# Hyperspectral analysis in plant breeding

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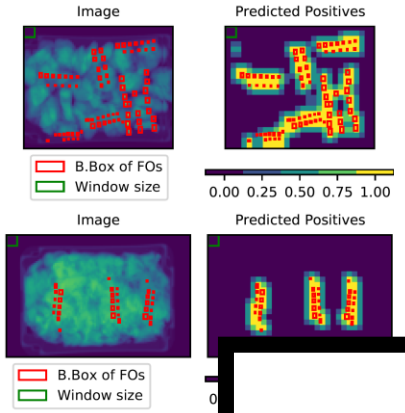
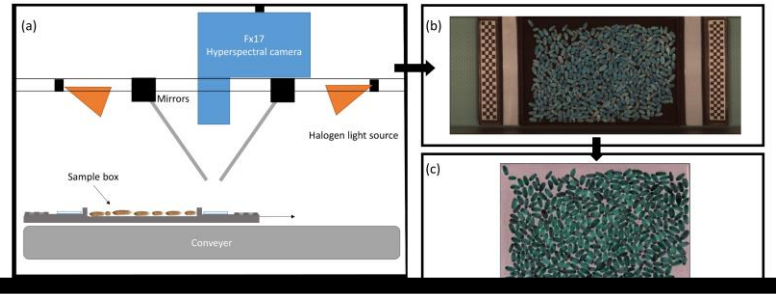
# A little about who I am

Currently: Senior scientist at FOSS
Previously: Postdoc at UCPH FOOD, UCPH Computer science, and FOSS

**X-ray imaging**




**Hyperspectral imaging**




**Multispectral imaging**


+ Deep learning algorithms

# About the talk's subject – an interdisciplinary research project

- Applying Artificial Intelligence (AI) in food research.
  - Collaboration between UCPH FOOD, UCPH Computer Science, and FOSS.
  - 2-year Post-doc started 1. November 2019

- Projects:
  - **Predicting grain quality parameters with hyperspectral imaging.**
  - Foreign object detection (FOD) in X-ray images
  - Predicting plant growth from RGB images
  - Fast assessment of extruded pea products quality

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# Today's wheat assessment (Whole kernels examples)

- NIR spectroscopy:
  - Protein level
  - Moisture level

- Inspection of purity
  - Damaged grain and foreign material.
    → A person manually inspects a sample.
    → Or **machine vision tools.** (*EyeFoss™)


*Infratec™

# Today's grain quality assessment (Flour examples)

- Baking quality
  → Bake a bread and see how it looks
- Sprouting damage
  → Falling number.
- Mycotoxins
  → Deoxynivalenol (DON)
- And many more

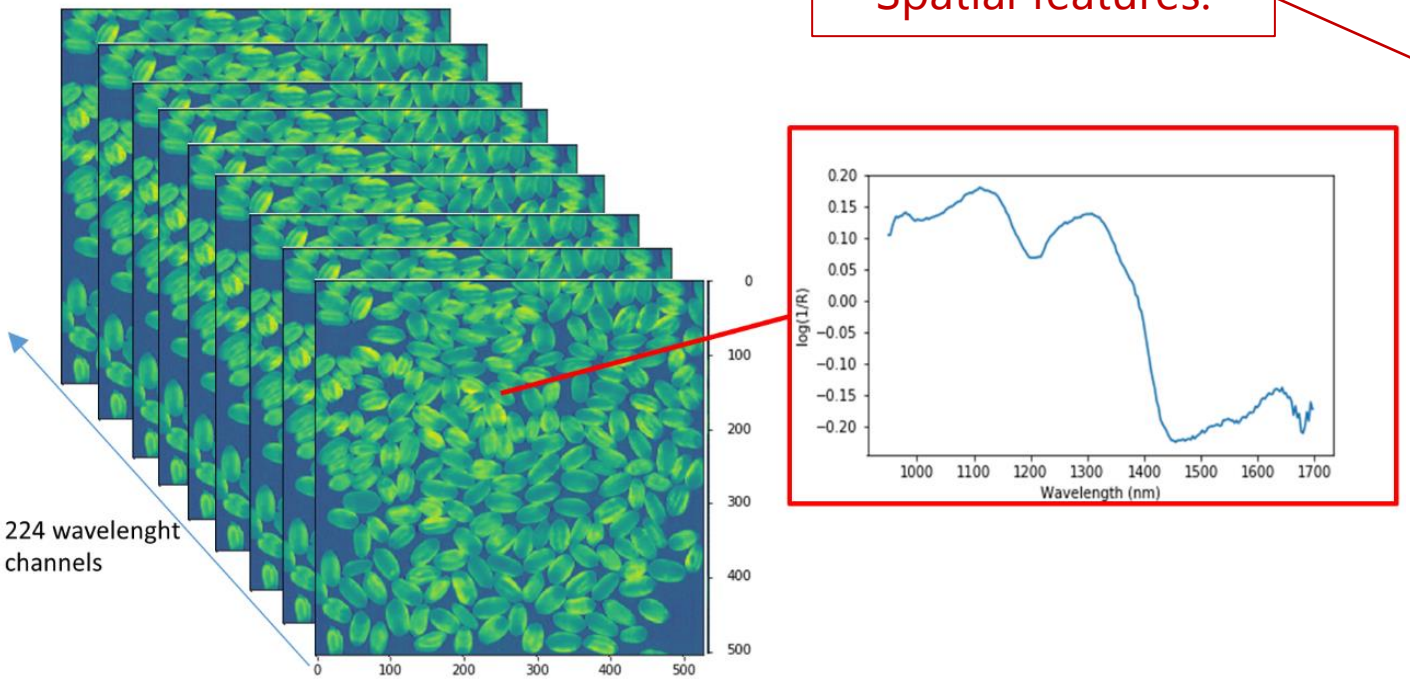
*https://www.grainscanada.gc.ca/en/grain-research/euality/cereals/wheat/methods-tests.html


*https://www.fossanalytics.com/en/products/alphatec

# Why NIR hyperspectral imaging (HSI)?

HSI contains both spatial and spectral information of the grains.


*Hyperspectral image of grains




Spectral features:

- **NIR spectra of kernels** (single kernel Infratec)**:**
  - Protein content
  - Moisture content

Spatial features:

- **Images of kernels** (Eyefoss)
  - Grain type classification
  - Grain purity

- **But what if we combine spatial and spectral?**
  - Falling number?
  - Sprouting energy?
  - Mycotoxin?

# Why Convolutional Neural Networks (CNN)?

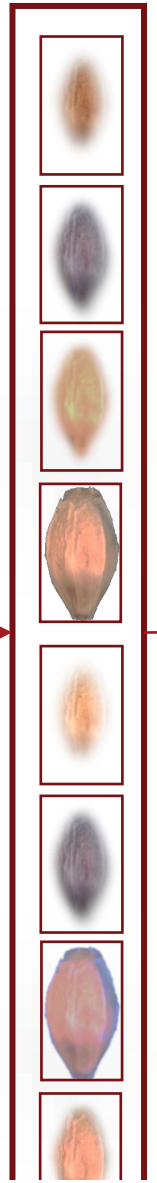
## What are CNNs?

- Deep artificial neural network.

