Image analysis

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Introduction

Phenotyping is a key approach to understand how plants interact with environmental change as well as respond to different treatments

- Conventional plant phenotyping involves *manual measurement of plant traits* (e.g., **area, biomass, height, plant growth rate**, etc) which is **slow, tedious** and expensive task
- Recently, computer-assisted methods for phenotyping, and in particular **imaging techniques** are becoming more popular

Plant phenotyping networks around the world

Network	Name	Web Location
APPF	Australian Plant Phenotyping Facility	http://www.plantphenomics.org.au/
APPN	Austrian Plant Phenotyping Network	http://www.appn.at/
DPPN	German Plant Phenotyping Network	https://dppn.plant-phenotyping-network.de/
EPPN	European Plant Phenotyping Network	https://www.plant-phenotyping-network.eu/
FPPN	French Plant Phenotyping Network	https://www.phenome-fppn.fr/
IPPN	International Plant Phenotyping Network	https://www.plant-phenotyping.org/
LatPPN	Latin American Plant Phenotyping Network	https://www.frontiersin.org/articles/10.3389/fpls.2016.01729/full
NaPPI	Finland National Plant Phenotyping Infrastructure	https://www.helsinki.fi/en/infrastructures/national-plant-phenotyping
NPPN	Nordic Plant Phenotyping Network	https://www.forageselect.com/nppn
Phen-Italy	Italian Plant Phenotyping Network	http://www.phen-italy.it/
UKPPN	UK Plant Phenotyping Network	http://www.ukppn.org.uk/
PheNo	**Norwegian Plant Phenotyping Platform**	*https://emphasis.plant-phenotyping.eu/News?news=Norway_Application_PheNo*

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RapiGrow

RapiGrow project aims to develop machine learning/deep learning models that can predict plant growth from images, and observe plant nutrient availability (e.g., phosphorus) by applying hyperspectral image analysis of plant growth

- As a case study, machine learning models will be developed to **predict plant biomass** from image-based features/traits (e.g., area)

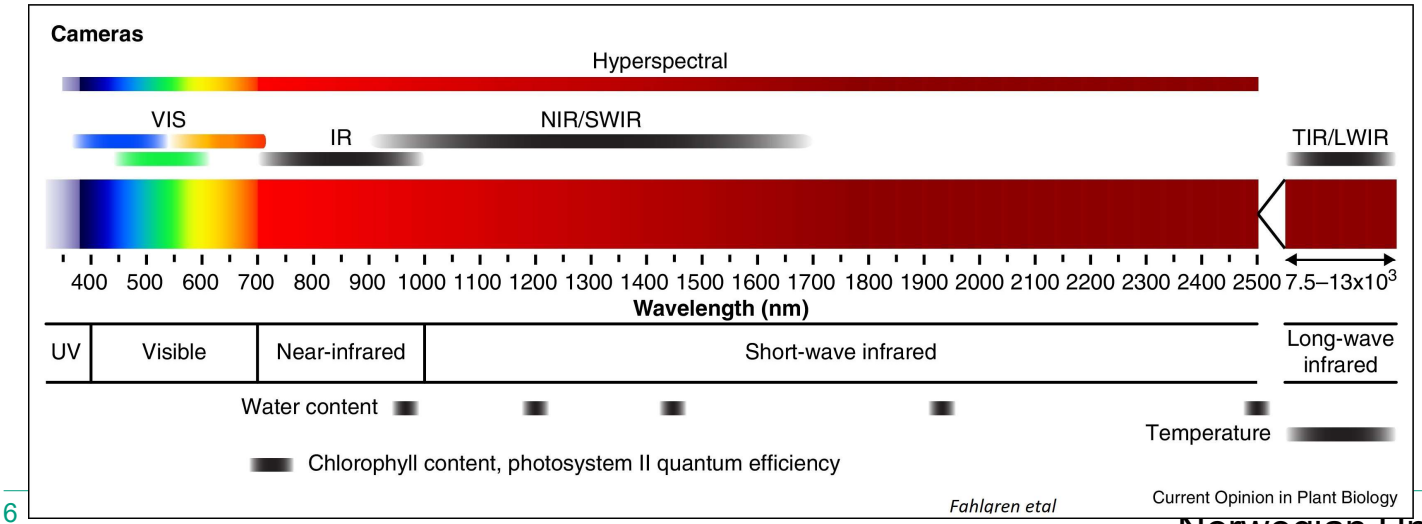
RapiGrow

The implementation approach involves the following major steps:

- Experimental setup and plant image acquisition
- Pre-processing
- Segmentation
- Feature extraction
- Prediction model development (train, validate and test)
- Prediction model evaluation

