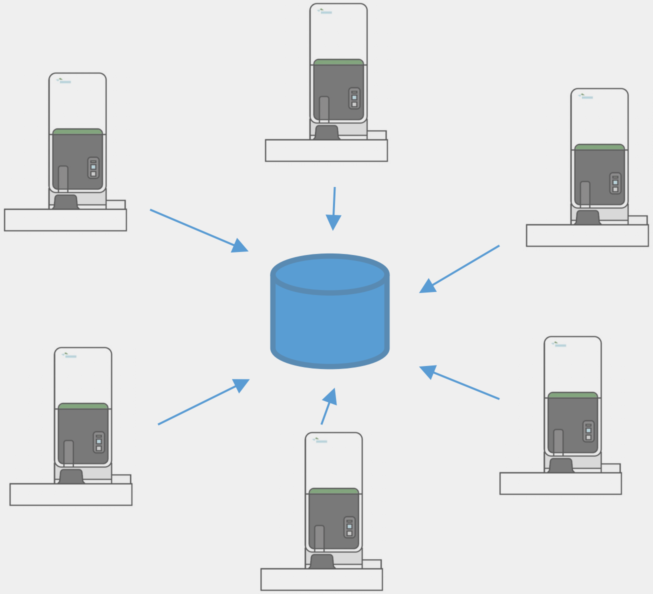


ML at scale



ML and code

python PyTorch

jupyter TensorFlow

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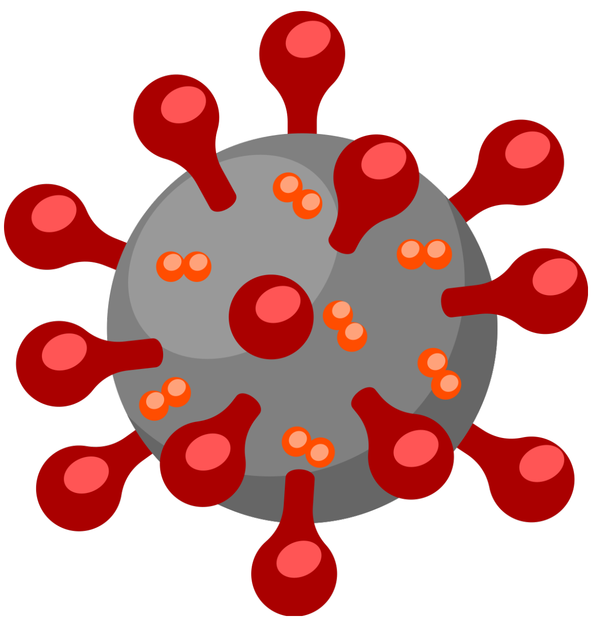
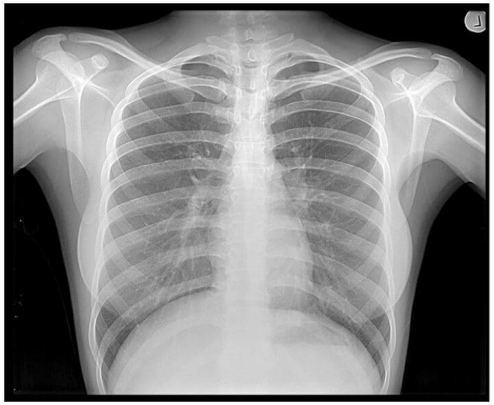
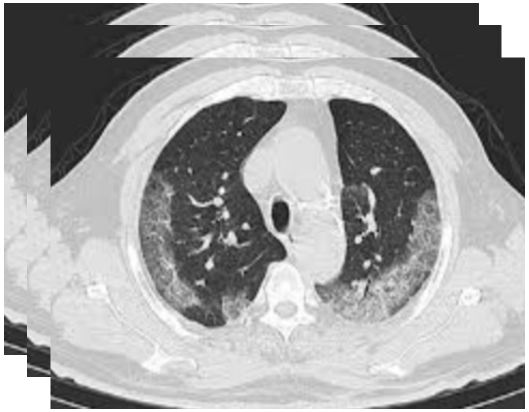
Issues with …

Joint with Derek Driggs, Matthew Thorpe, Julian Gilbey, Angelica I. Aviles-Rivero, Cathal McCague, James Rudd, Evis Sala, Carola-Bibiane Schönlieb and many AIX-COVNET members

ML for COVID-19 imaging







Roberts, M., Driggs, D., Thorpe, M. et al.
Common pitfalls and recommendations for using machine learning to detect and prognosticate for COVID-19 using chest radiographs and CT scans.
Nature Machine Intelligence 3, 199–217 (2021).
https://doi.org/10.1038/s42256-021-00307-0

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COVID-19: A perfect test case for image based ML

- Never before have we had access to data:
  - at such scale for a single disease
  - all collected around the same time period
  - collected on the same machines
  - for a disease with a short infection time

So why did image based ML fail to contribute significantly to the COVID-19 pandemic?

