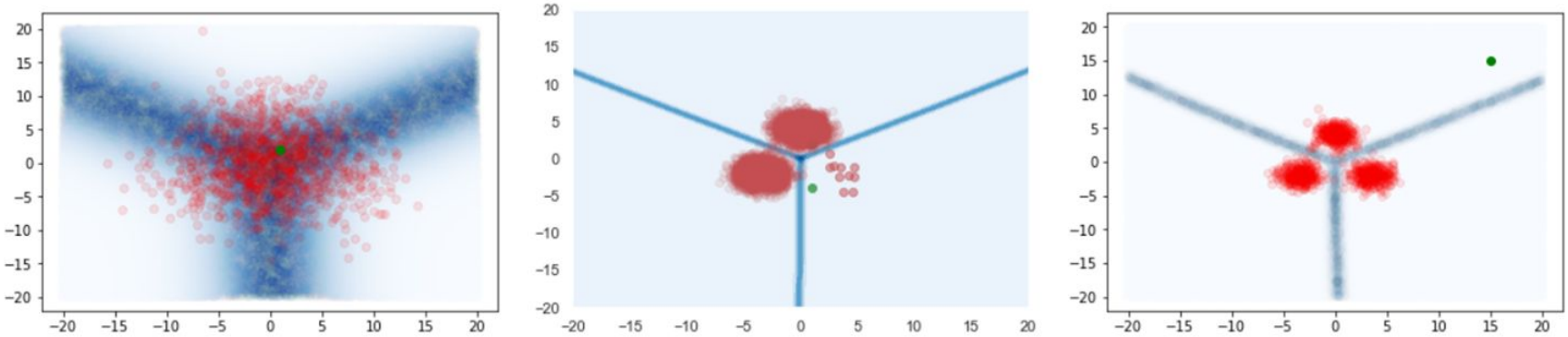
Part 1: General Introduction into Uncertainty & Domain Shift

Vatsal Raina

Uncertainty refers to the measure of confidence or lack of certainty in a model's predictions.

It captures how much the model "knows what it doesn't know."

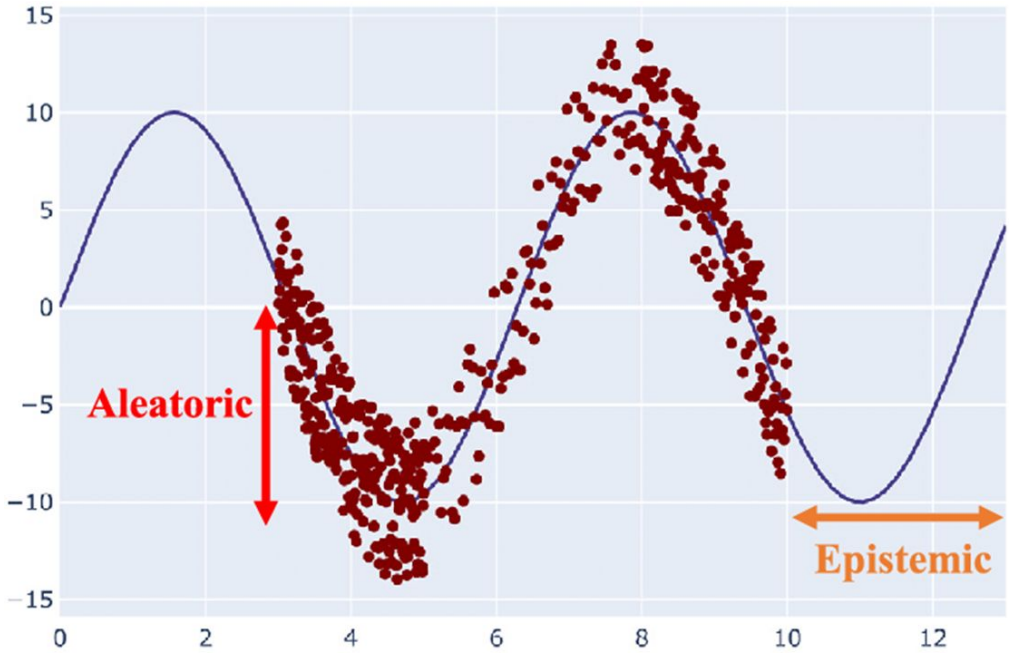
Sources of Uncertainty - *Classification*