Conv layer

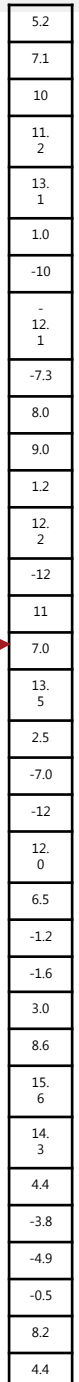
| | | |
|---|---|---|
| 1 | 0 | -1 |
| 2 | 1 | -1 |
| 1 | -1 | -1 |

Conv layer

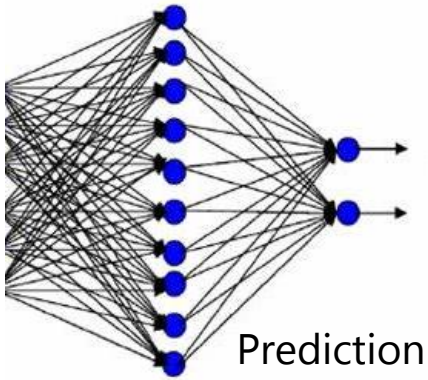


Conv layer

Conv layer




ANN



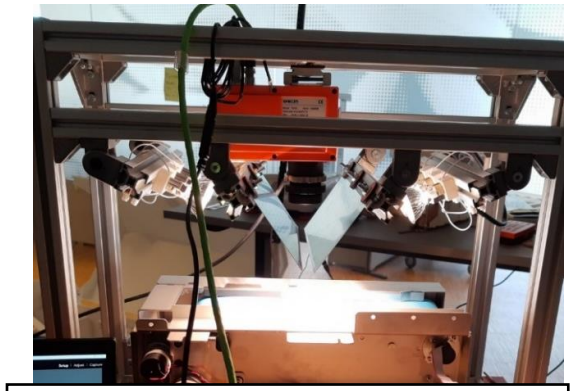
Prediction

CNNs can be trained to find patterns useful in predicting parameters from large image datasets!

PyTorch

TensorFlow

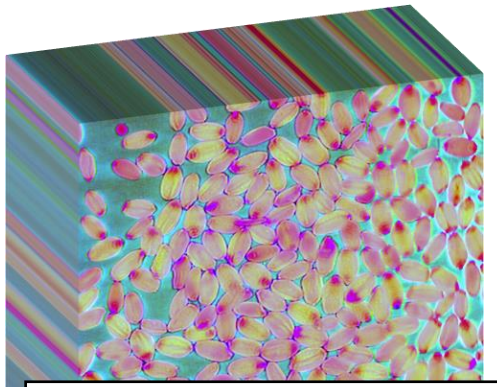
# Project Roadmap:



Specim FX17 camera setup

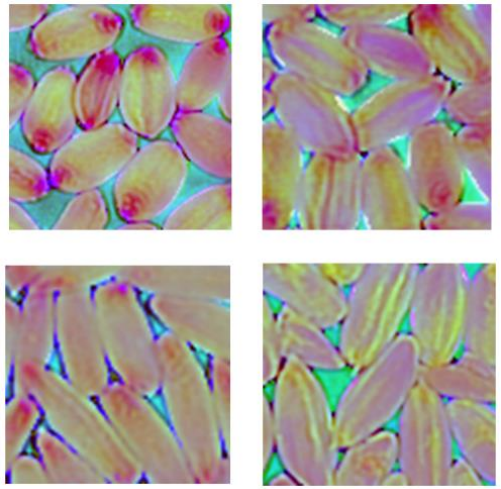
Imaging setup?

Preprocessing the hypercube?



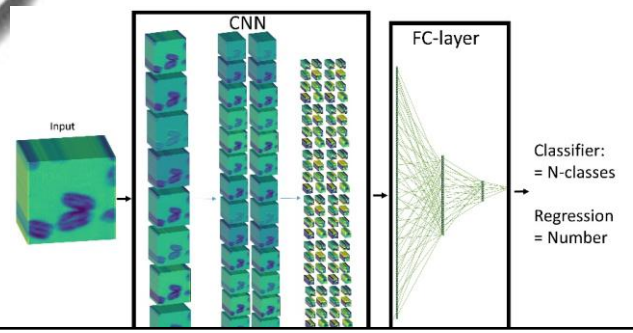
Reduce and/or correct data?

Sample preparation?



Use cases?

Network architecture?



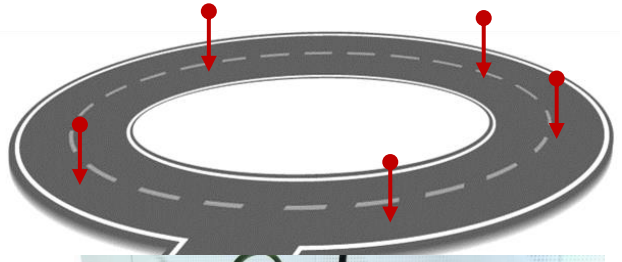

CNN networks for HSI?

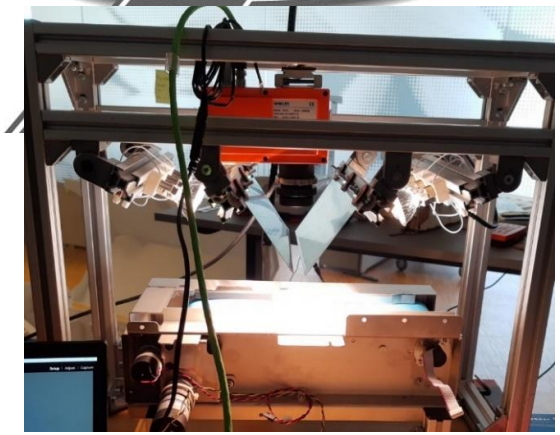
Flexible deep learning -hyperspectral NIR solution for grain analysis

# Use cases:

1. Bulk grain variety classification
   8 grain classes

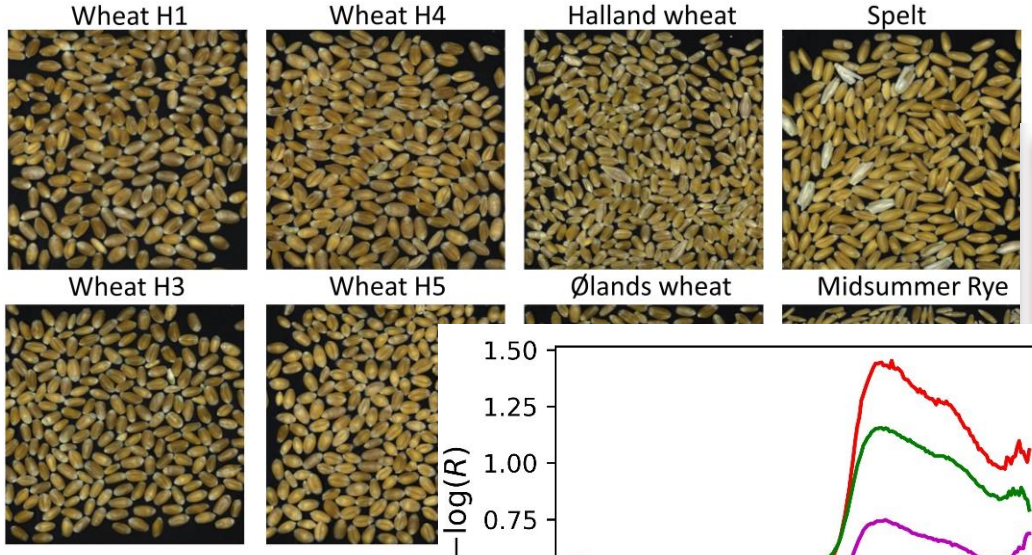
- Acquire hypercubes
- Crop sliding window (128 x 128 x 224)
  - 16000 for training
  - 6400 for validation
  - 3200 for test





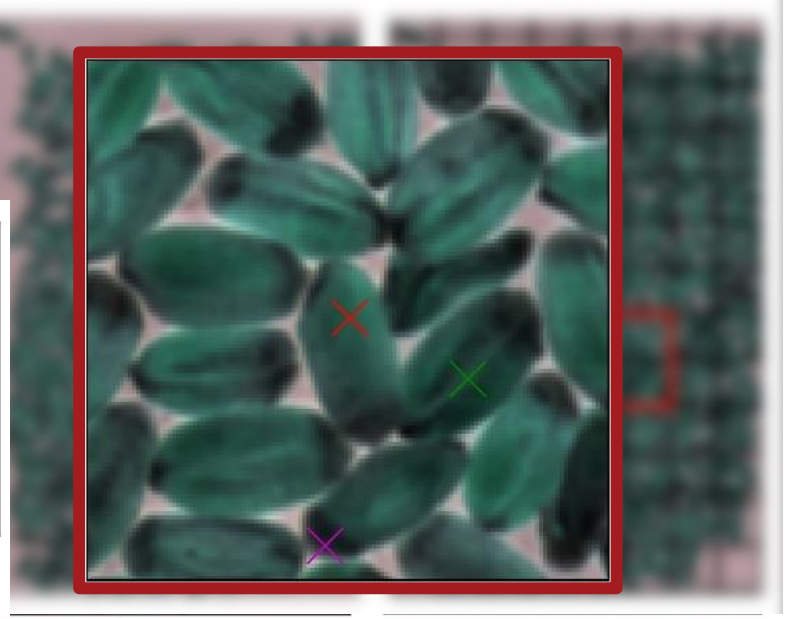
Why:
Grain variety is a standard classification problem for HSI

Solved with both spectroscopy and machine vision!



