

# Artificial Intelligence in Ecology and Evolution : potential and limits

E2M2 webinar

Paul Tresson

26/06/25

# Outline

1. Why use deep learning in ecology ?
2. What are the cases where deep learning does work ?  
and other models don't
3. What are the cases where deep learning doesn't work ?  
Common traps when working with living things
4. How to sample and evaluate ?
5. Perspectives

## Why use deep learning in ecology ?

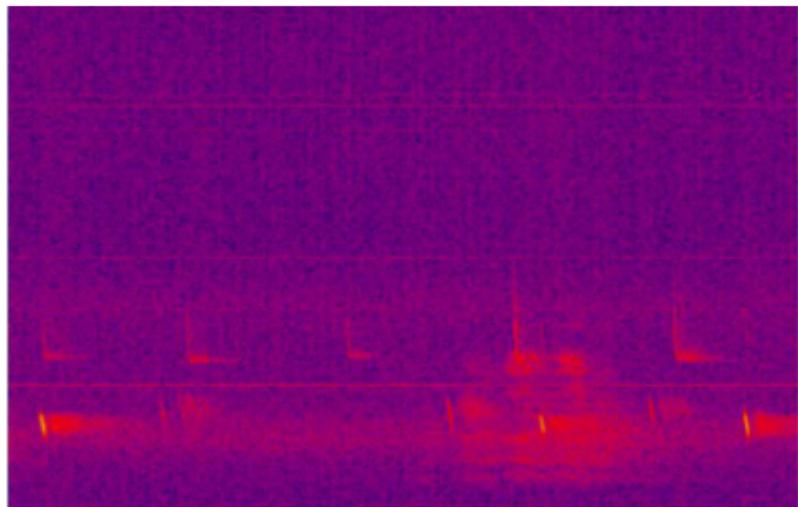
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## More and more data



- UAVs, Satellite

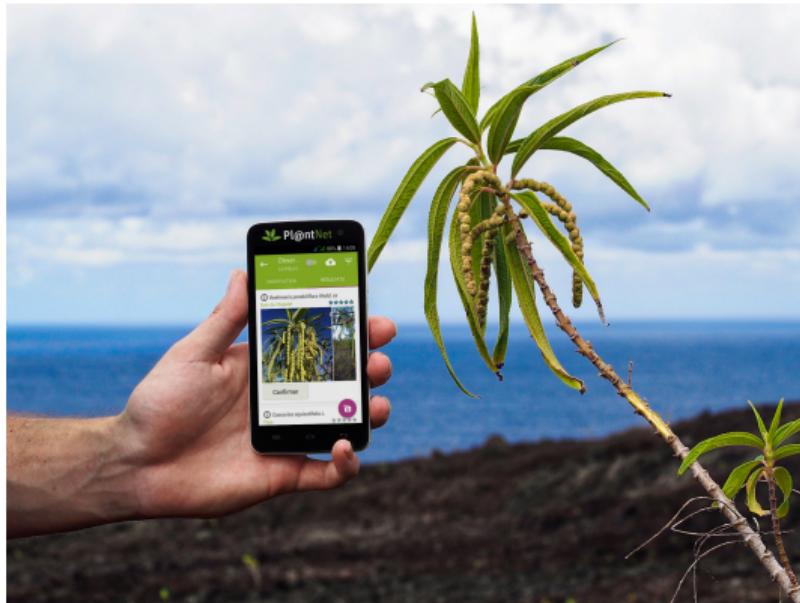
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- UAVs, Satellite
- Camera trap, acoustic

Mac Aodha *et al.* 2022

## More and more data



[plantnet.org](http://plantnet.org)

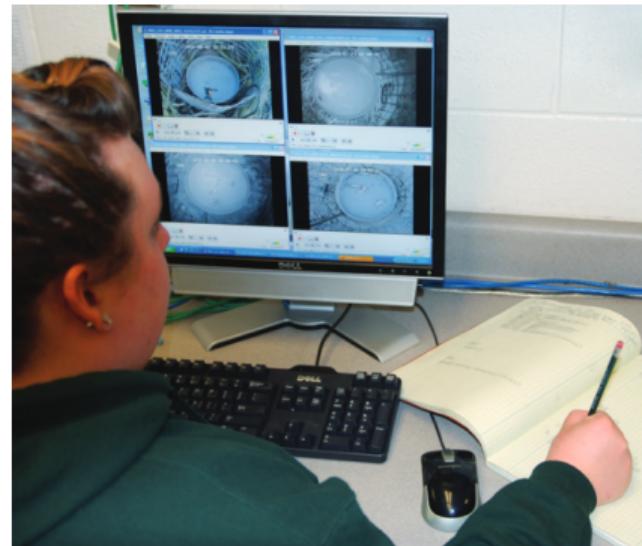
- UAVs, Satellite
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- Citizen science

## More and more data

- UAVs, Satellite
  - Camera trap, acoustic
  - Citizen science
- **Better coverage, better monitoring**

## Data analysis and interpretation is time consuming

- A computer does not sleep
- A computer does not get tired



Grieshop et al. 2012

# Data analysis and interpretation is time consuming

- A computer does not sleep
  - A computer does not get tired
- **Automation now possible**



IN CS, IT CAN BE HARD TO EXPLAIN THE DIFFERENCE BETWEEN THE EASY AND THE VIRTUALLY IMPOSSIBLE.

xkcd 1425, 2014

**What are the cases where deep  
learning does work ?**

**and other models don't**

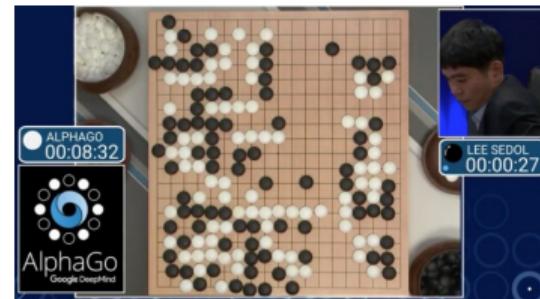
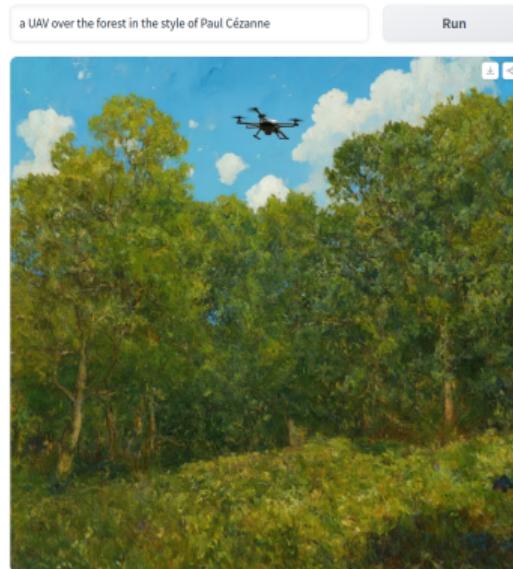
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## Model complex, non-linear and abstract relationships

Hi can you write me a haiku about forest with a subtle reference to Asterix ?

 Tall trees whispering,  
Mischief stirs in Gaulish woods—  
Magic roots run deep.



# Interpolation and generalisation



*Unonopsis stipitata* Diels

PlantClef 2020 Dataset

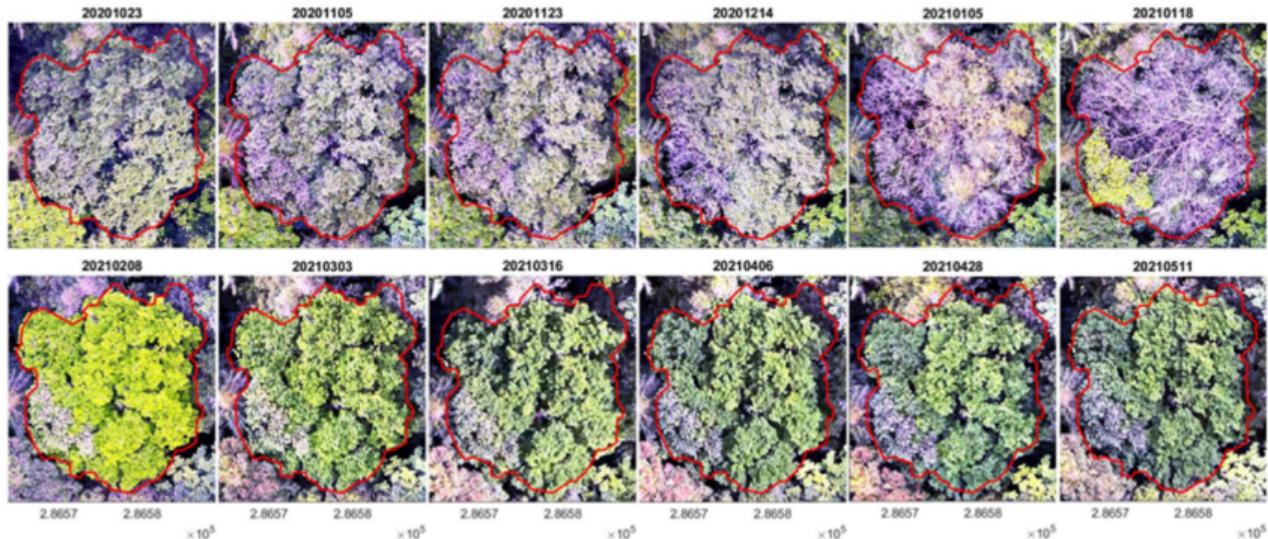
## What are the cases where deep learning doesn't work ?