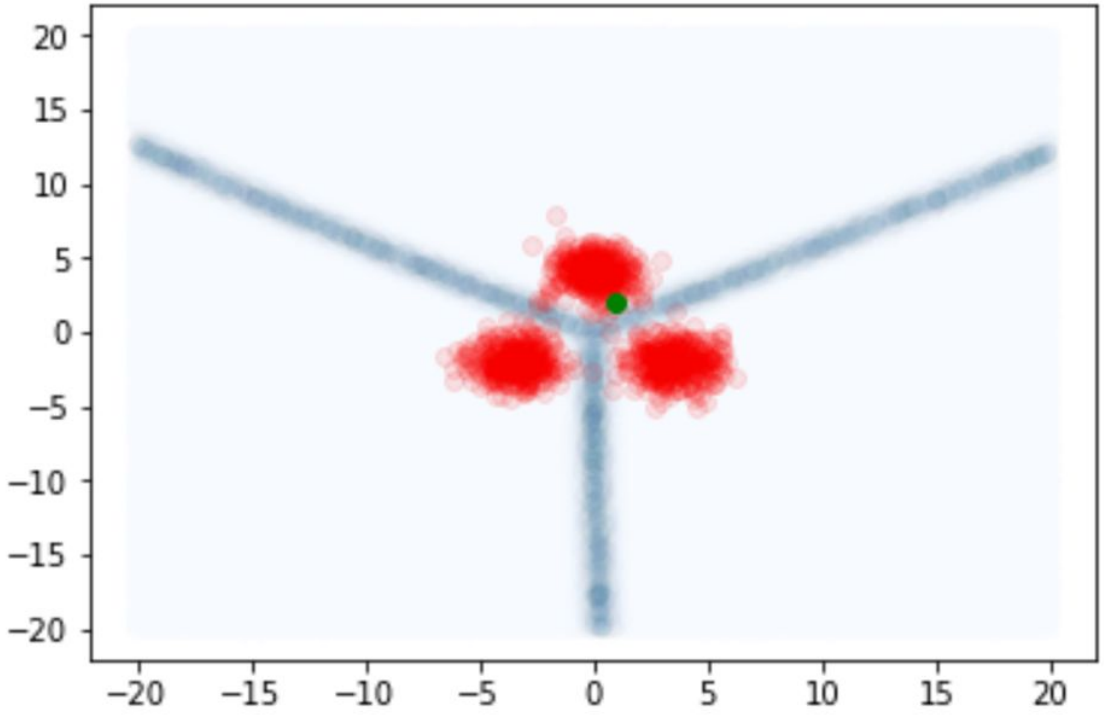
(a) Data Uncertainty (b) Knowledge Uncertainty (c) Knowledge Uncertainty

- Data Uncertainty $\rightarrow$ Aleatoric Uncertainty
- Knowledge Uncertainty $\rightarrow$ Epistemic Uncertainty