Imaging techniques and experimental setup

- **Digital color (RGB) imaging**: structural plant traits like leaf area, stem length, plant growth rate
- **Hyperspectral imaging**: physiological plant traits like leaf and canopy water content, quantifying chemical properties

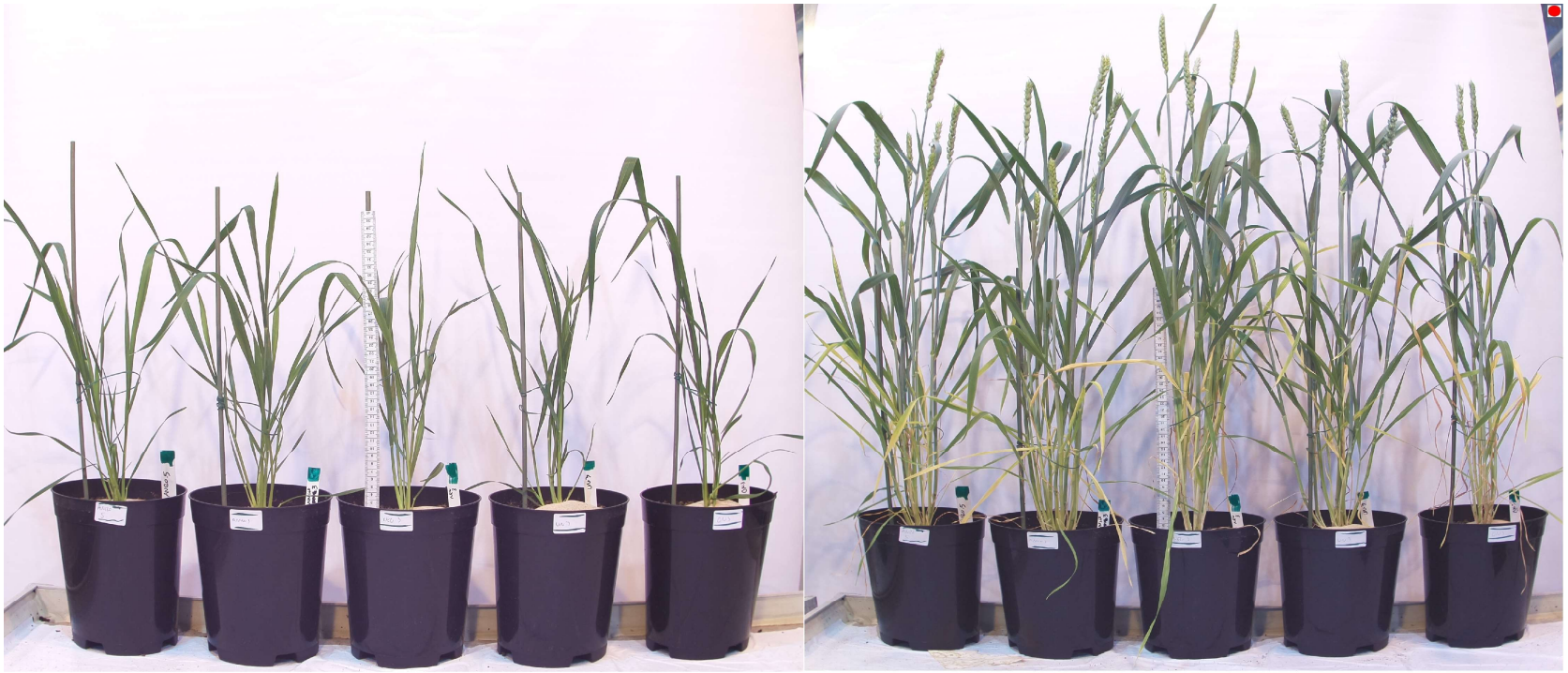


Imaging techniques and experimental setup

- Raspberry Pi computer and Camera module
- Automated data collection using Python