Common traps when working with living things

---

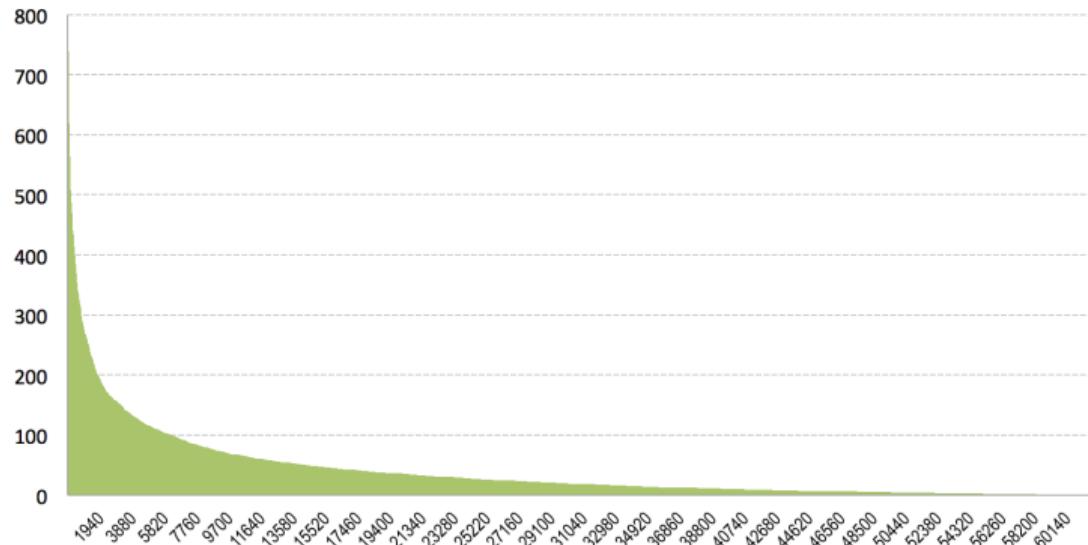
# Constraints in ecology

Data from the real world is noisy,



## Constraints in ecology

Data from the real world is noisy, unbalanced,



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Data from the real world is noisy, unbalanced, hard to collect,



# Constraints in ecology

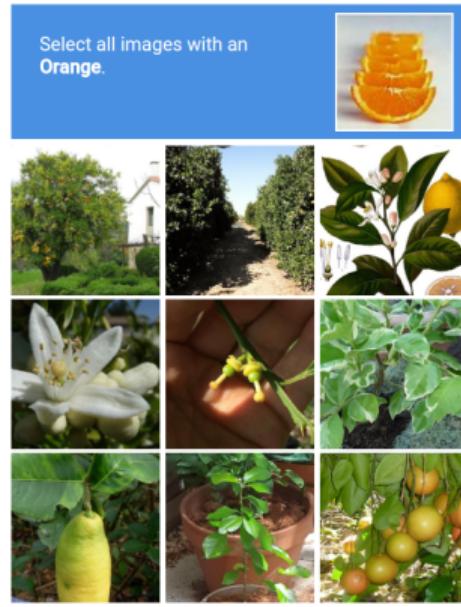
Data from the real world is noisy, unbalanced, hard to collect, hard to interpret.

Select all images with an Orange.

C    Verify

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Data from the real world is noisy, unbalanced, hard to collect, hard to interpret.

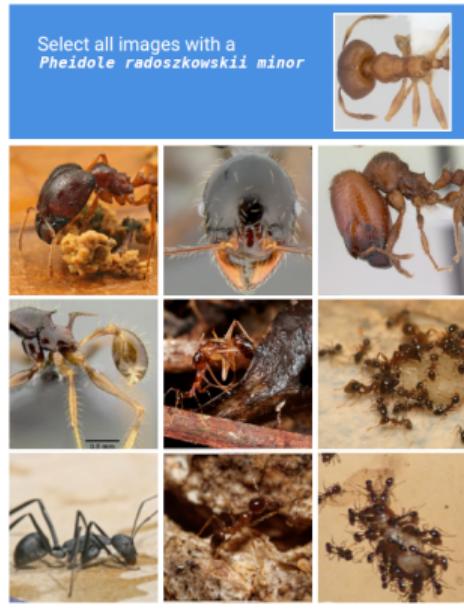


Verify

# Constraints in ecology

Data from the real world is noisy, unbalanced, hard to collect, hard to interpret.

Select all images with a  
*Pheidole radoszkowskii minor*



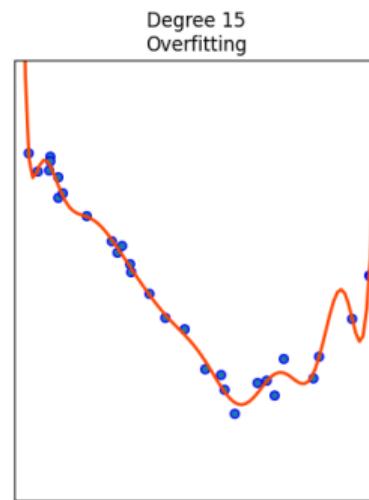
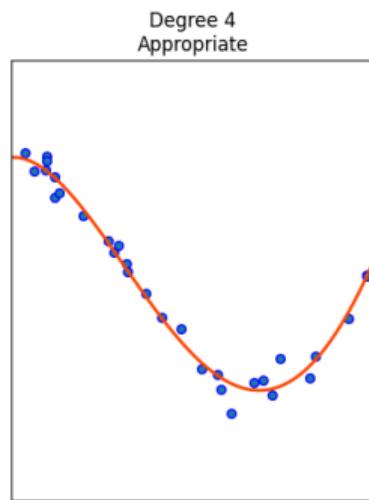
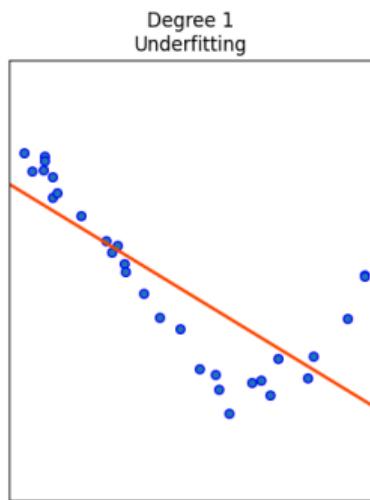
The grid contains nine images of ants, likely Pheidole species, used for a classification task. The images include various views of ants, some in groups, some in close-up, and some in their natural habitat. One image in the top row is clearly a Pheidole radoszkowskii minor ant, while the others are either different species or different morphs of the same species.