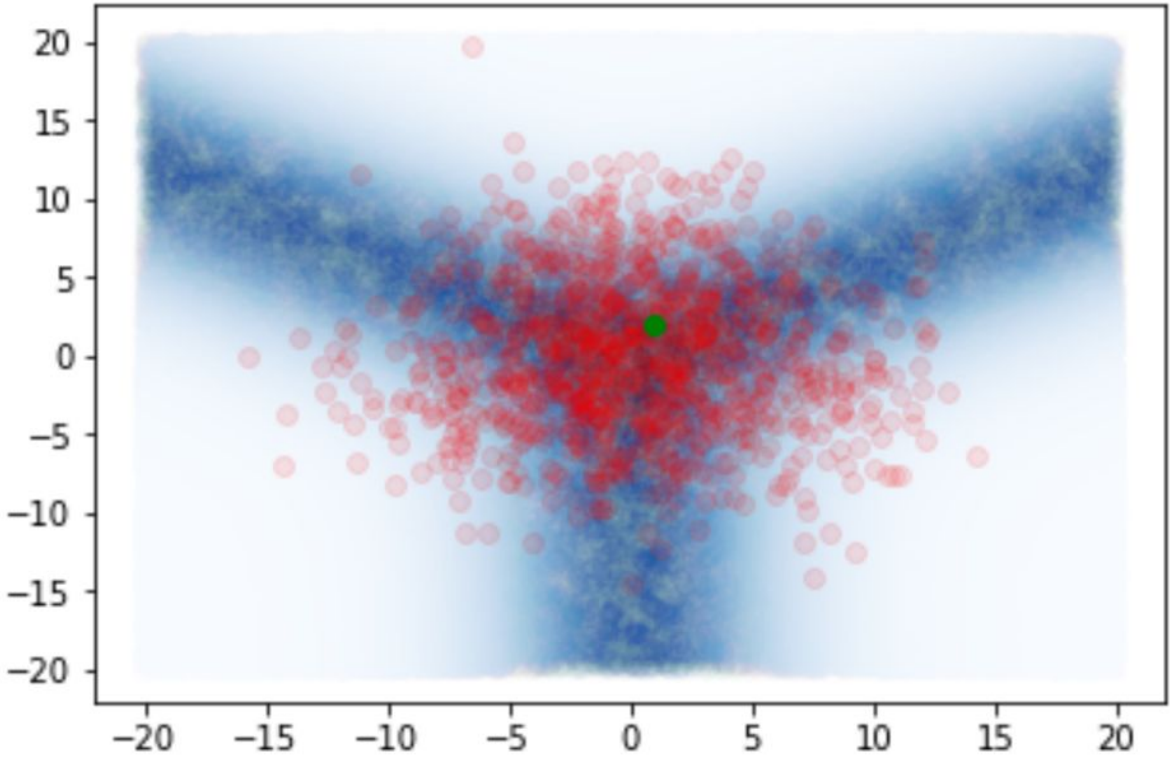
Sources of Uncertainty - *Regression*



Data (Aleatoric) Uncertainty - Classification

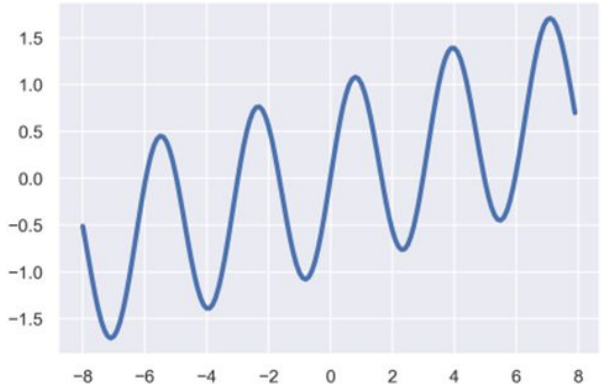


Data (Aleatoric) Uncertainty - Classification

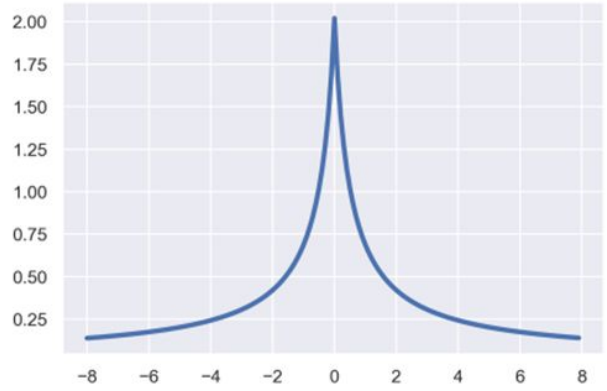


- Distinct Classes

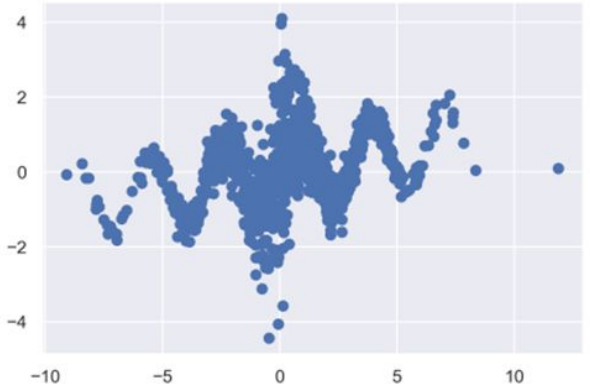
- Overlapping Classes



(a) Function $\mu(x) = \sin(2x) + \frac{x}{10}$



(b) Noise std $\sigma(x) = 0.02 + \frac{2}{|x^2|+1}$

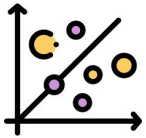


(c) Sampled Data $y \sim \mathrm{p}(\mu(x), \sigma(x)))$

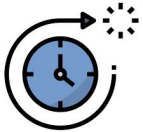
- Data Uncertainty for Regression $\rightarrow$ additive noise $\sigma(\boldsymbol{x})$
  - Homoscedastic - input **independent** $\sigma(\boldsymbol{x}) = C$
  - Heteroscedastic - input dependant $\sigma(\boldsymbol{x}) = g(\boldsymbol{x})$