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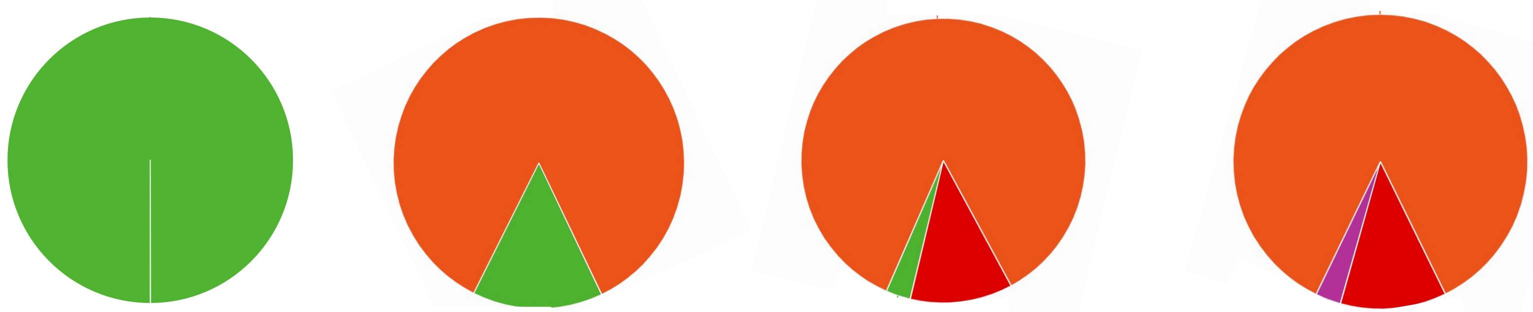
Systematic Review

- **Eligibility:** Any papers using ML and CXR/CT imaging for COVID-19 diagnosis or prognosis.

Screened	**Eligible for Review**	**After Quality Review**	**Of Safe Clinical Utility**
2,212	320	62	0



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Basic pitfalls: Frankenstein datasets

- Know where your data comes from!