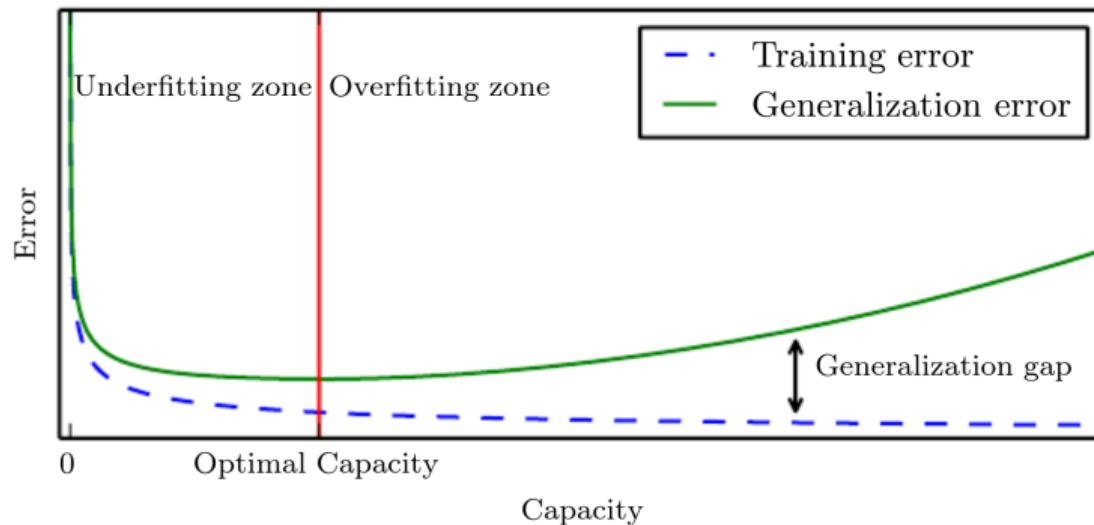
Verify

# Overfitting

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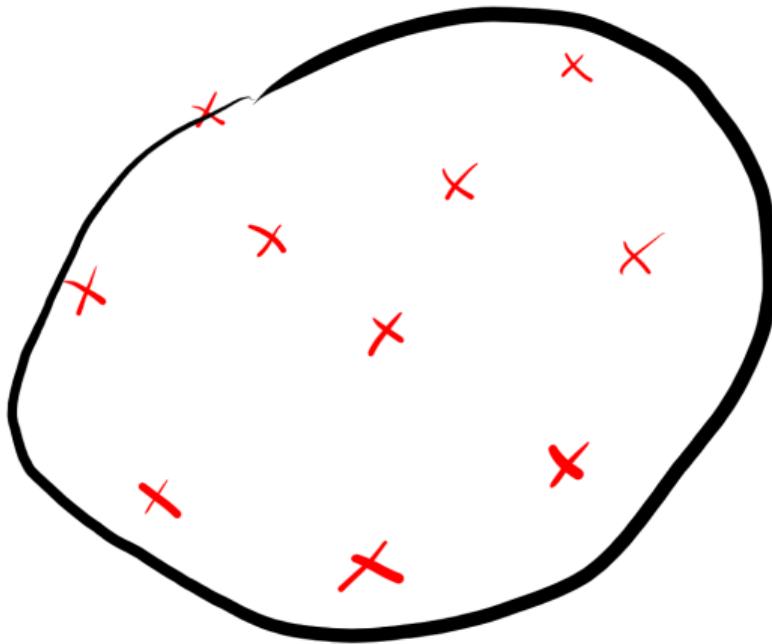
# Overfitting



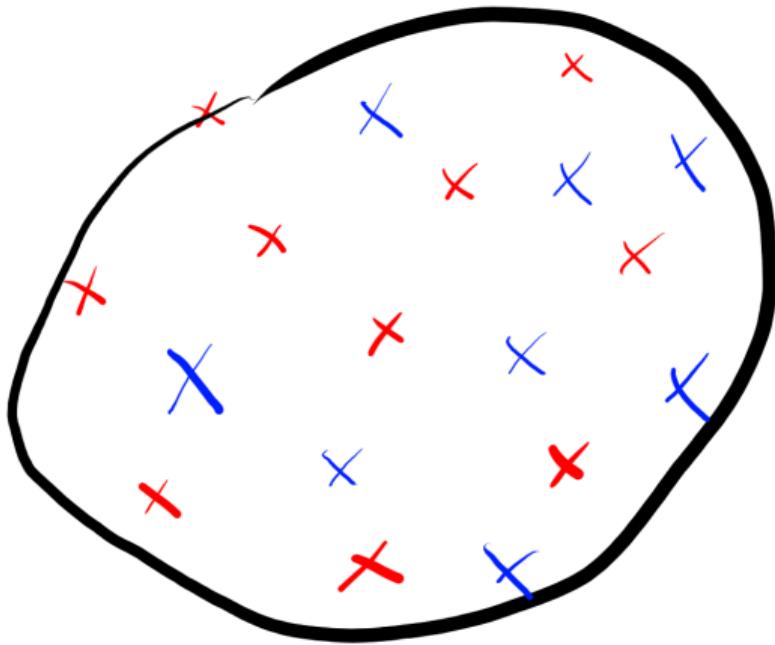
Goodfellow et al., 2016



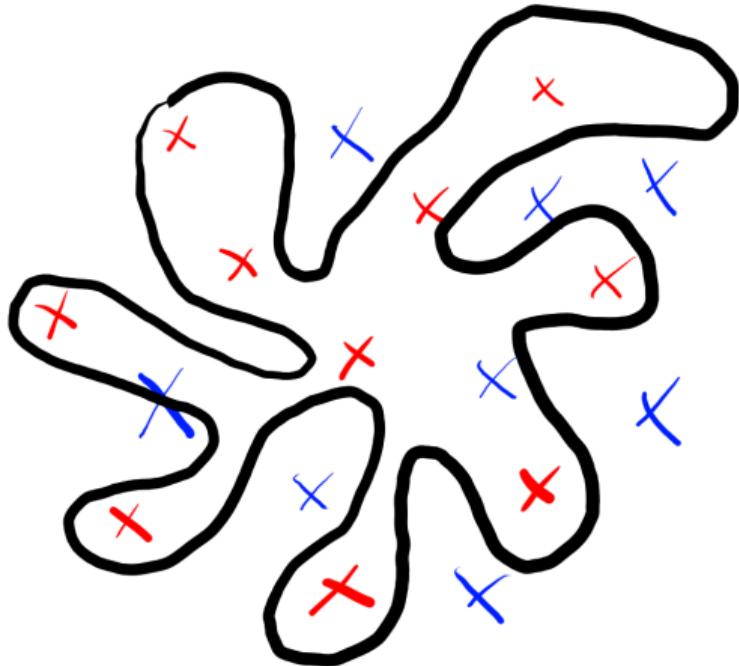
Train set



A good fitted model



Test set



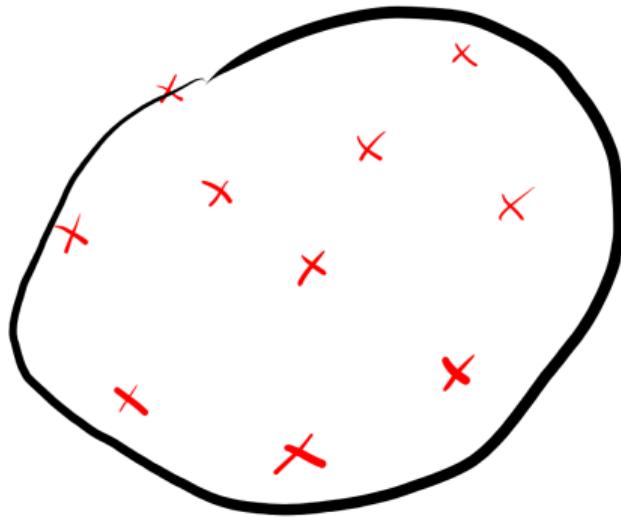
Overfitting

# Biases

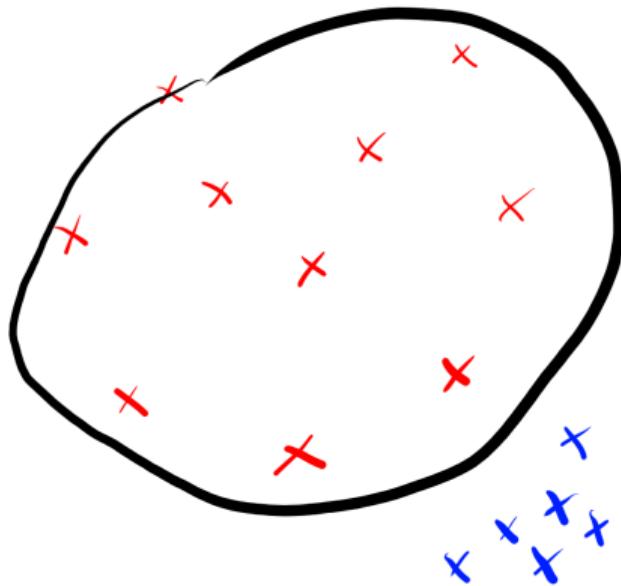
## Biases in the train set



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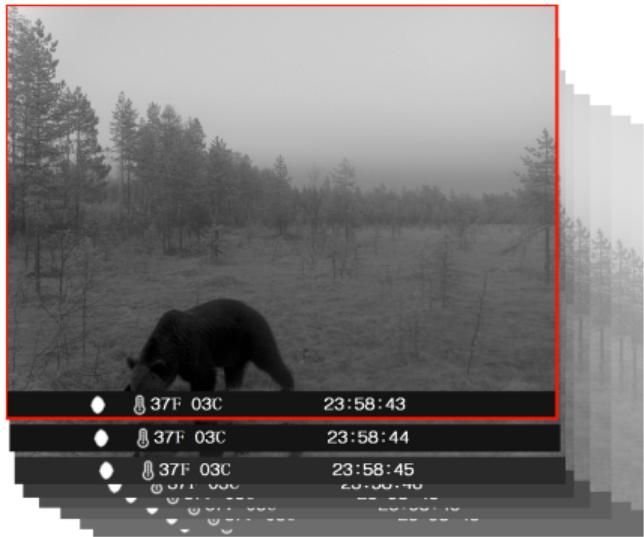
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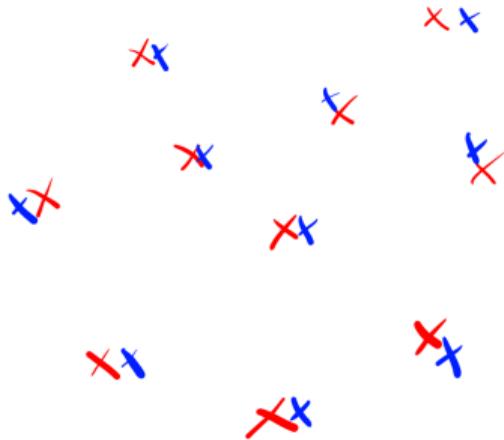
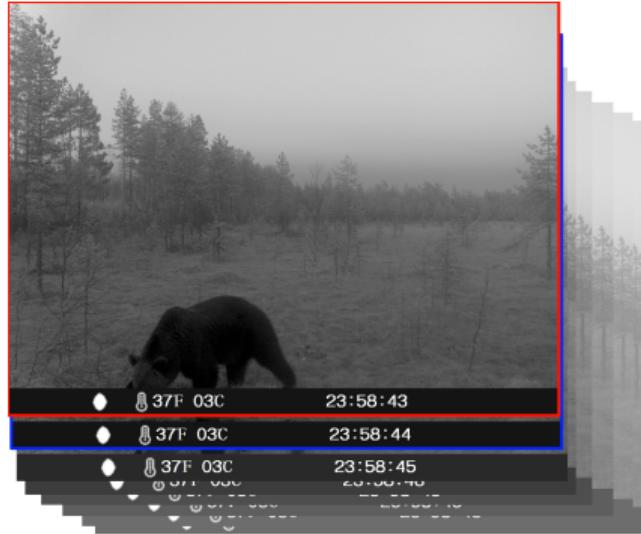
## Biases in the train set - autocorrelation