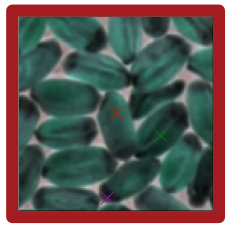






# Use Case: Grain variety classification

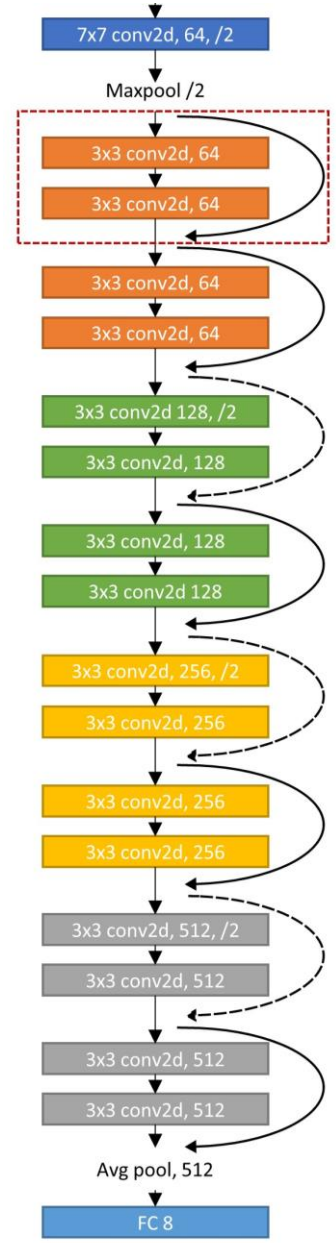
## Network architecture:

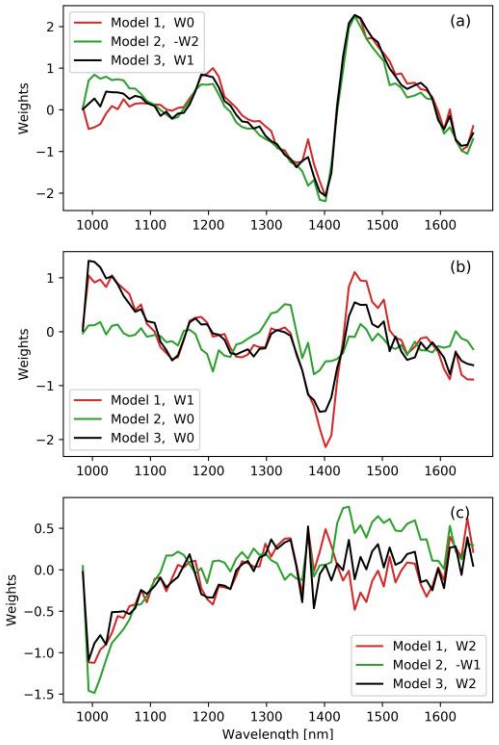


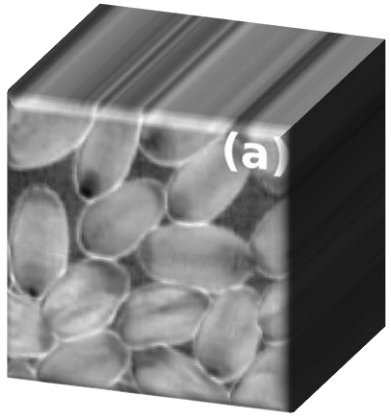
→ Downsample layer → Benchmark CNN for RGB → 8 classes?

224 to 3 spectral channels.