Example reasons for data uncertainty

Measurement Error



Data Noise



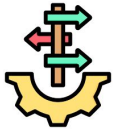
Temporal Uncertainty

Sampling Uncertainty

Bias in Data Collection

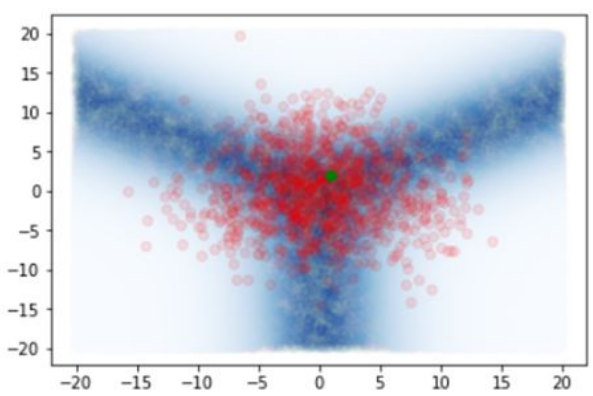
Inconsistent Data Formats

Missing Data

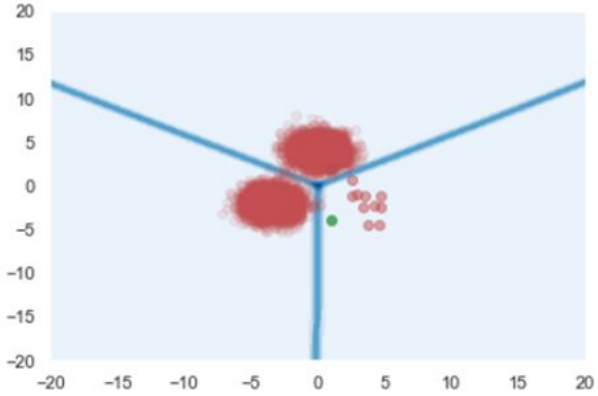


Ambiguity in Data Sources