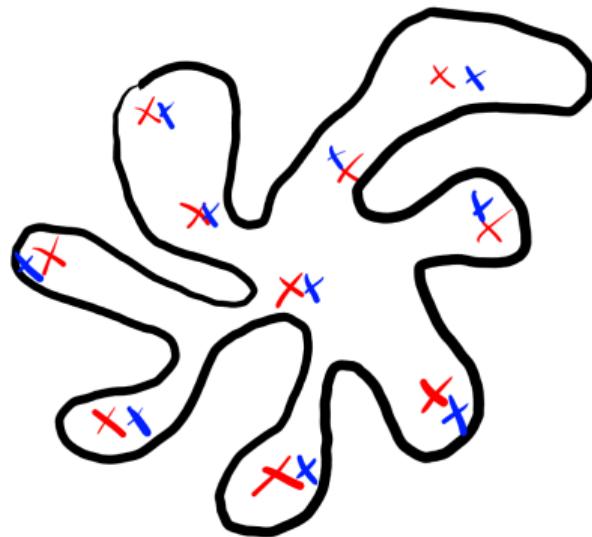
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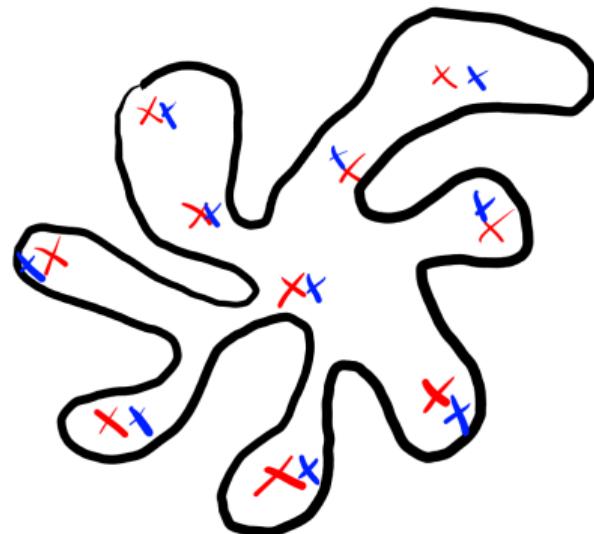
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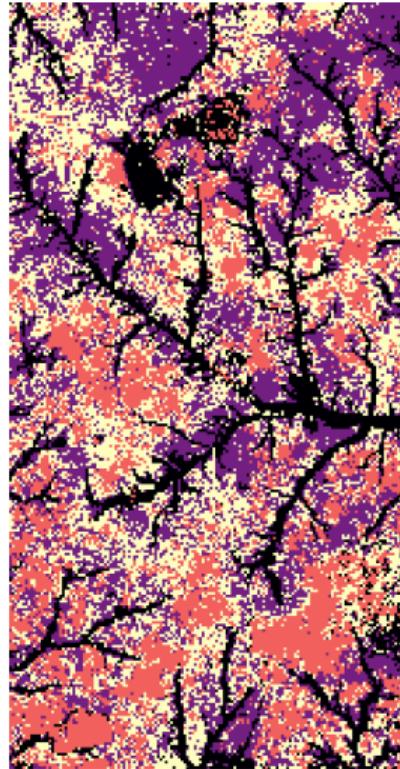
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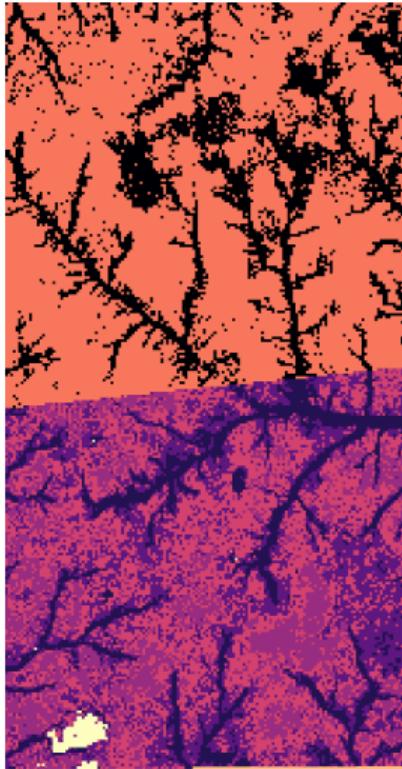
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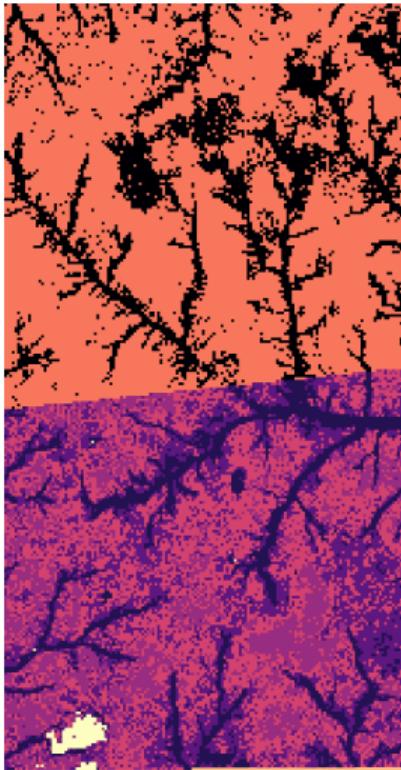
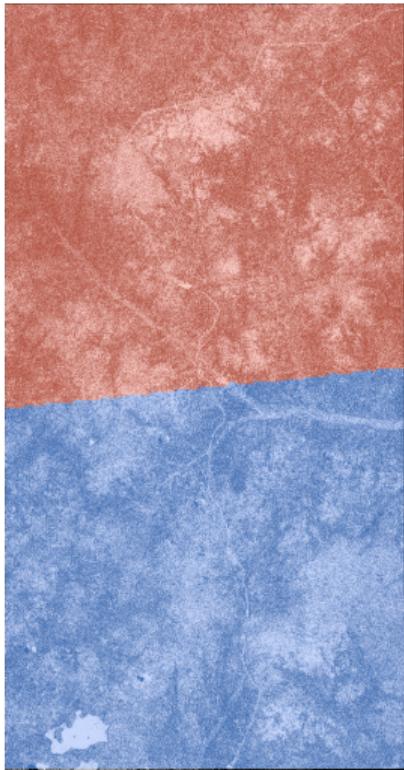
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## Biases in the train set - Spatial autocorrelation