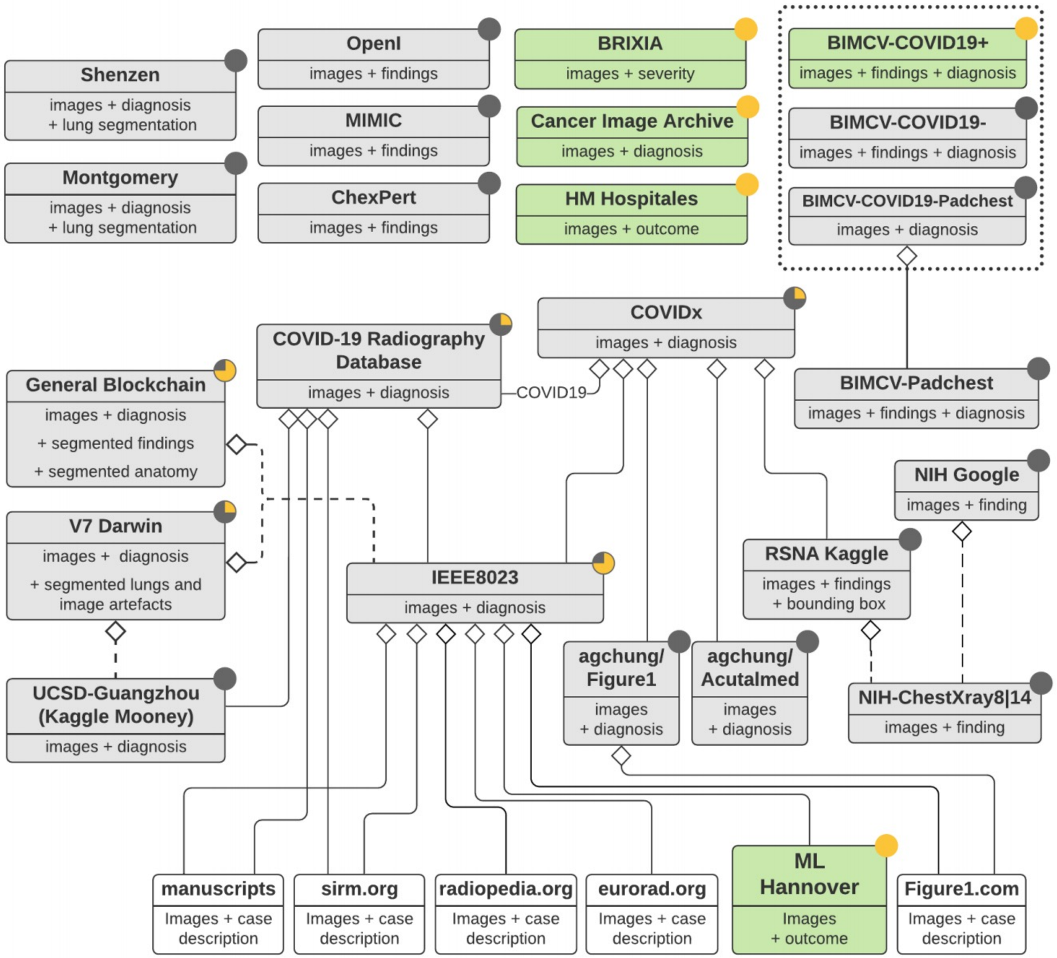

Figure from Cruz et al. (2021)

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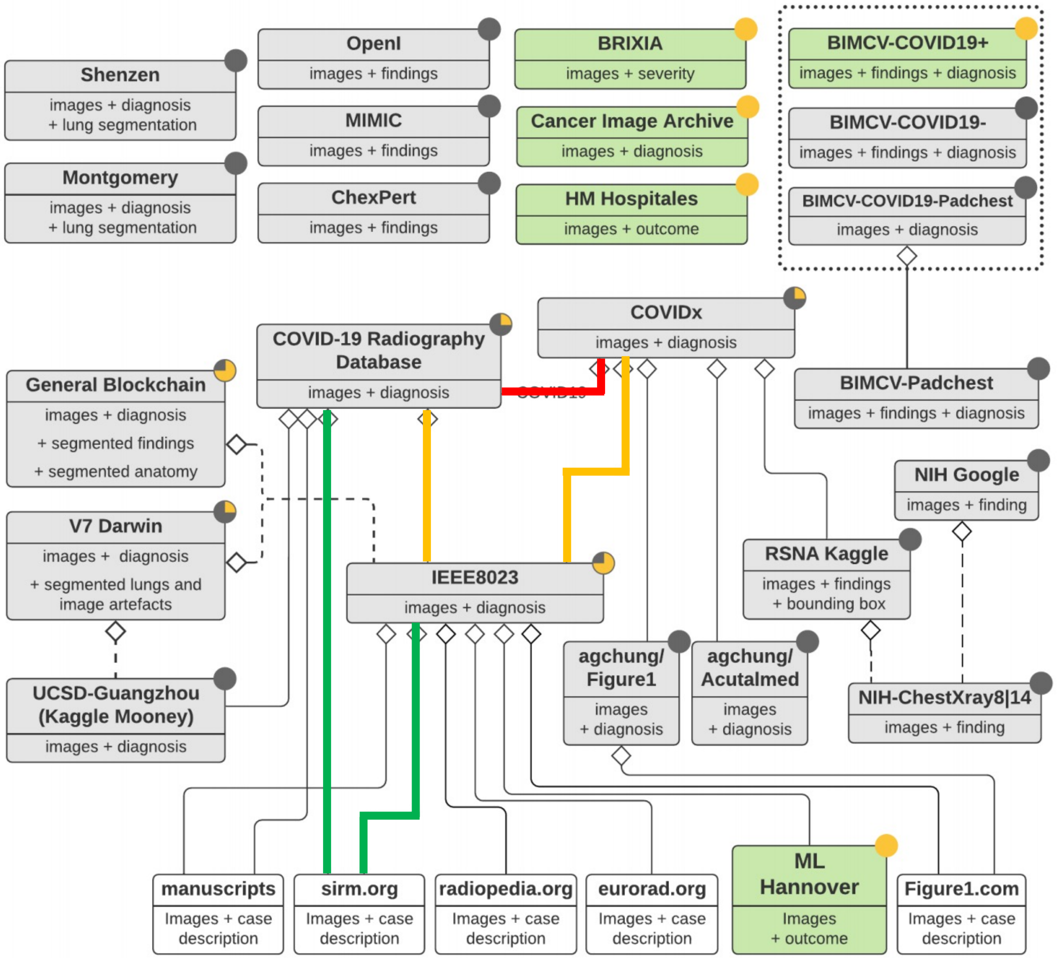