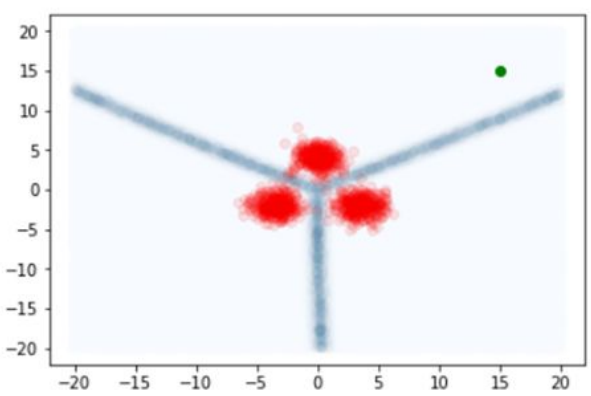
Sources of Uncertainty



(a) Data Uncertainty



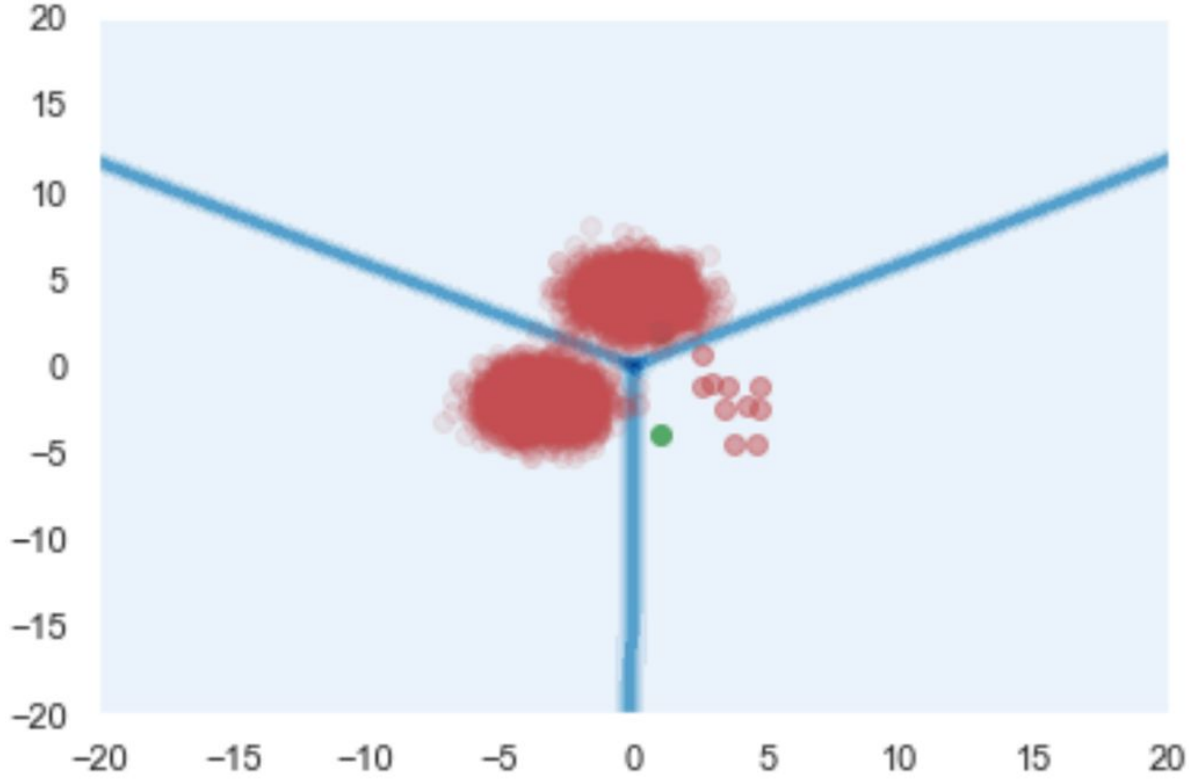
(b) Data Sparsity



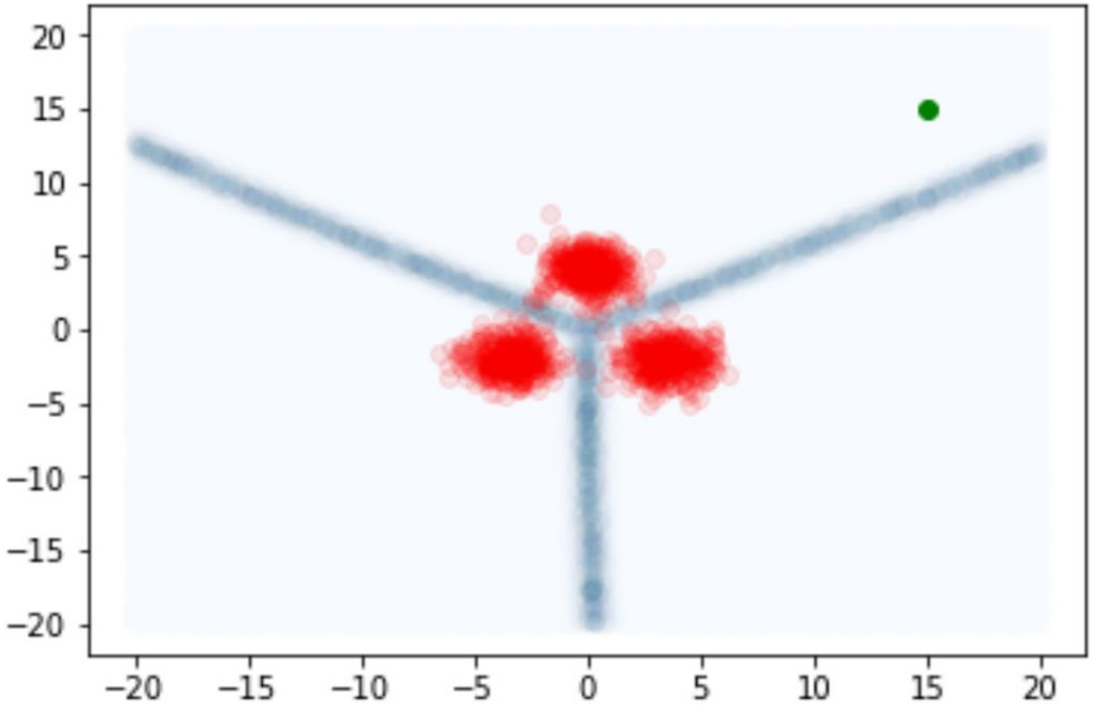
(c) Out-of-Distribution inputs

- Knowledge (epistemic) uncertainty refers to both:
  - Data Sparsity and Out-of-distribution inputs