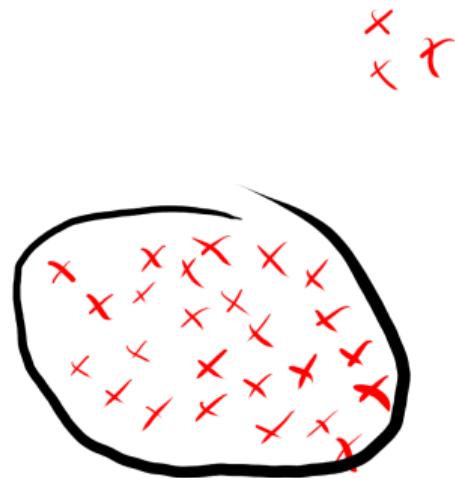


## Unbalanced data

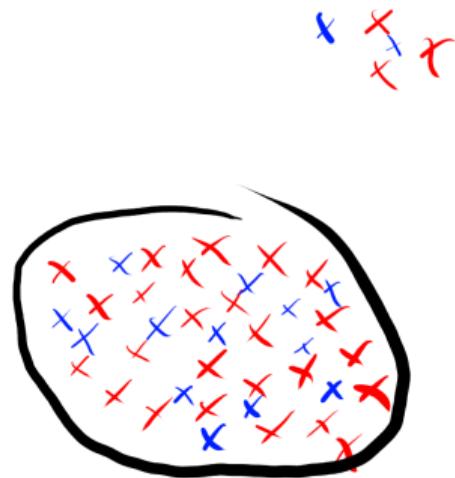
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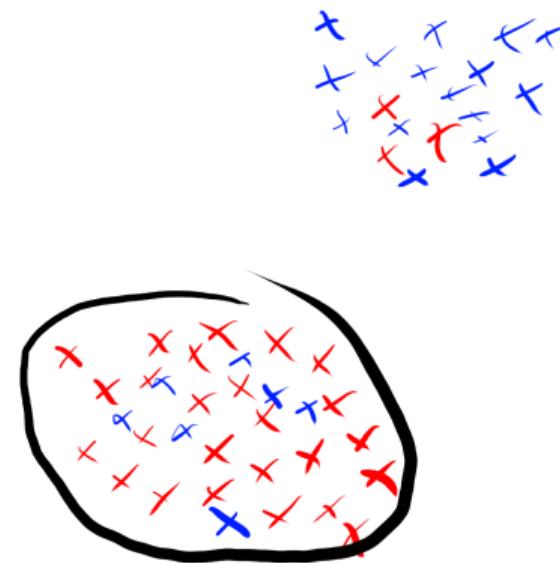
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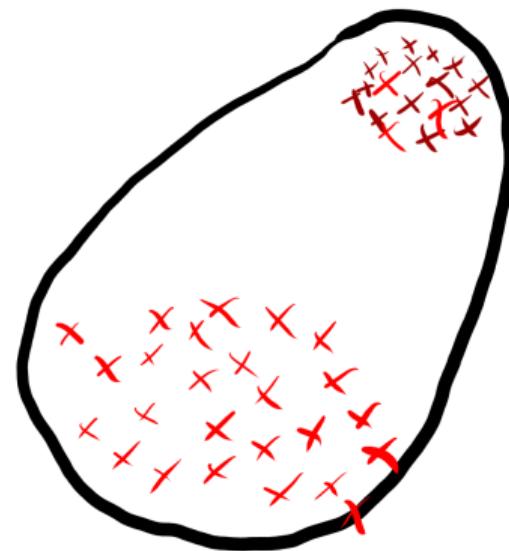
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- Oversample ?



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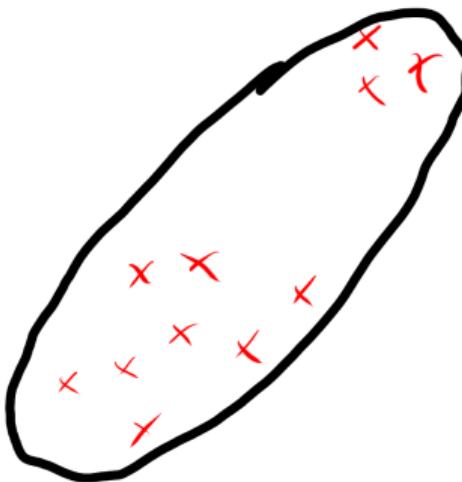
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- Undersample/saturate ?



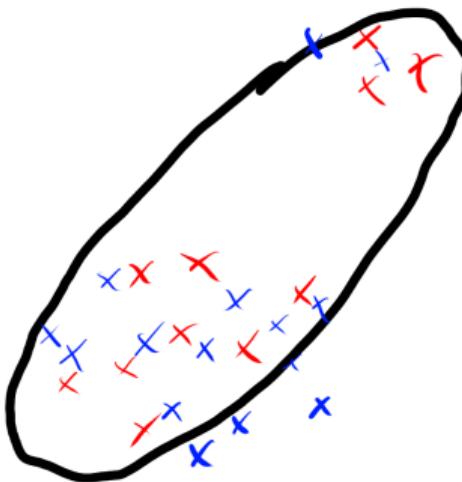
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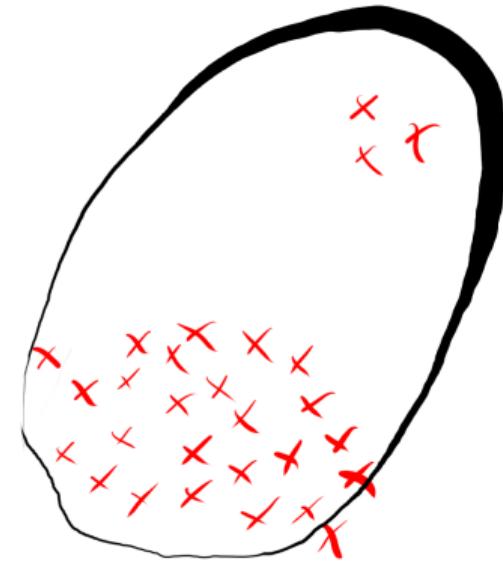
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## Deal with unbalanced data

- Oversample ?
- Undersample/saturate ?
- Adapt loss ?



## Deal with lack of data

- Data augmentation



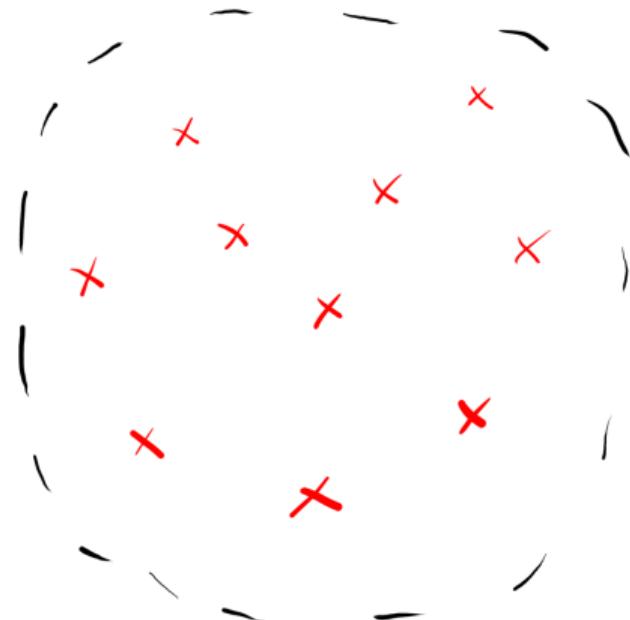
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## Deal with lack of data

- Data augmentation
- Pretrained model

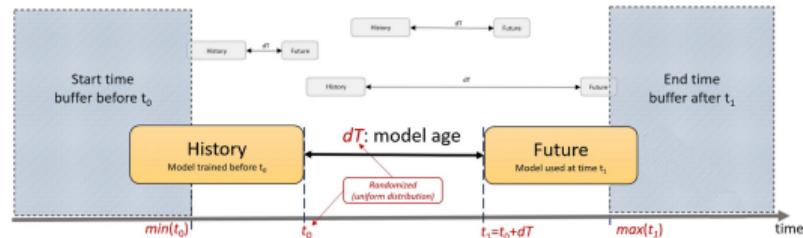


## Deal with lack of data

- Data augmentation
- Pretrained model
- ... **collect more data**

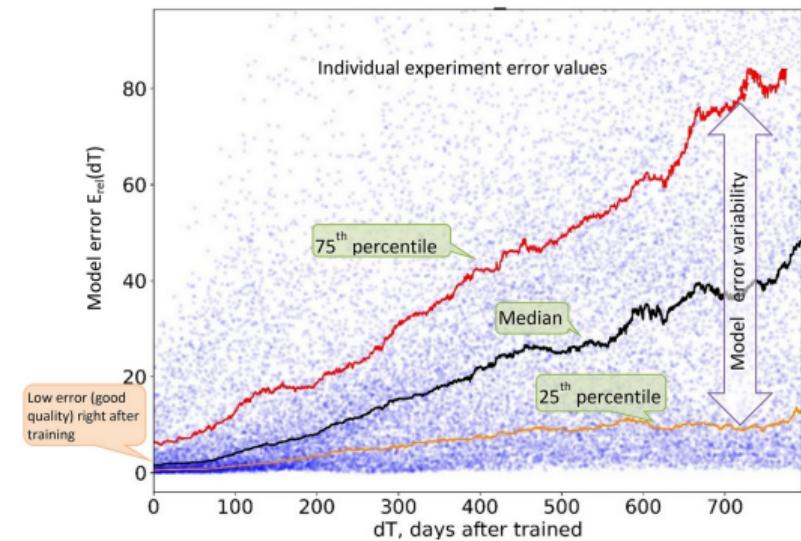
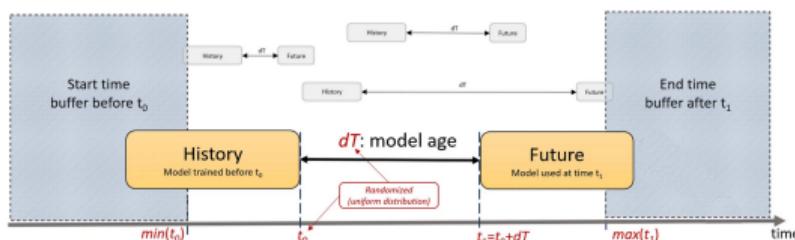
## Out of distribution

# Out of distribution : Evolution with time



Adapted from Vela et al. 2022

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## Out of distribution : Global changes

Conditions will evolve in never seen before conditions:

- Given ecosystem in unprecedented climatic conditions

## Out of distribution : Global changes

Conditions will evolve in never seen before conditions:

- Given ecosystem in unprecedented climatic conditions
- Species migrate/invoke in new territories

## Out of distribution : Invasive species

New unknown species in the training test appears in a region.