ResNet18

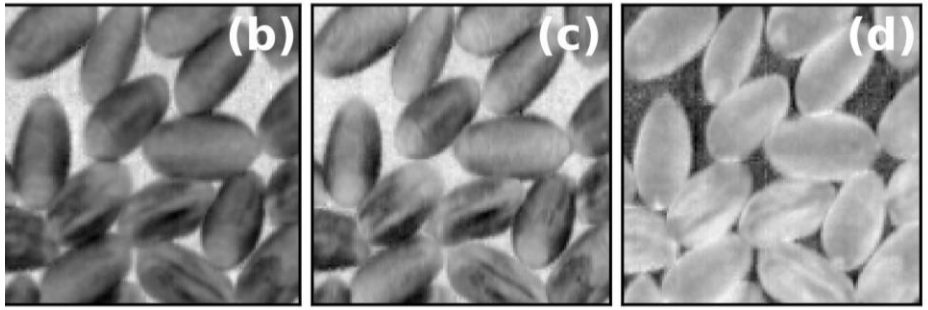



Hypercube

Pseudo RGB



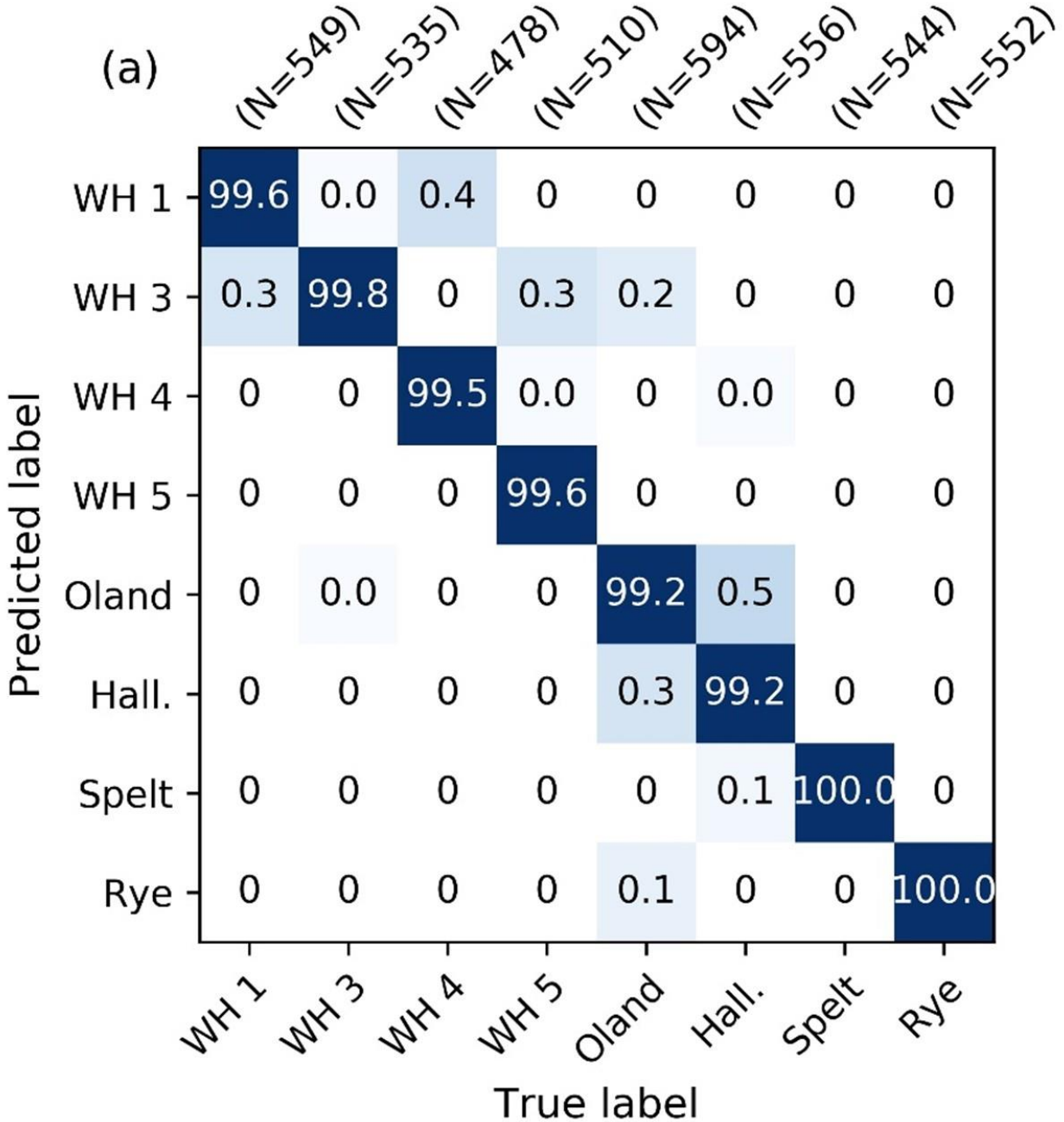
# Results

Winter type A

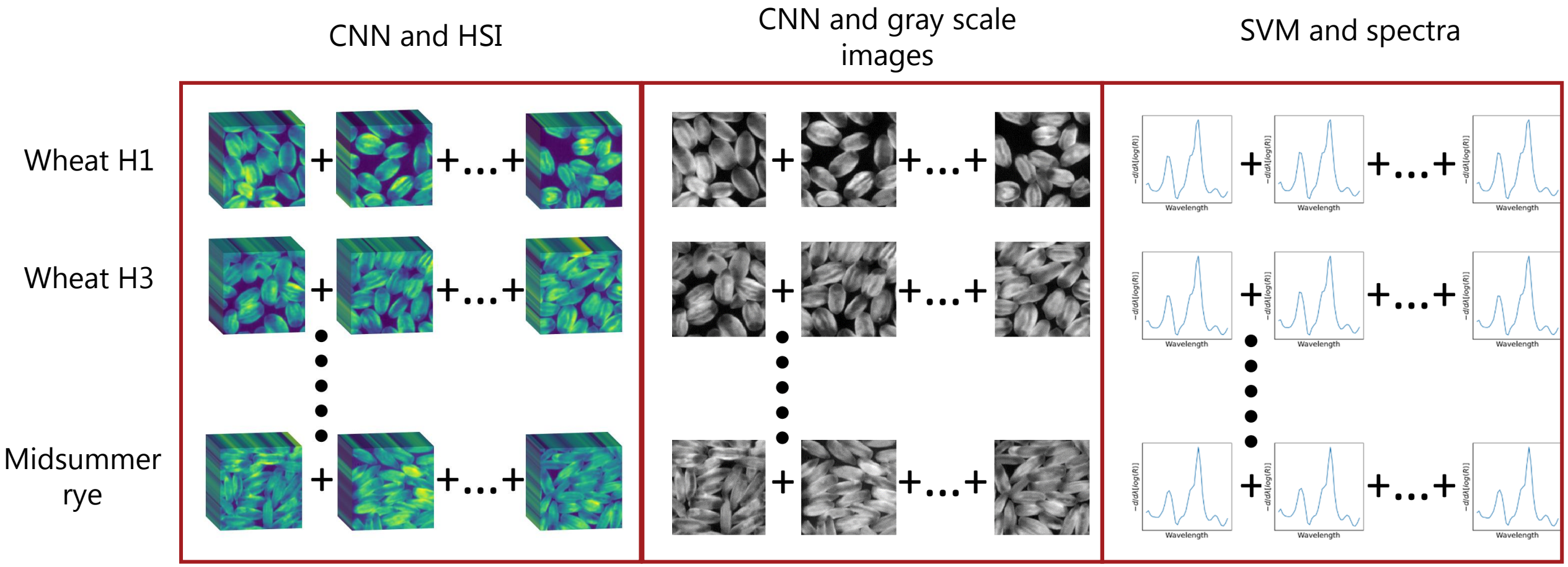
Spring wheat

Winter type A

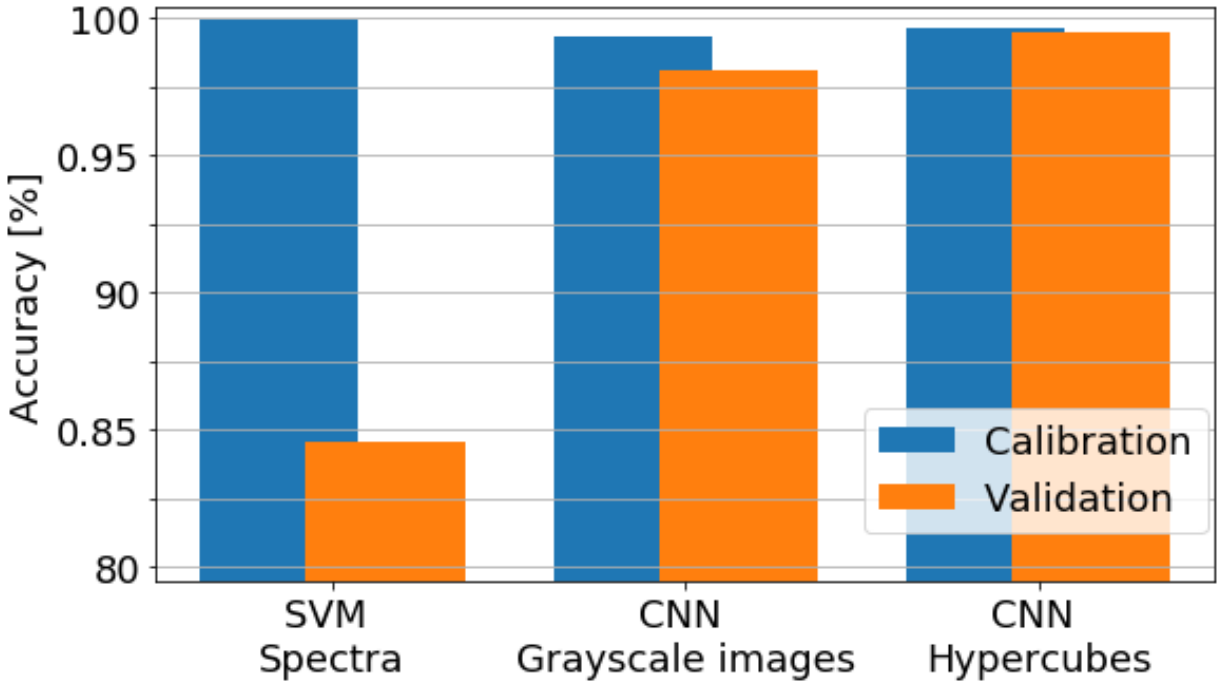
Winter type B