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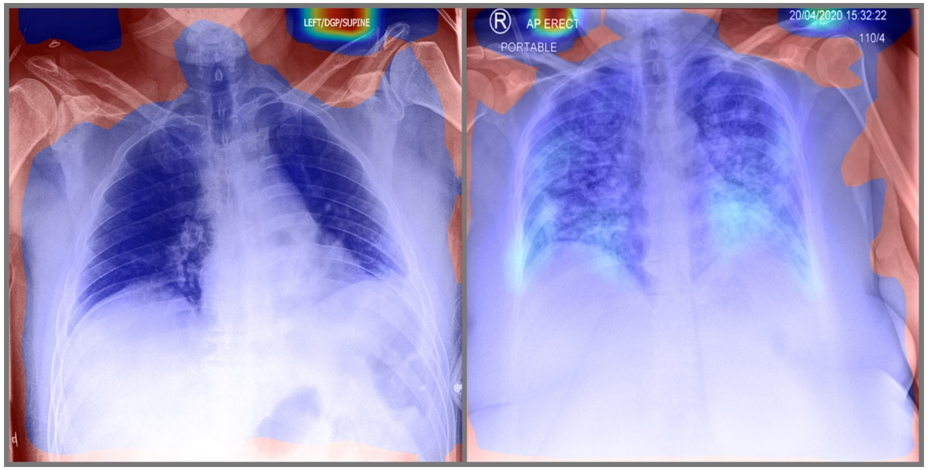
Basic pitfalls: biases in images

- Know where your data comes from!
- Appreciate the biases in your data.



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Basic pitfalls: biases in labels

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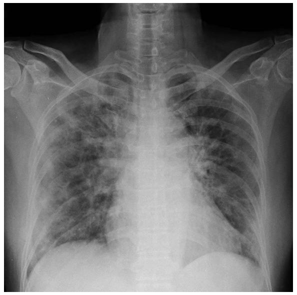
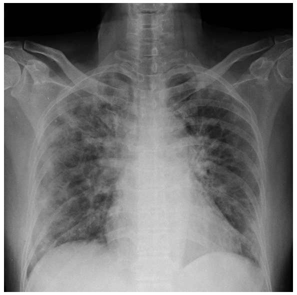
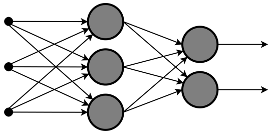
- Appreciate the biases in your data.
- Ground truth assigned based on images.



Positive
Negative





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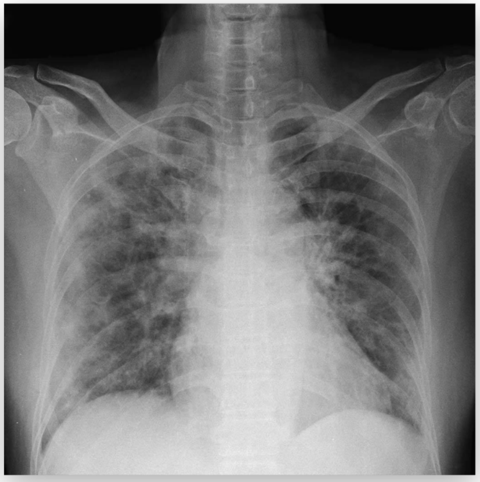
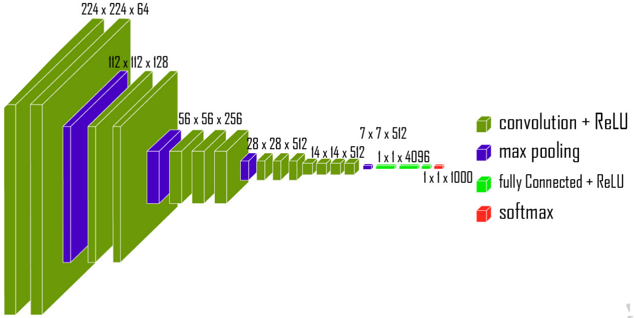
Basic pitfalls: biases in models

- Know where your data comes from!
- Appreciate the biases in your data.
- Ground truth assigned based on images.
- Resolution driven by pretrained networks





