Progress and challenges with high resolution UAV imaging and multispectral time series data

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Research questions

- 1. Multispectral UAV imaging for trait prediction
 - which camera is best, Micasense RedEdge or Phantom 4 multispectral?
- 2. Can we use P-splines to estimate heading and maturity dates from multispectral UAV time series data?
- 3. Can we use high-resolution UAV images to detect wheat heads with deep learning?



1. Camera comparison – which is best?







Phantom 4 Multispectral (P4M)

	P4 Multispectral	Micasense RedEdge M
Red	650 ± 16 nm	668 ± 5 nm
Green	560 ± 16 nm	560 ± 10 nm
Blue	450 ± 16 nm	475 ± 10 nm
Red Edge	730 ± 16 nm	717 ± 5 nm
NIR	840 ± 26 nm	840 ± 20 nm

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1. Camera comparison – which is best?



Micasense RedEdge-M



Phantom 4 Multispectral (P4M)

- Yield trial with 300 spring wheat lines x 2 reps at Vollebekk 2021
- 5 parallel mission flights:
 - Beginning of June tillering stage
 - Last week of June stem elongation
 - Beginning of July heading stage
 - End of July onset of maturity
 - End of July maturing progresses
- Trait prediction using multispectral relationship matrix and random effect models
- Cross-validation (80/20 train/test, 200 iterations)



Multispectral similarity (covariance) matrices





Phantom 4 Multispectral

4 Plant phenotyping NMBU

Trait prediction accuracy

- No visible difference in trait prediction performance between the two cameras
- Results align with our previous work using machine learning for trait prediction (Shafiee *et al.,* submitted)
 - camera has influence on numerical reflectance values, but no influence on prediction accuracy
- Phantom 4 is just as good as Micasense RedEdge





2. Spline interpolation of time-series data

- Inspiration from Pérez-Valencia *et al.* (2022) (Scientific Reports 12: 3177)
- Data used: season 2021, P4M camera
- NDVI calculated based on raw bands
- NDVI extrapolated:
 - NDVI @sowing = 0
 - NDVI @harvest = 0
- Spline function fitted for each experimental unit (plot)
- Calculated 1st derivative based on the spline function



Raw NDVI data. Dots are flights for a sample of plots



Spline-interpolated NDVI data





P-spline interpolation of dense mission data - NDVI

Correlation matrix of NDVI values for each interpolated date (n=1000) across the season. Red - r < 0, Blue - r > 0



Red - r < 0, Blue - r > 0Season start

Season end





P-splines and their derivatives – example of a field trial plot

- Blue NDVI curve over the season (spline-interpolated, scaled and centered)
- Red first spline function derivative based on the blue curve, scaled and centered (mean = 0, sd = 1)
- Orange vertical line -heading date
- Green vertical line maturity date
- Hard to deduce heading date
- Maturity date happens after the steep decline of NDVI values have started to slow down (at local maximum of Dx after the global minimum of Dx)





3. High-resolution low altitude UAV flights

 Matrix 300 RTK with DJI Zenmuse P1 camera



- Tested in 2022 field season
 - 12 meter flight altitude

 Are images good enough for head detection? AAAS Plant Phenomics Volume 2021, Article ID 9846158, 9 pages https://doi.org/10.34133/2021/9846158 Plant Phenomics

Database/Software Article

Global Wheat Head Detection 2021: An Improved Dataset for Benchmarking Wheat Head Detection Methods

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Using close-up images from the field robot

• YOLO5 deep learning model



Image size:1024x1024 Cropped from the main image



Detected heads using YOLO5 Accuracy: up to 95%



Image captured at 12 m using Zenmuse P1



Zoomed and cropped image

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Applying YOLO5 model on the image





Best Accuracy = 69%

The way ahead

- In some cases the accuracy is very low
- Is this related to the camera angle or light condition?
- How can we improve the model?



Accuracy = 16%



Take-home messages

- Phantom 4 Multispectral is as good as Micasense RedEdge for trait prediction in wheat
- Using P-splines could be a workable solution for estimating maturity dates from time-series multispectral data
- Wheat head detection using highresolution low-altitude UAV flights is possible
 - but further training of deep learning models will be needed

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