# Benchmark CNN classification



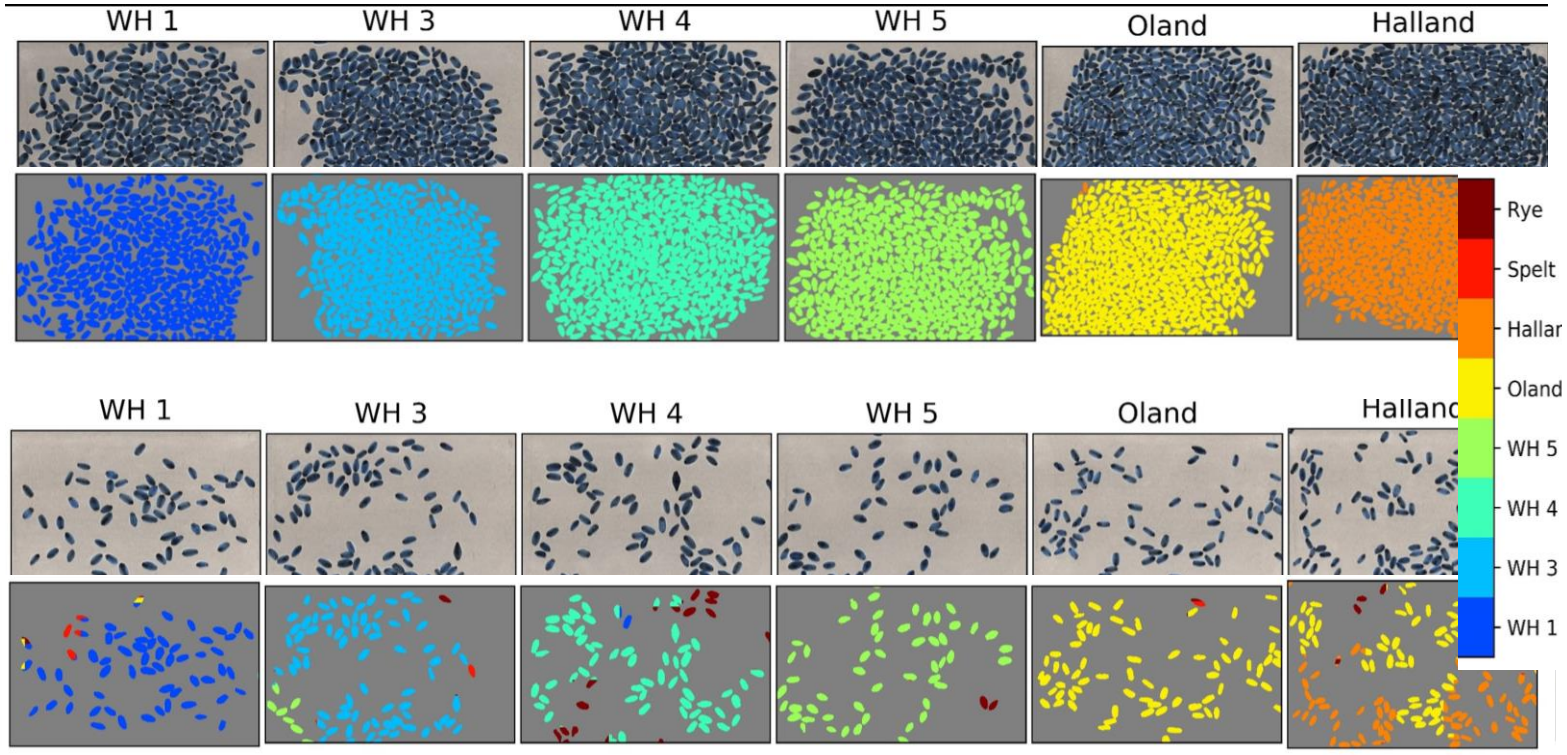
# Use Case: Grain variety classification - Benchmark results

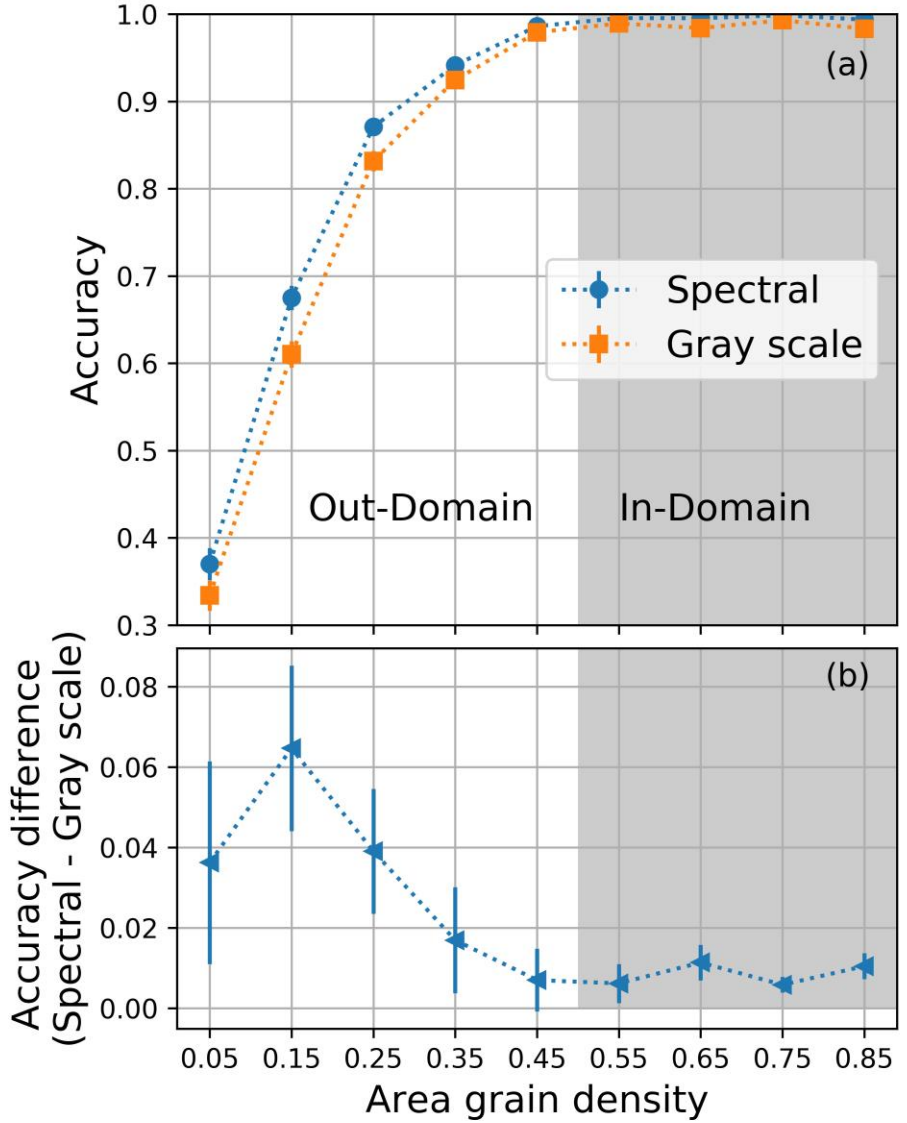



Lesson learned so far:
Both spectral and spatial properties are different between grain varieties!

CNN on hypercubes improves performance!