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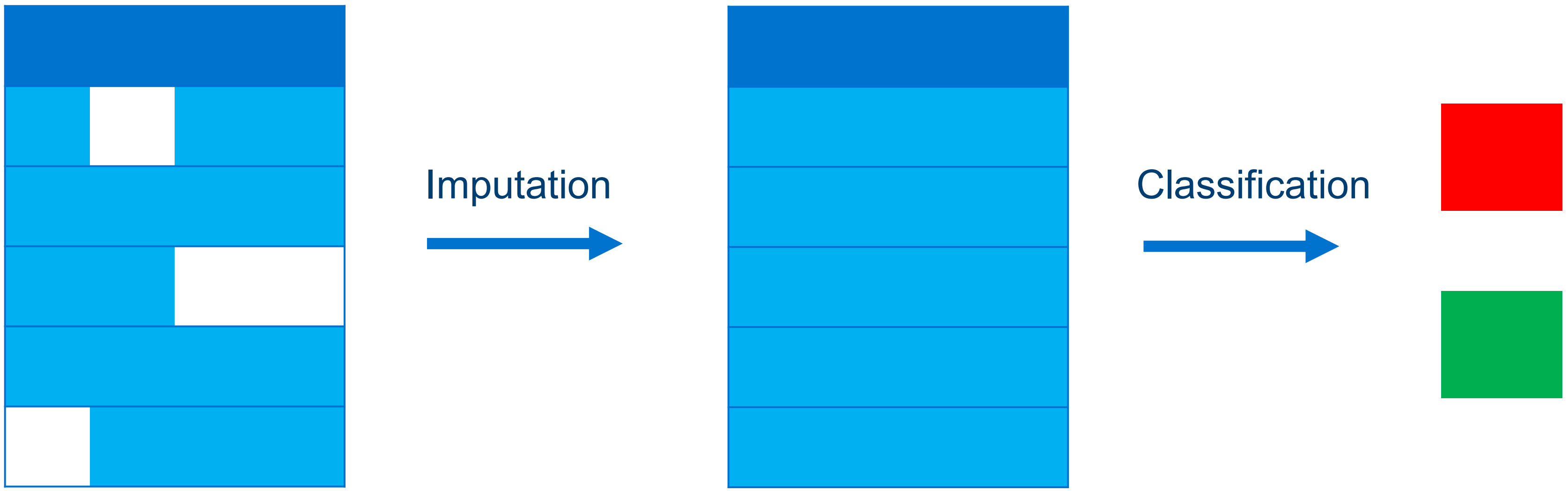

Shadbahr, T.*, **Roberts, M.***, Stanczuk, J.*, Gilbey, J.*, Teare, P.*, Dittmer, S., ... & Schönlieb, C.-B.
Classification of datasets with imputed missing values: does imputation quality matter? (2022). Under Review.
arXiv preprint arXiv:2206.08478.

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Why is imputation important?

- QRISK is a model for predicting your risk of a cardiovascular disease.

[1] Hippisley-Cox J, Coupland C, Vinogradova Y, Robson J, May M, Brindle P et al. Derivation and validation of QRISK, a new cardiovascular disease risk score for the United Kingdom: prospective open cohort study *BMJ* 2007; 335 :136 doi:10.1136/bmj.39261.471806.55

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- An improved algorithm is now a standard used in the UK NHS.

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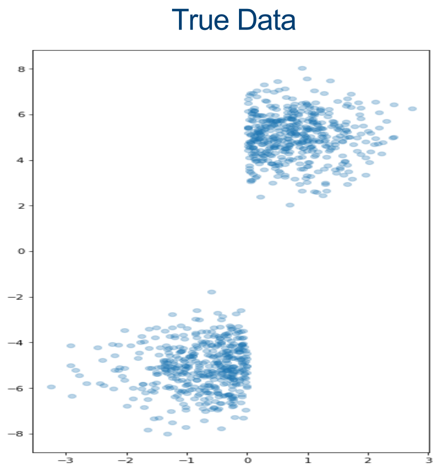
How should we measure quality?



Mean / root mean square error is a common metric for measuring imputation quality.