Knowledge (Epistemic) Uncertainty - Classification

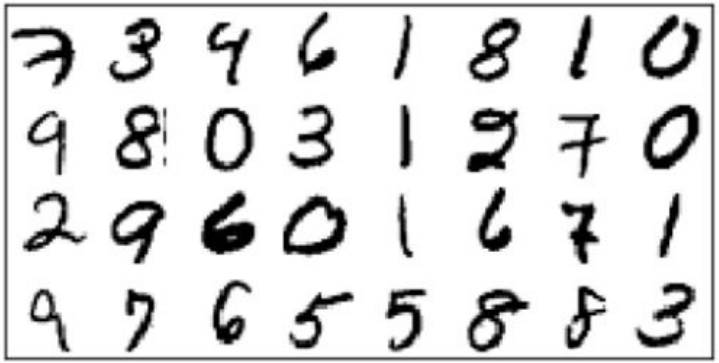


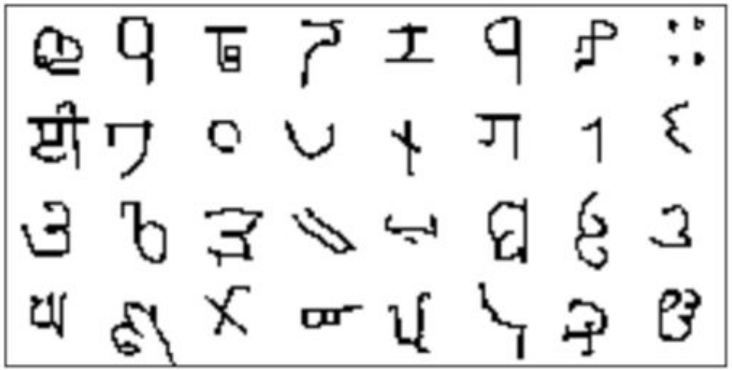
Knowledge (Epistemic) Uncertainty - Classification