Imaging techniques and experimental setup

Sample images



Sample images

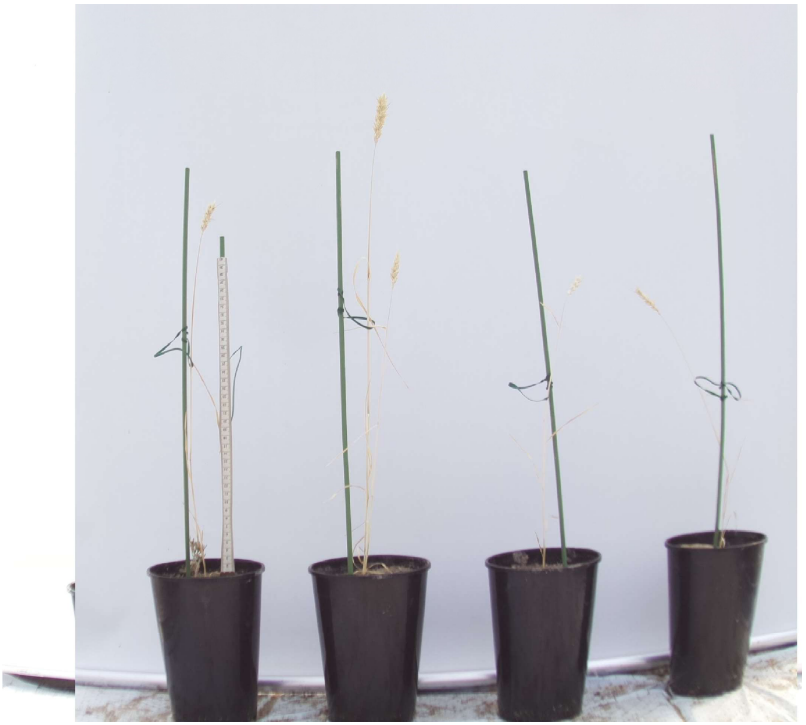


Image pre-processing and segmentation

- Different segmentation techniques (color index, threshold, and learning-based segmentation)

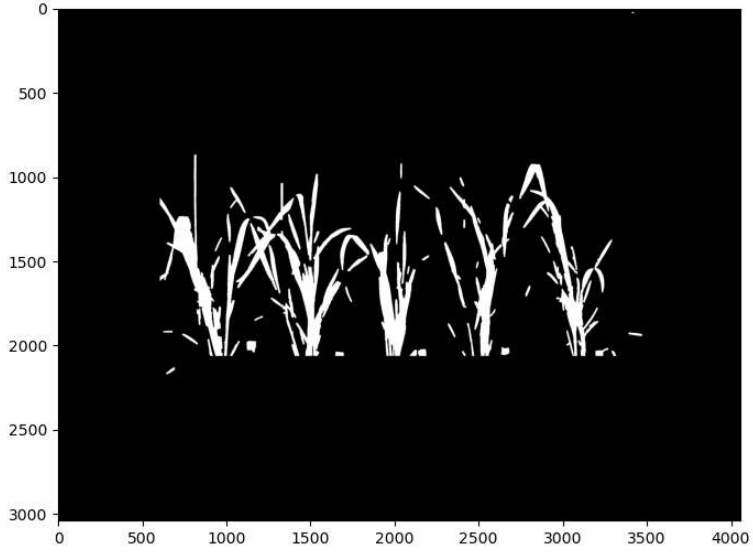
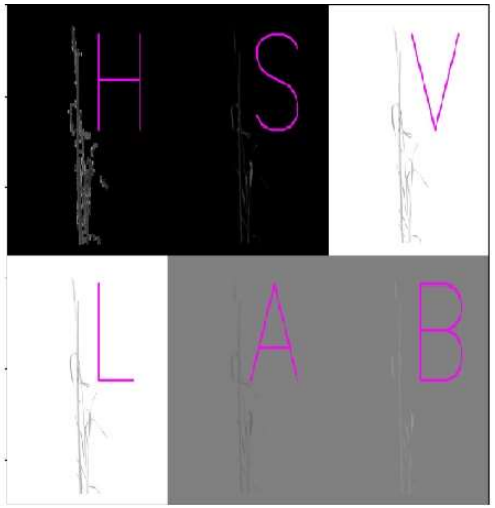


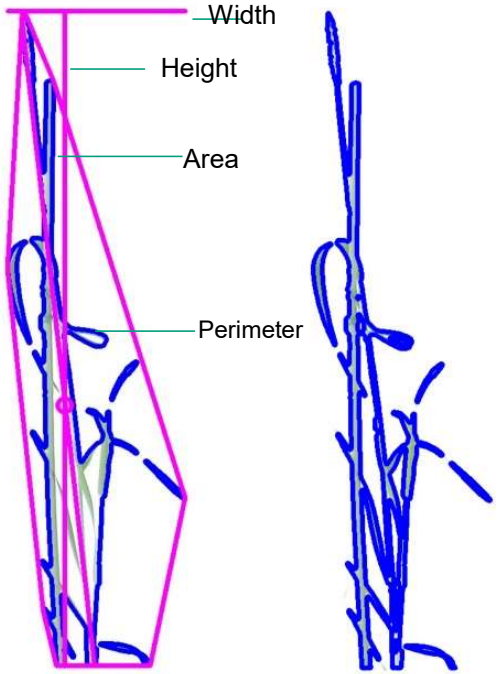
Image preprocessing and segmentation

Different segmentation techniques (color, Otsu's thresholding, and learning-based segmentation)