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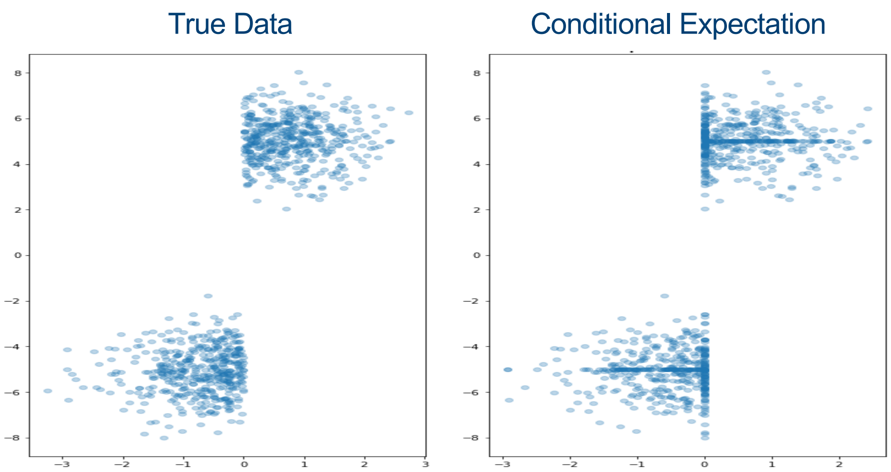

MSE = 1.001641
W_1 = 0.000286

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W_1 = Wasserstein distance between imputed and real value distributions

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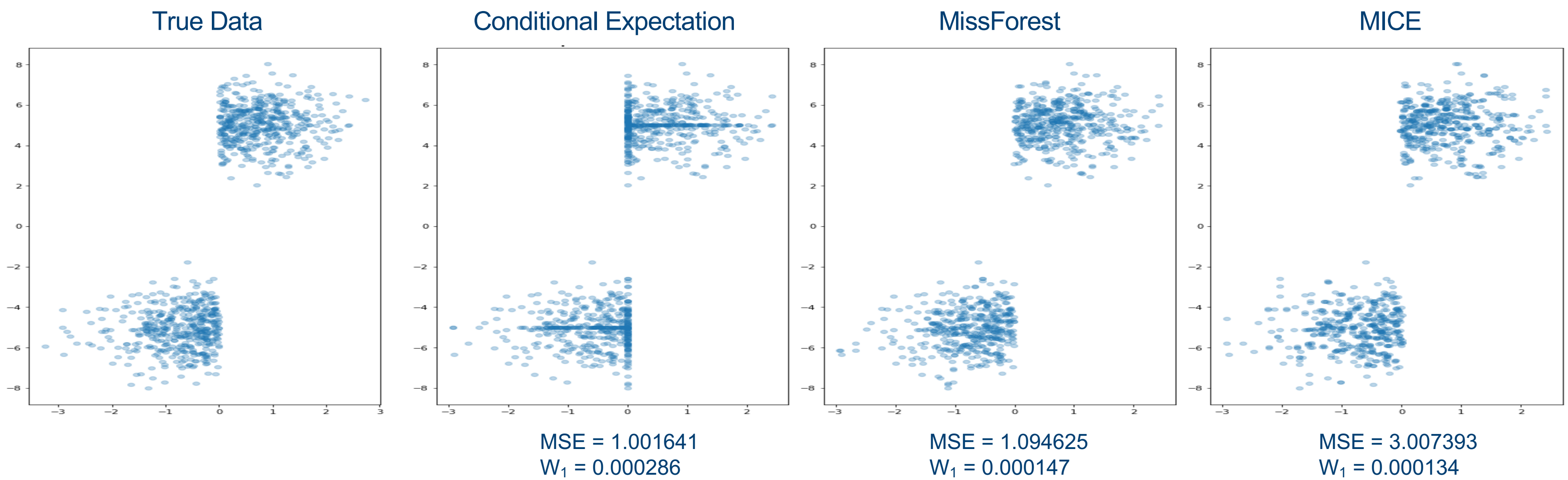

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What are the issues?

- We find that many new methods fail both to:
  - recreate data distributions
  - give stable imputations
- This compromises model interpretability
- Missingness may be informative for the models

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Joint with Sören Dittmer, James Rudd, John Aston, Carola-Bibiane Schönlieb

Issues with …

ML and code

python™

TensorFlow

PyTorch

jupyter

Dittmer, S.*, **Roberts, M.***,., ... & Schönlieb, C.-B.
Navigating the challenges in creating complex data systems: a development philosophy (2022). Under Review.
arXiv:2210.13191.

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Marauding as software engineers

10 years ago, this was a software engineer….

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Marauding as software engineers

10 years ago, this was a software engineer….