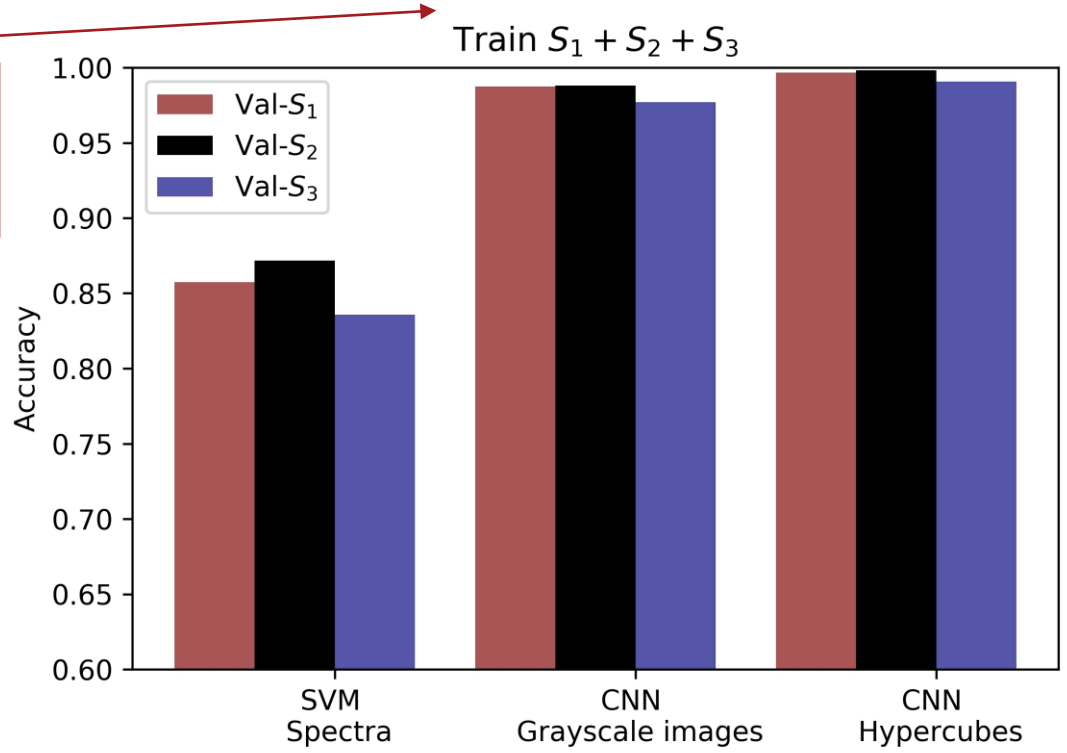
# Robustness: Density dependence of the kernels – CNNs are sensitive

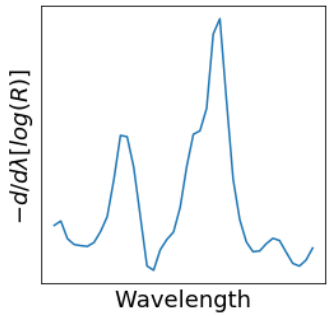


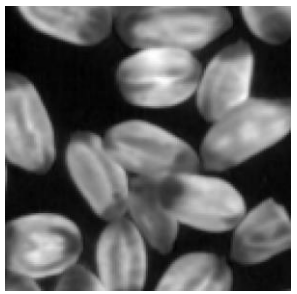



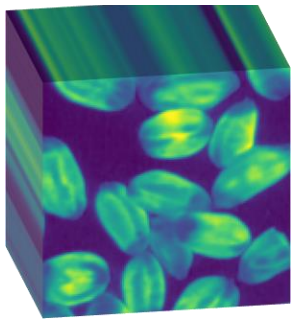
# Robustness: How does it perform when small changes are introduced

Trained on all training data!



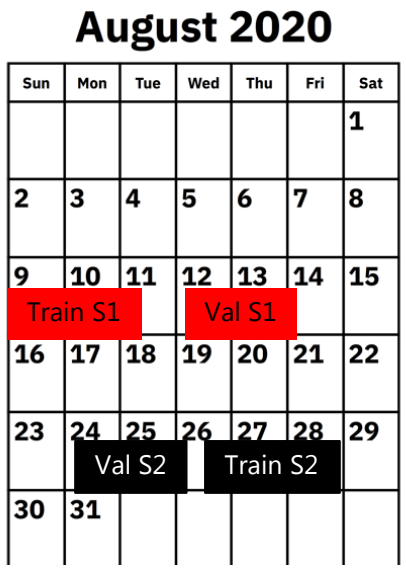



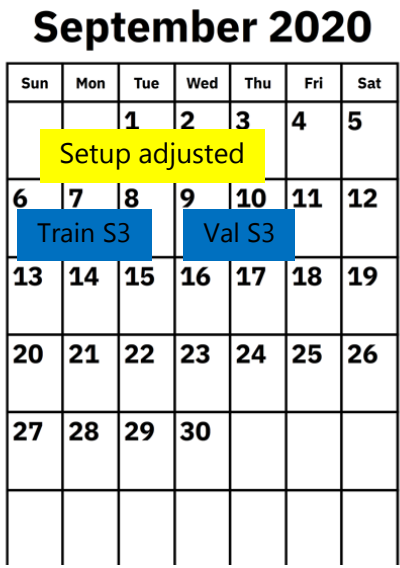


Robustness of the model: Experiment conducted in three sequences:

$$S_1, S_2, \text{and } S_3$$

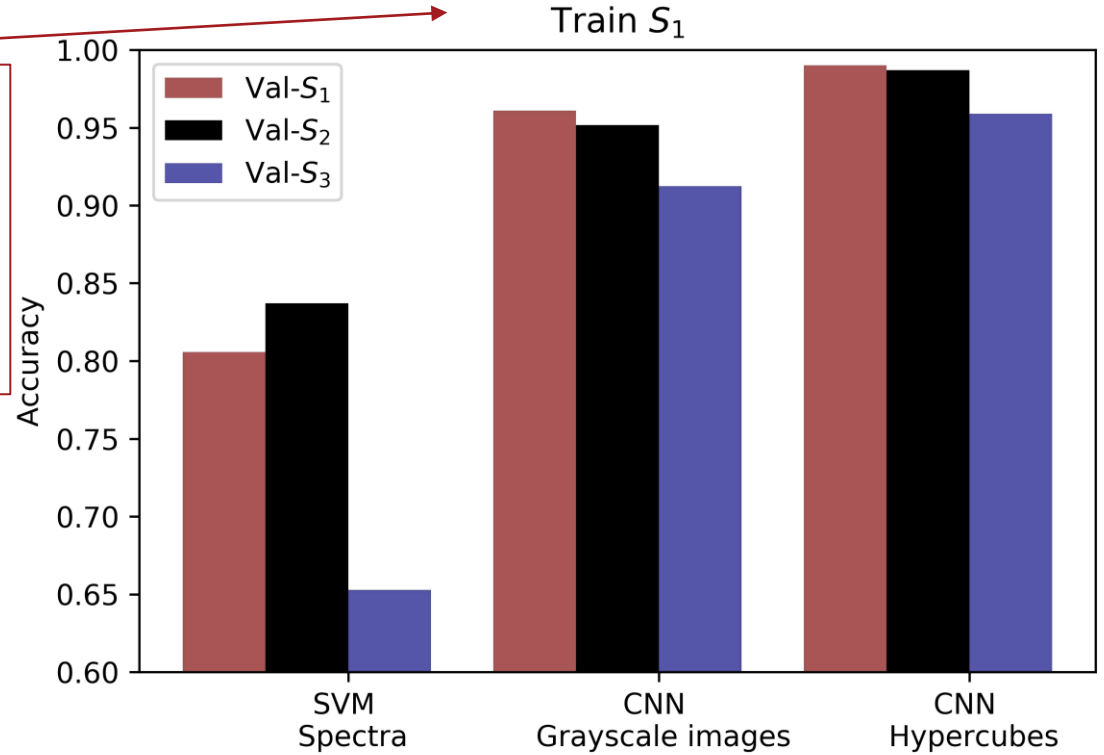
Small adjustment of setup between $S_2, \text{and } S_3$

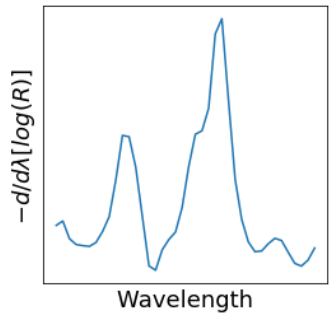


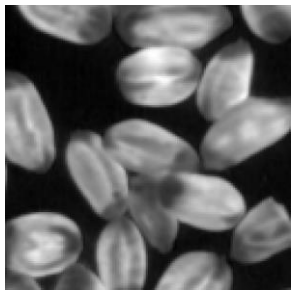



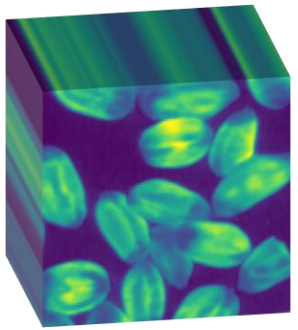
# Robustness: How does it perform when small changes are introduced

Trained only on training data from 1. sequence!