- False Positive : confusion with known species

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## Out of distribution : Invasive species

New unknown species in the training test appears in a region.

- False Positive : confusion with known species
- False Negative : model misses the new species
- Handmade check on model confidence

**Need to be very careful on how to evaluate**

## How to sample and evaluate ?

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## Random split ?

“random split training validation 80/20”

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For the uncurated dataset, we randomly sample 142 million images

Oquab et al., 2023

## Random split ?

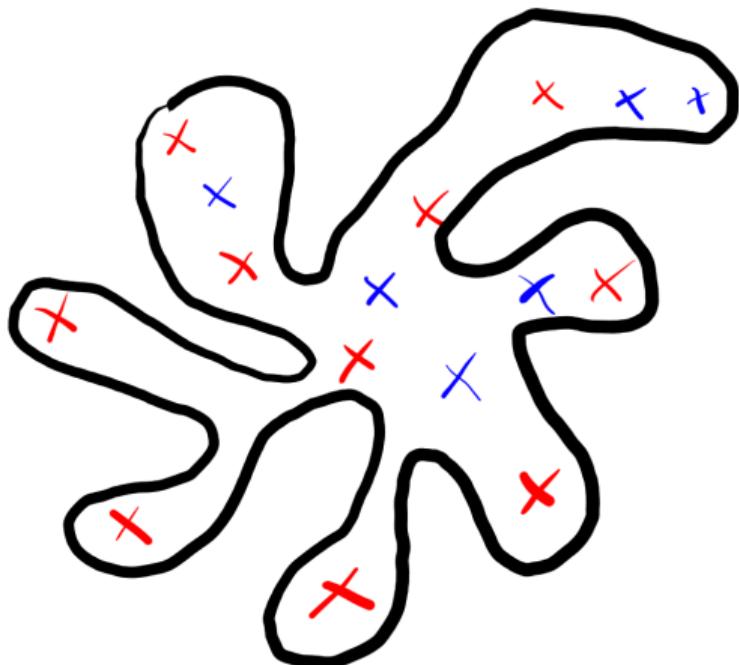
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For the uncurated dataset, we randomly sample 142 million images