Now it is also a:

- Data scientist
- Mathematician
- Statistician
- Machine learning engineer

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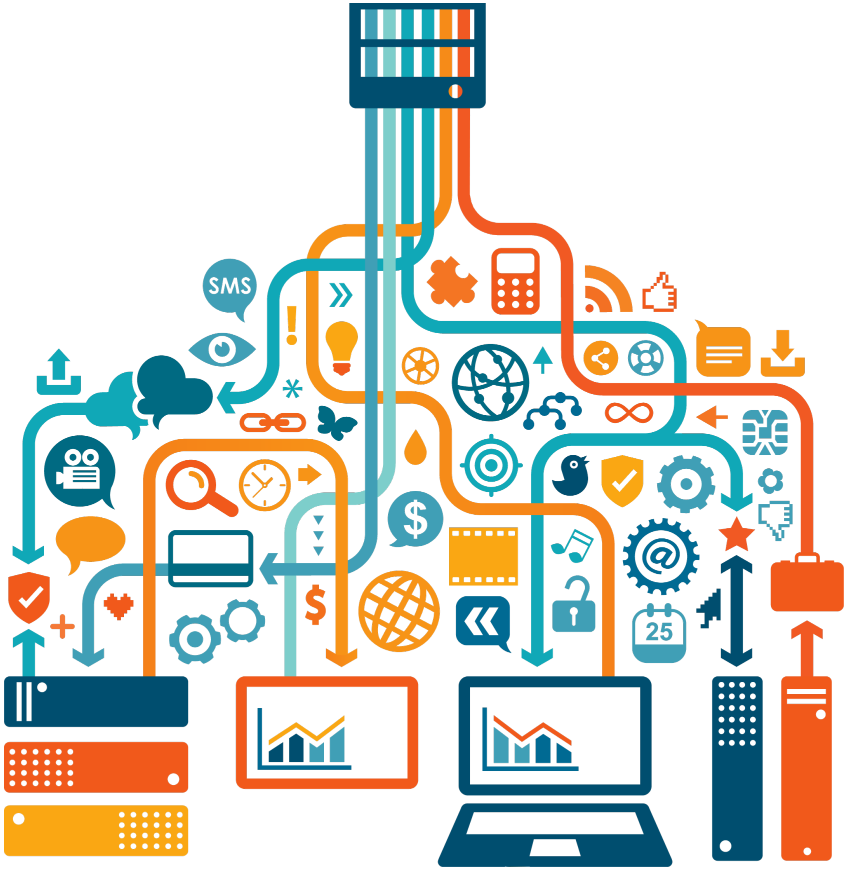
Issues with the new world

An explosion of data and sources

We must often structure and preprocess this data ourselves

Without deep domain knowledge, we have lost control of the biases in the data



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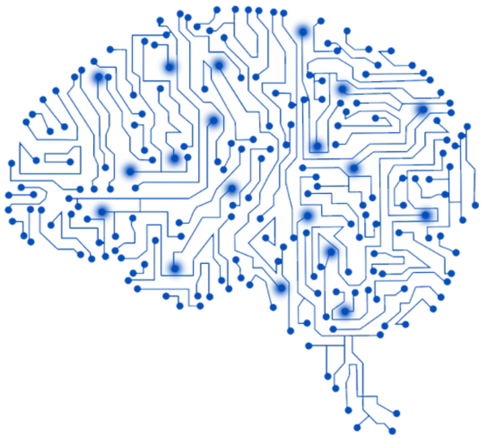

Idealistic illustration of machine learning

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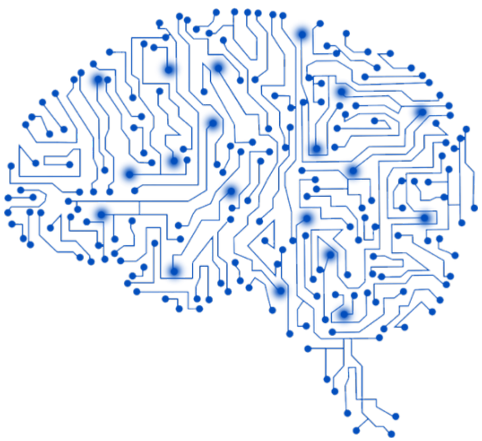

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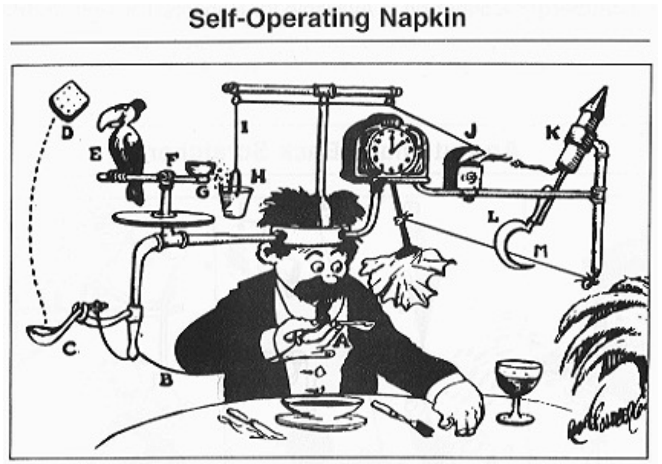