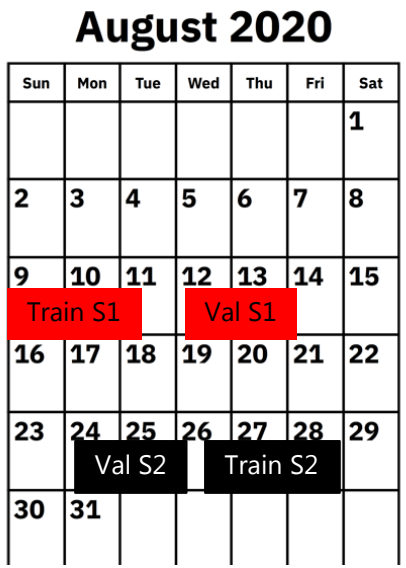



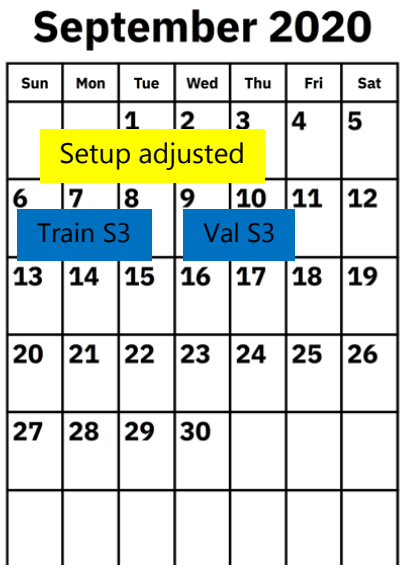


Robustness of the model: Experiment conducted in three sequences:

$$S_1, S_2, \text{and } S_3$$

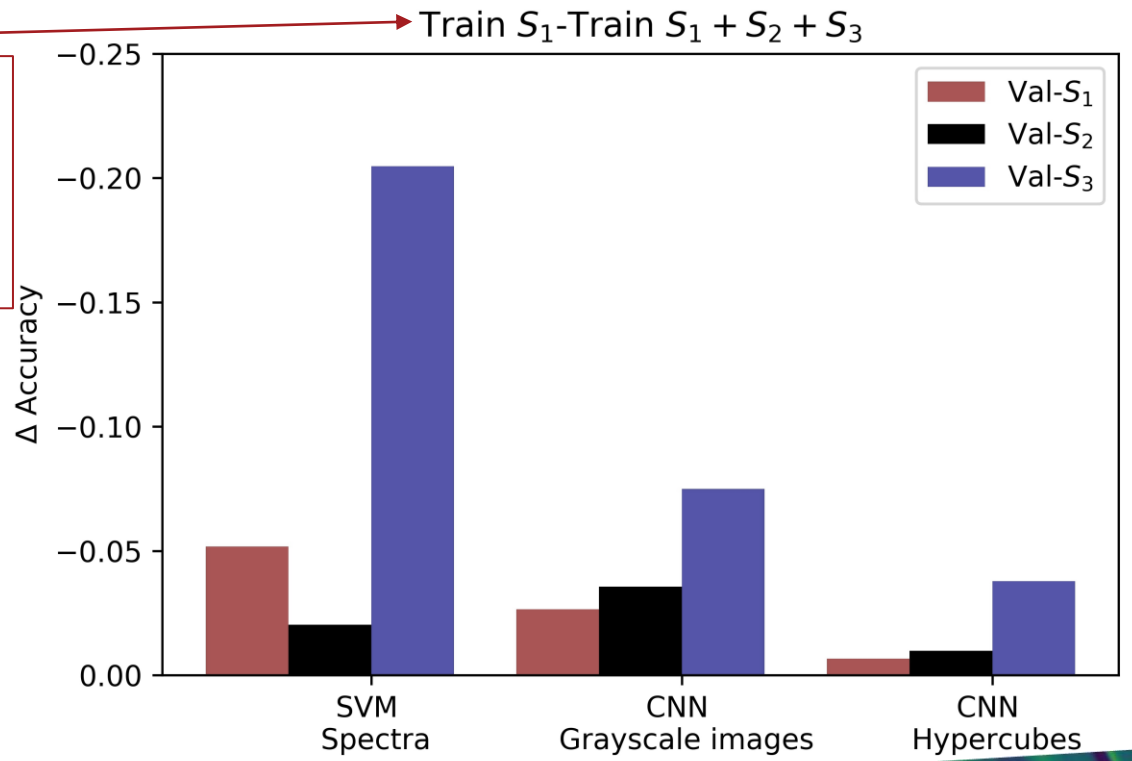
Small adjustment of setup between $S_2$, and $S_3$

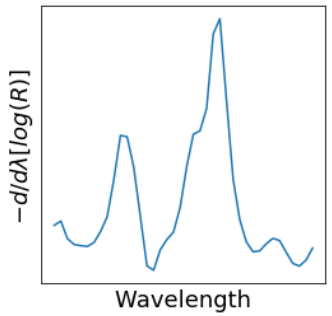


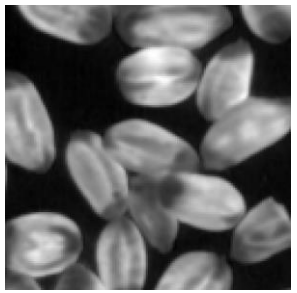



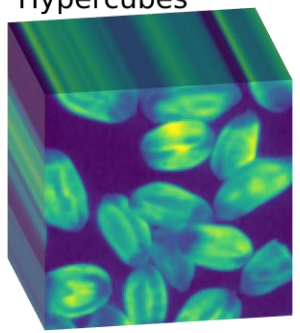
# Robustness: How does it perform when small changes are introduced

Difference in data trained only on S1 and all!

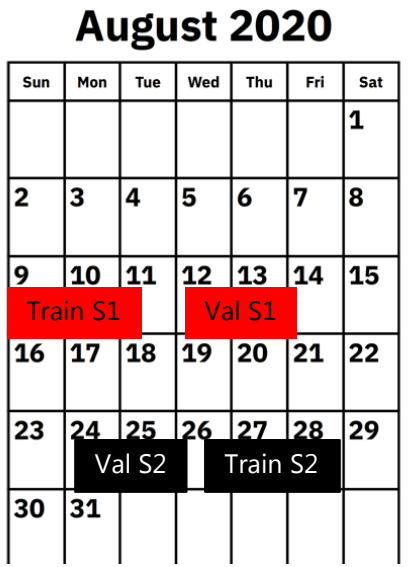


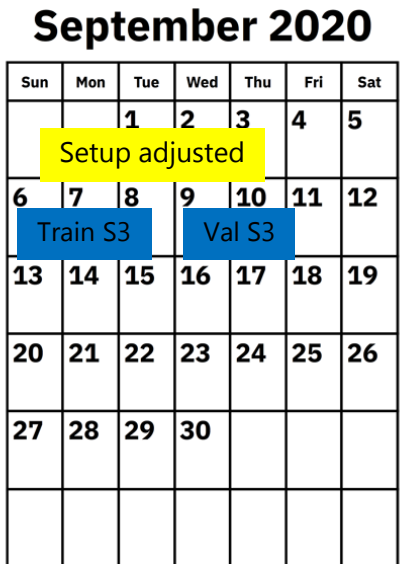





CNN on hypercubes may improve robustness!