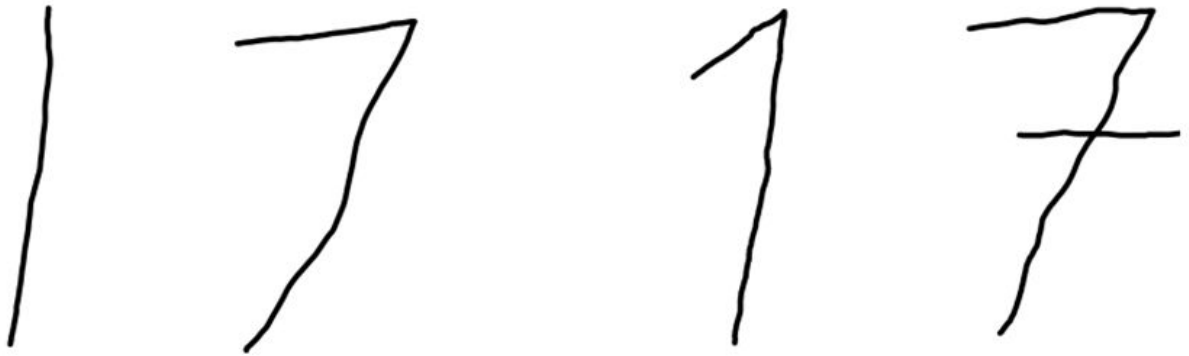
Data Sparsity + OOD is all
DOMAIN SHIFT

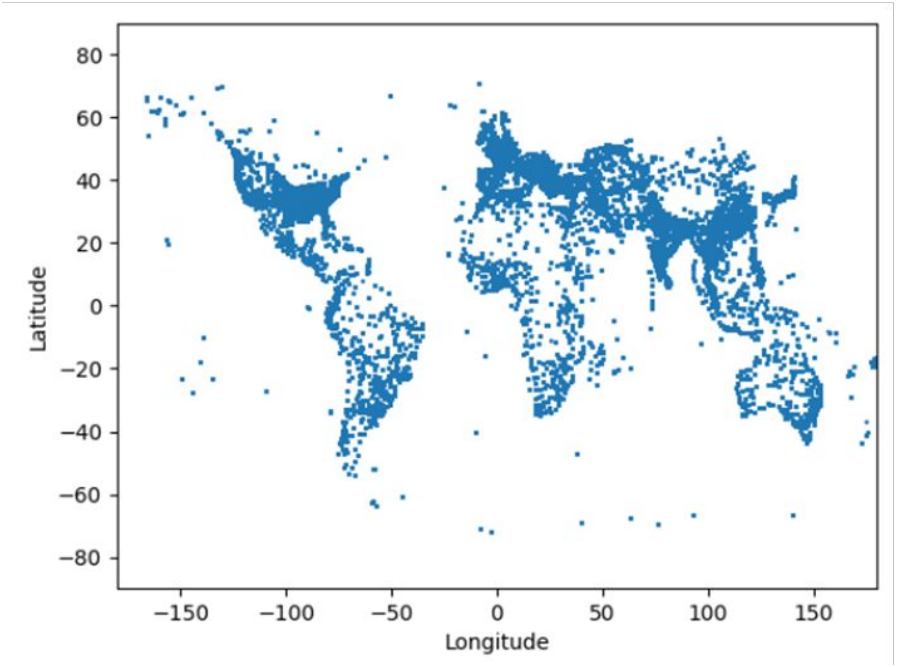
- Unseen classes

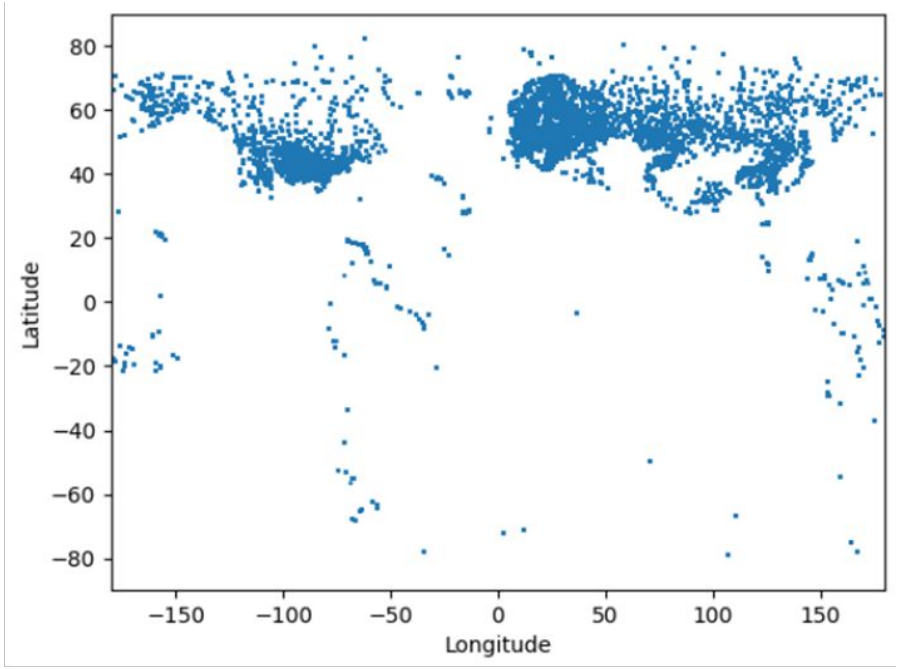


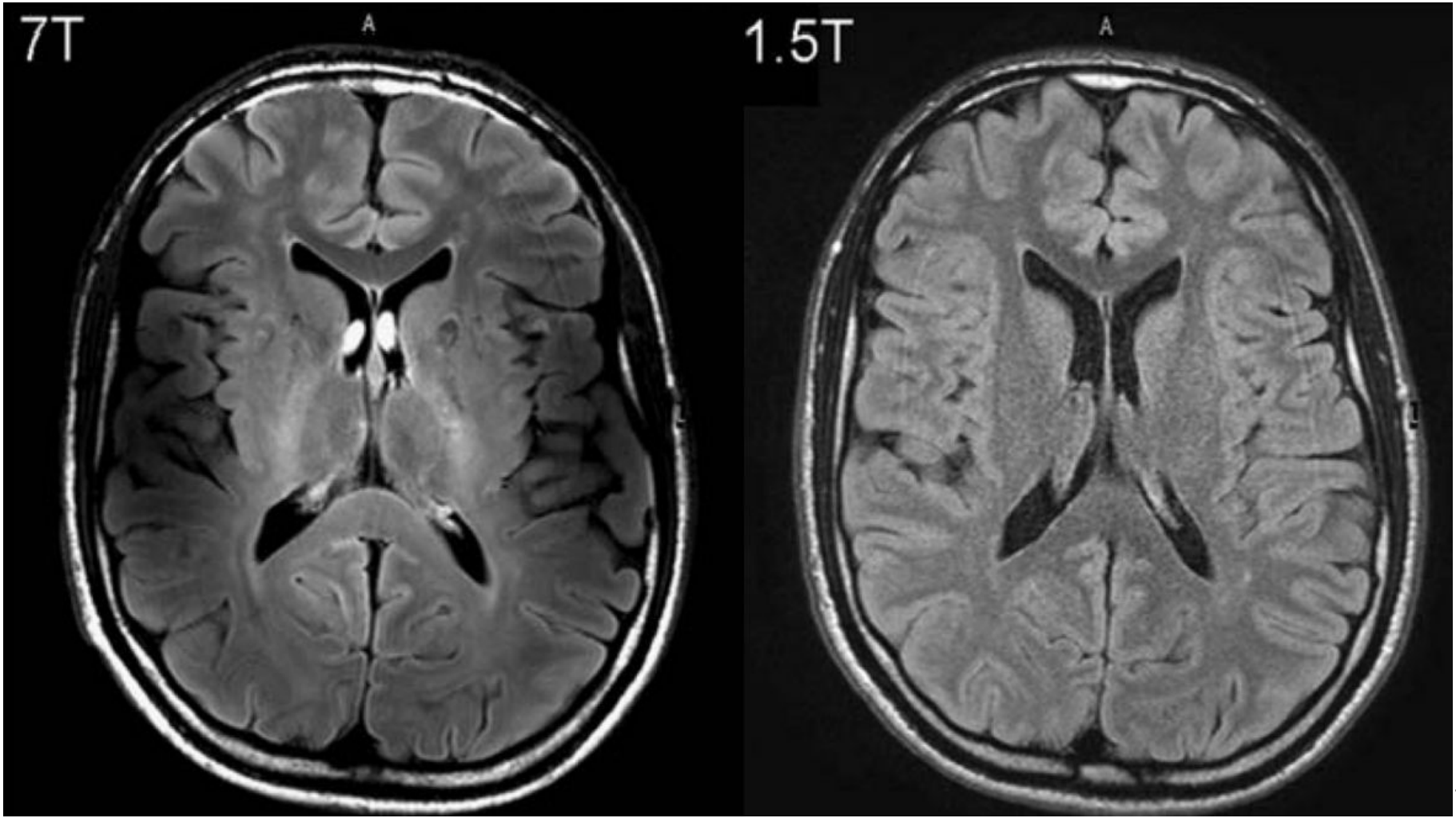


- Unseen variations of seen classes

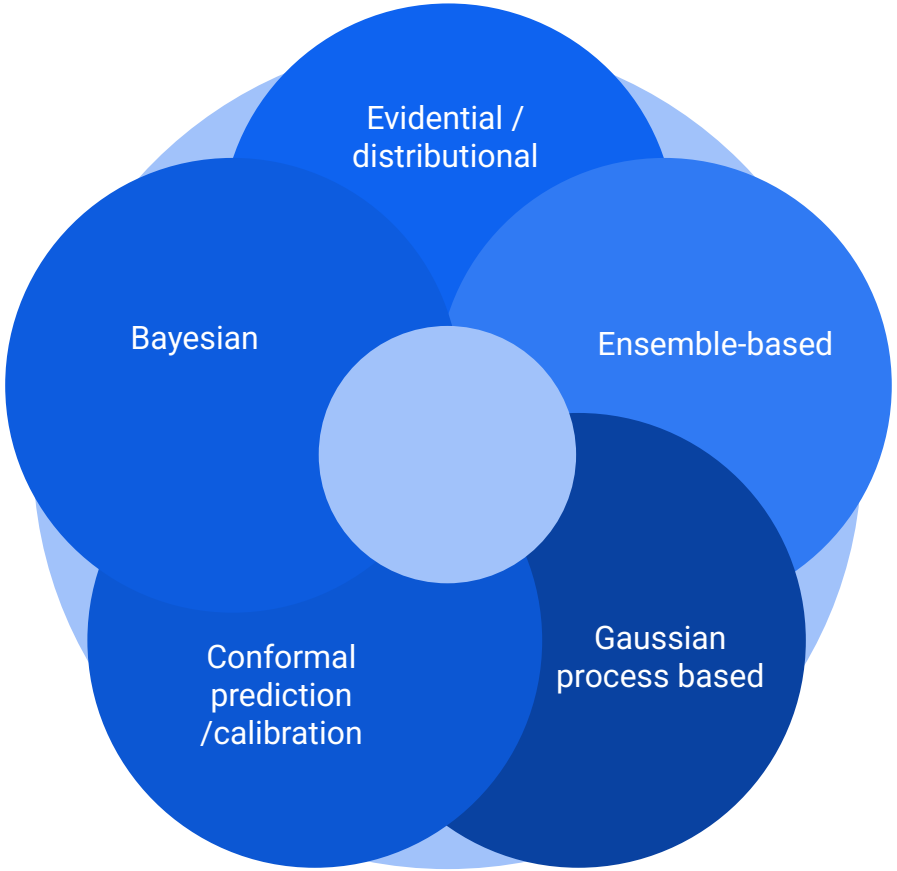



Latitude
Longitude
80
60
40
20
0
−20
−40
−60
−80
−150
−100
−50
0
50
100
150


Latitude
Longitude
80
60
40
20
0
−20
−40
−60
−80
−150
−100
−50
0
50
100
150


7T
A
1.5T
A

Modelling Uncertainty Quantification



Next

- The sources of uncertainty in medical imaging?
- Why is measuring uncertainty useful?
- How can we practically measure uncertainty?
- How to assess the quality of uncertainty quantification?