The reality …

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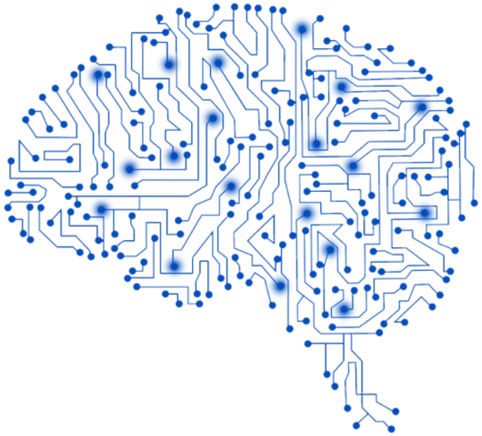
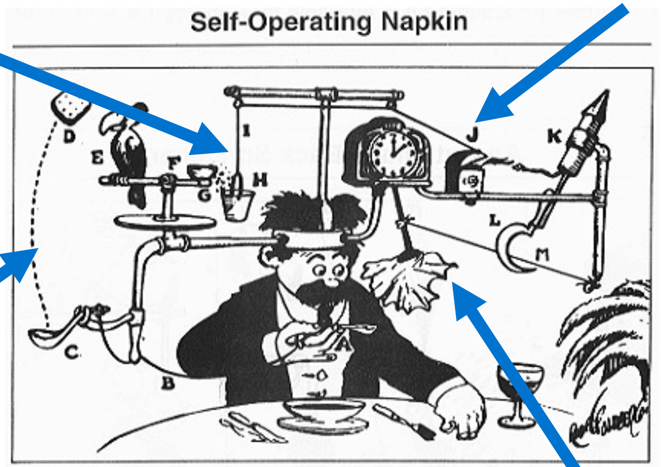


Idealistic illustration of machine learning

Data pre-processing

Model training



Data loading

The reality …

Evaluation

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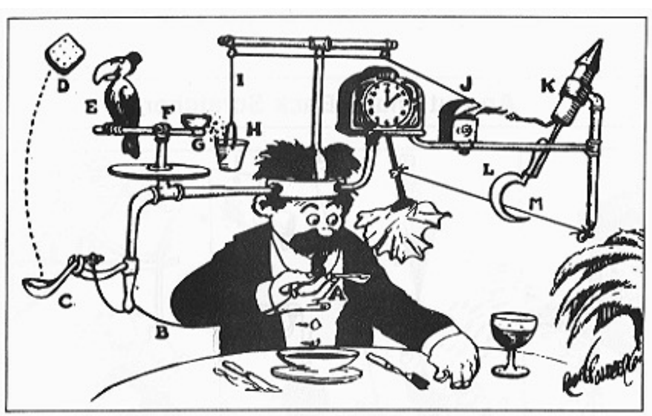

Typical workflow for an ML project

- Code is built as a monolith
- It is tinkered with until it stops giving errors
- Train using all the data and then analyse the results

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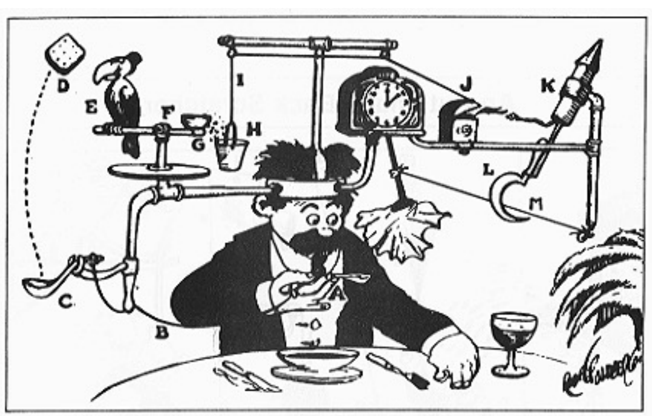

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General recommendations / thoughts

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- Practitioners need to rethink coding methodologies, e.g. AGILE
- If you don't enforce your assumptions in the code, someone will break it

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Thank you

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