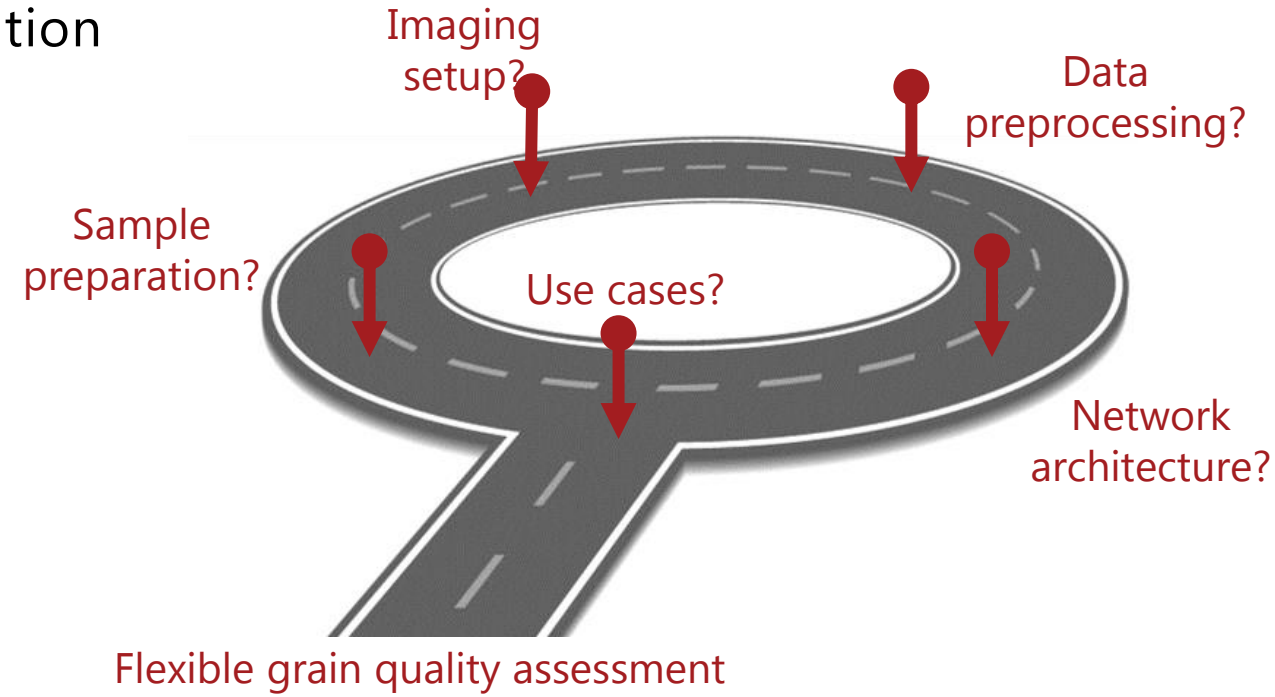



# Take home

- Combining spatial and spectral properties provides additional information!

- Combining HSI and CNNs can be done and can ..
  - Improve performance and perhaps robustness.
  - Utilize both spatial and spectral information

- But a complete understanding of the "roadmap" is important when applying deep learning!



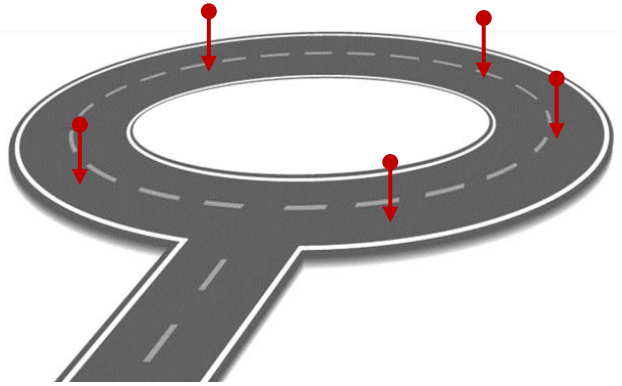
# Continued work

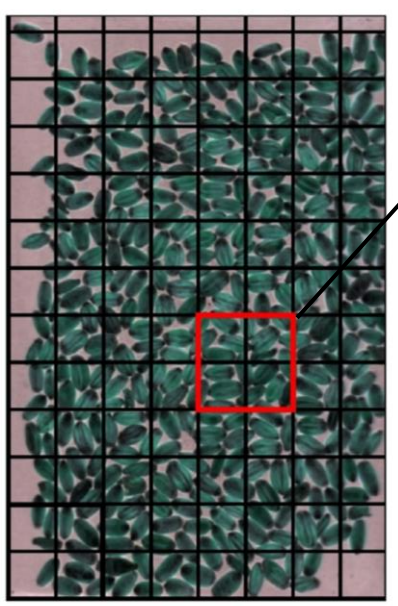
**2. Protein Regression**

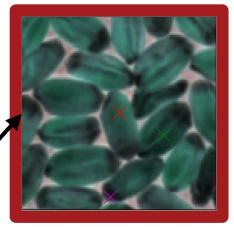
→ PhD project by Ole Engstrøm*

Can we do regression with a CNN directly on HSI data?

Know protein regression is possible with NIR!



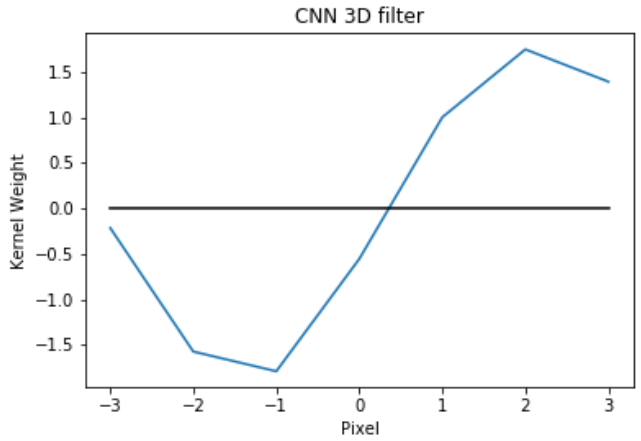




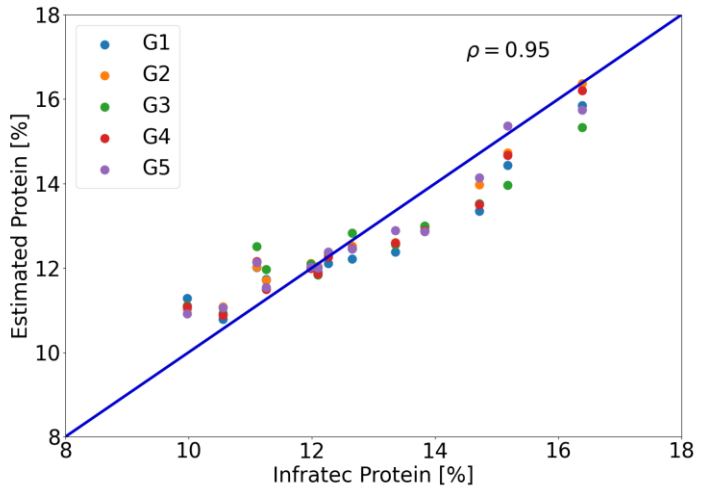
Spectral filter layer → Downsample layer → ResNet-18 → Protein %

50 grain samples
- Each ~100 g.

## Results:




The CNN can ..
- Learn spectral preprocessing
- Learn Regression




*« Regression Analysis on Hyperspectral Images », UCPH Computer science, 2021

# Thank you for listening

- The project continues with Ole Engstrøm PhD
  - If anyone has an interesting grain problem where hyperspectral imaging and CNNs could be used then contact me ☺ on esd@foss.dk