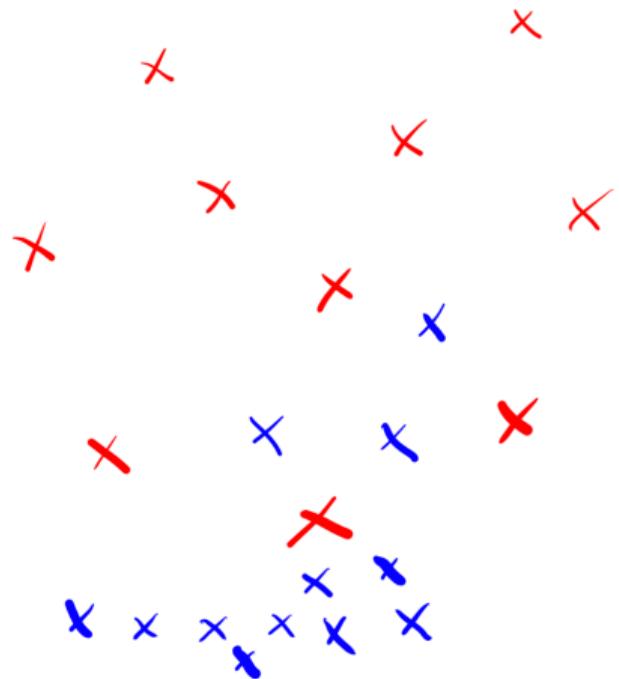
Oquab et al., 2023

Works for huge DL papers, maybe not for you

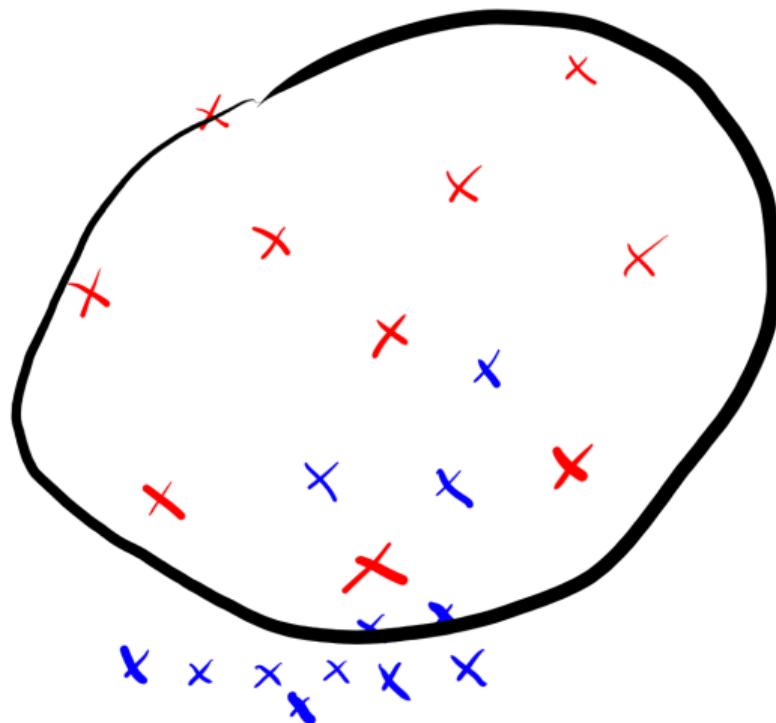
## Overfitting the test set



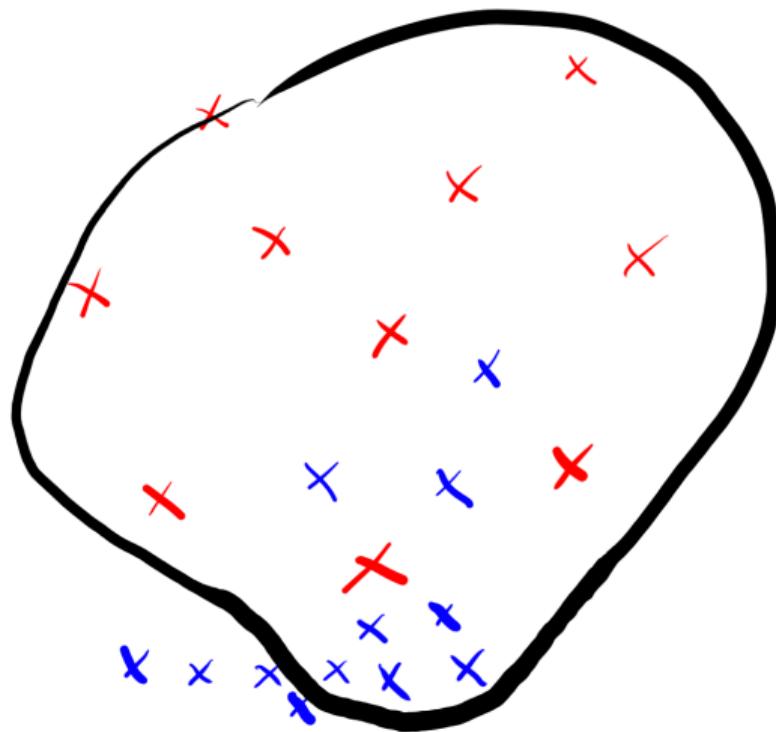
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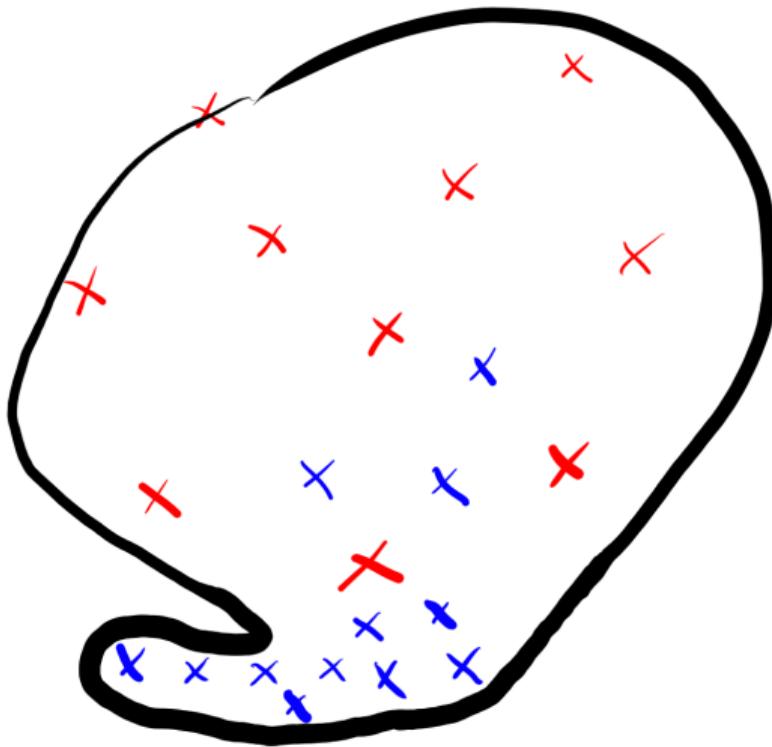
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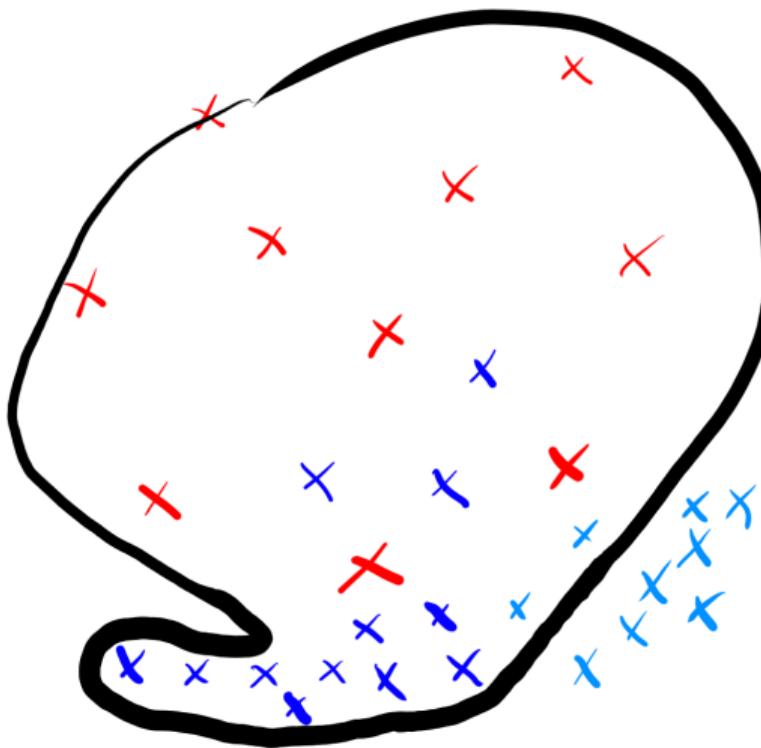
## Overfitting the test set



## Overfitting the test set



## Overfitting the test set



# Cross-validation

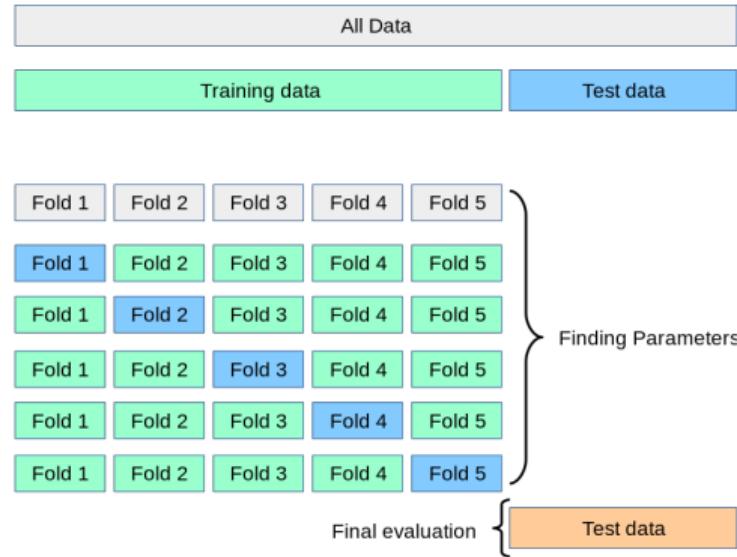


Figure from scikit-learn docs

## Cross-validation

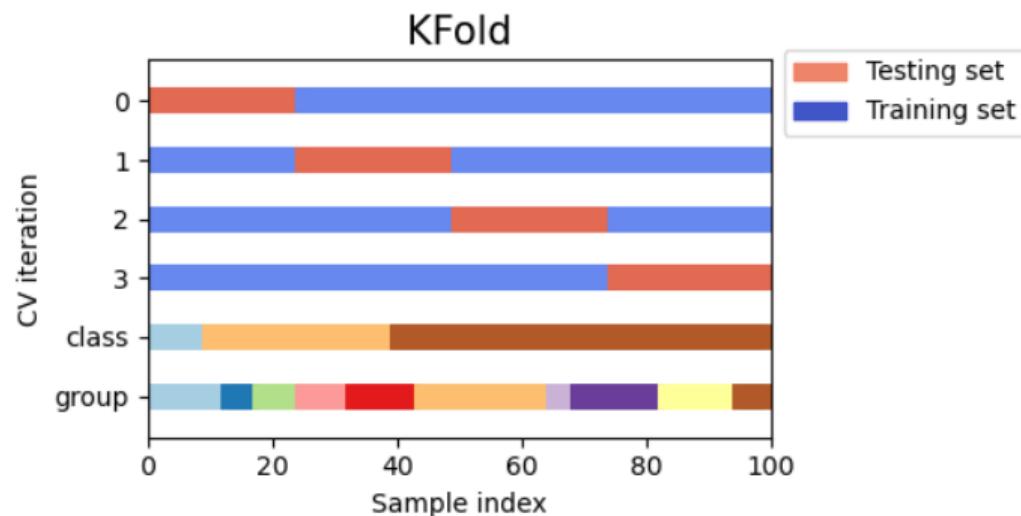


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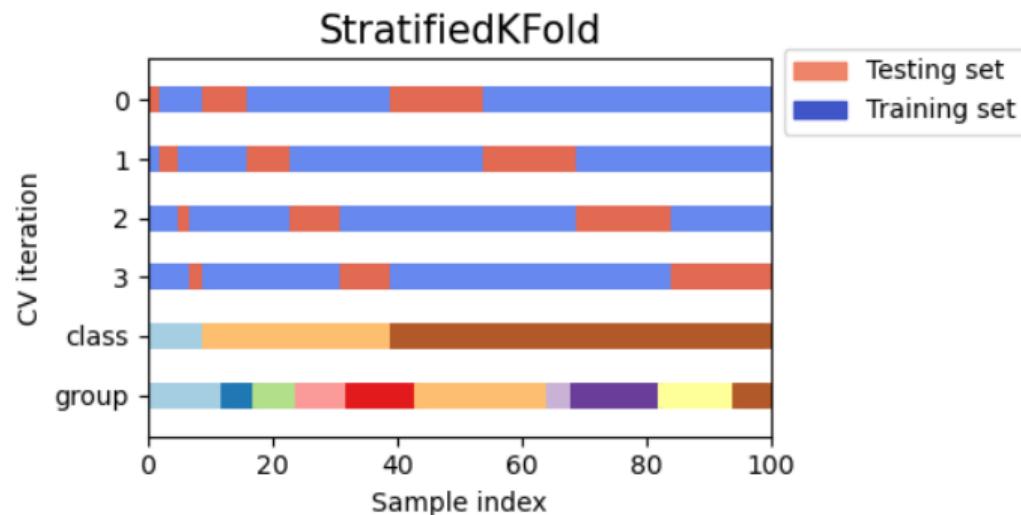
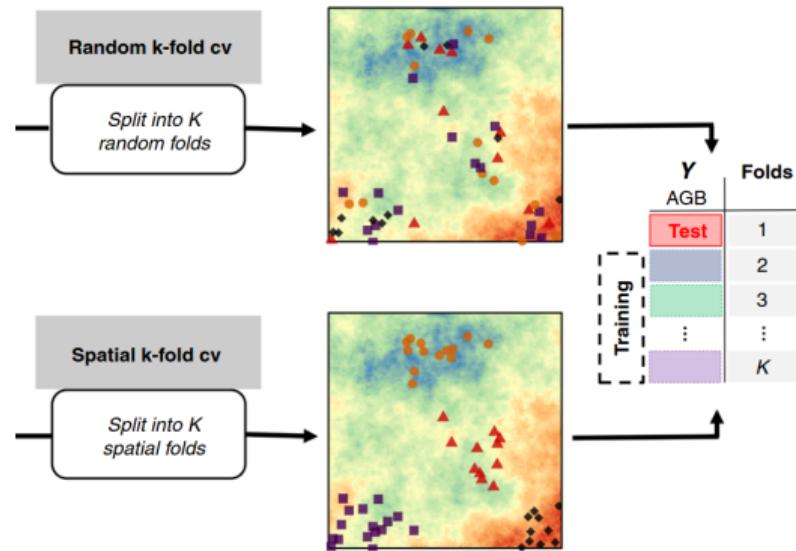


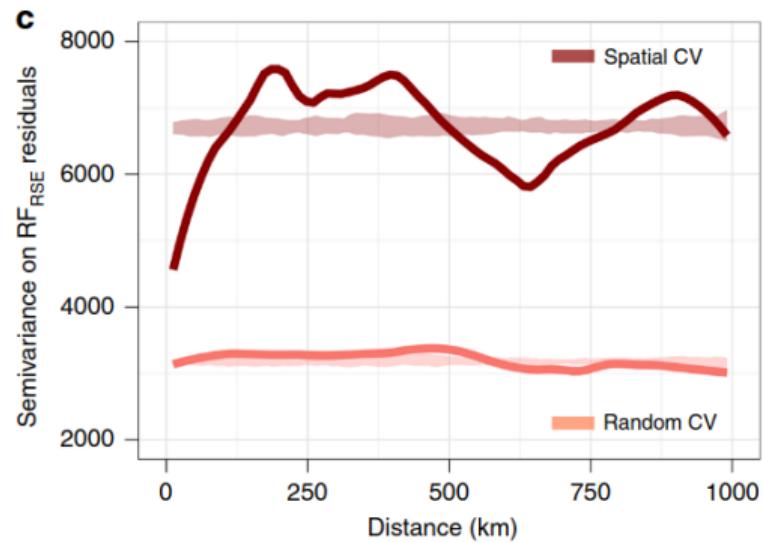
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# Spatial cross-validation



See. Ploton et al., 2020

## Spatial cross-validation

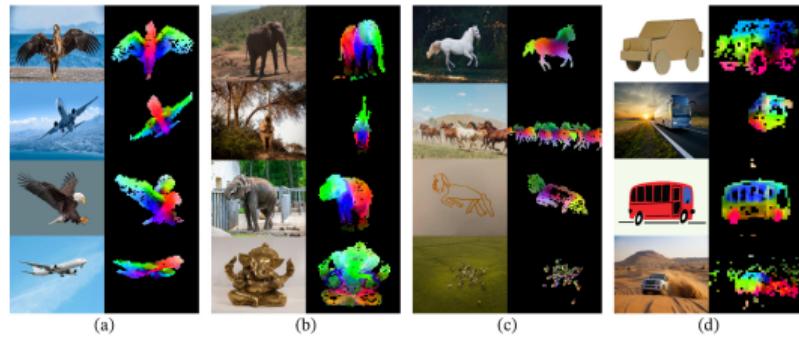


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## Perspectives

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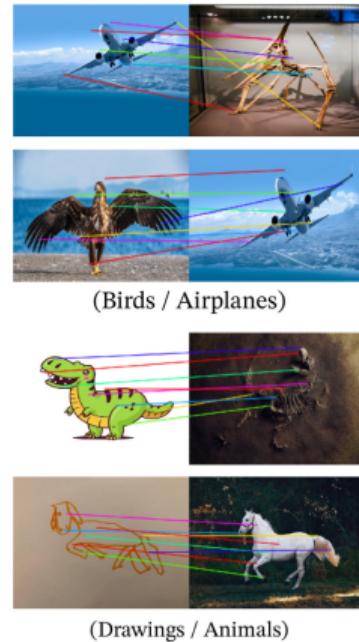
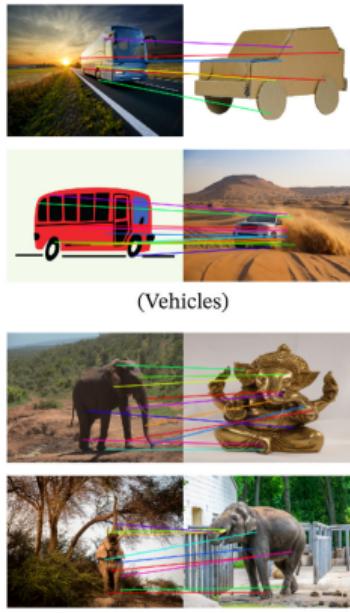
# Models are more robust and generalist



- Self-supervised Learning (Pre-training)

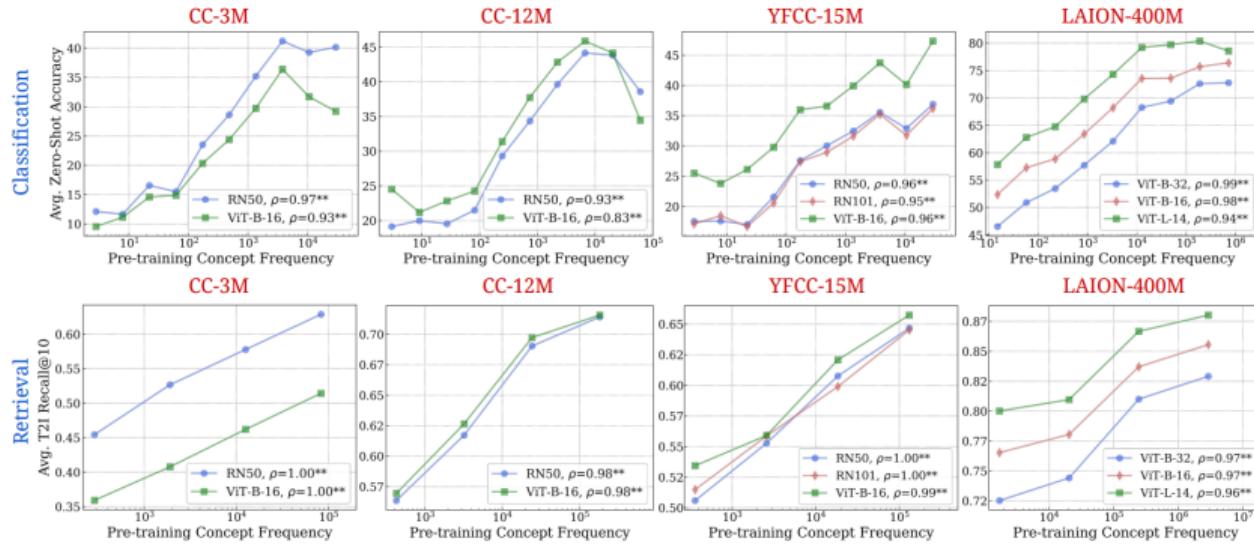
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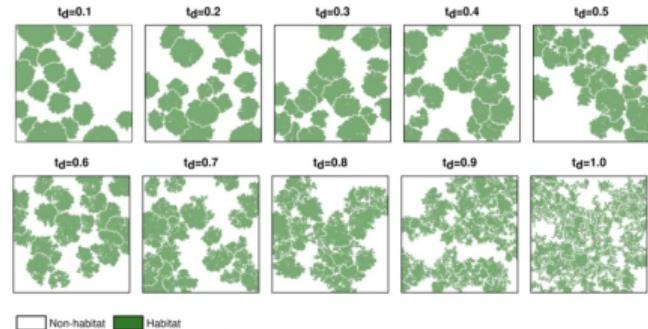
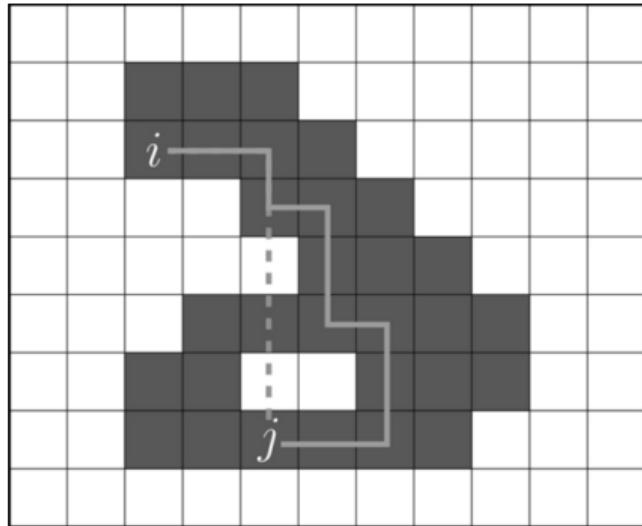
- Self-supervised Learning (Pre-training)
- Better performances and robustness

# Zero-shot at a cost



Udandarao et al. 2024

# Not only deep learning



Justeau-Allaire et al., 2024

# Conclusion

Should I use deep learning in my research ?

- ✓ Lot of incoming data                            ✗ Need for explainability
- ✓ Low-level data                                    ✗ Need for certainty
- ✓ Cumbersome but (relatively) easy to analyse                            ✗ Need for reliability

Thank you for your attention !

Any questions?

# Useful ressources

## State of the art

- Huggingface
- PapersWithCode

## Getting started

- Pytorch
- Keras

## Understanding papers

- Yannic Kilcher
- AI coffe break

## Understanding visually

- 3blue1brown
- deepia