Feature extraction

- Measurement of morphological traits, such as area, perimeter, height, width, etc



Feature extraction

jupyter rg_summary_stats Last Checkpoint: 31.08.2021 (autosaved)

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Run Code

Out[22]:

	area	perimeter	width	height	convex_hull_area	longest_path
1	25785.0	4788.927722	406	698	160303.0	4836
2	35329.0	5155.861492	406	732	171239.5	5120
3	24265.0	3272.229572	115	728	68062.0	4780
4	408436.0	2820.000000	406	1006	407025.0	7430
5	408436.0	2820.000000	406	1006	407025.0	7430
6	119448.0	2982.315796	406	741	192712.5	5382
7	408436.0	2820.000000	406	1006	407025.0	7430
8	408436.0	2820.000000	406	1006	407025.0	7430
9	30774.0	4905.923761	381	728	179952.5	5099
10	27136.0	5079.267294	354	721	167642.0	5043
11	408322.0	2821.899495	406	1006	407023.5	7428
12	408436.0	2820.000000	406	1006	407025.0	7430
13	408434.0	2819.414214	406	1006	407024.0	7428
14	408436.0	2820.000000	406	1006	407025.0	7430
15	408436.0	2820.000000	406	1006	407025.0	7430
16	408436.0	2820.000000	406	1006	407025.0	7430
17	101298.0	5085.143842	406	724	198039.5	5265
18	408436.0	2820.000000	406	1006	407025.0	7430
19	329472.0	8536.223581	406	1006	406982.5	7407
20	408436.0	2820.000000	406	1006	407025.0	7430

Actual above-ground dry biomass

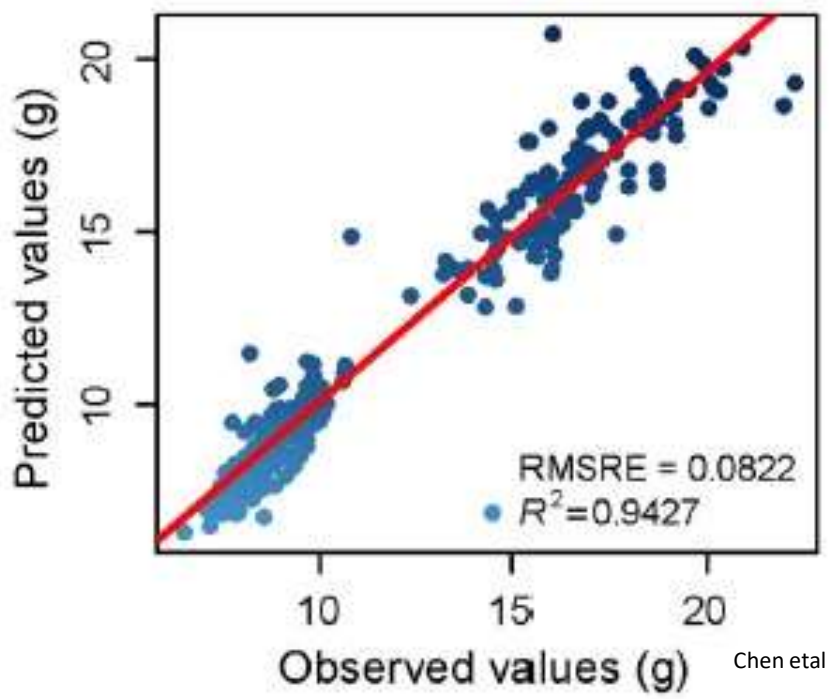
1	Notes	Block	Plant	# Ears	Ear Biomass	Mean Ear Bio	Plant and	Dry plant	Seed (g)
2		ET	UN	9	18,212	2,023555556	21,286	10,669	
3		ET	AN120	11	20,556	1,868727273	22,482	11,865	
4		ET	ON	7	11,169	1,595571429	18,523	7,906	
5		ET	NEO	8	14,676	1,8345	22,283	11,666	
6		ET	ANN40	9	16,912	1,879111111	23,496	12,879	

Prediction model

- Train, validate and test
- MLR, PLSR, Deep neural networks for prediction
- Prediction model evaluation using R^2 and root-mean-square error (RMSE)

Predicted vs actual dry weight/biomass

- Image based predicted biomass vs manually measured biomass should be similar to this figure



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Conclusions

- Aa low-cost high-throughput image-based plant phenotyping system is developed using *Raspberry Pi* computer and *camera sensor* that captures plant image of shoots and characterizes plant traits to analyse plant growth dynamics.
- The study has demonstrated that image-based plant phenotyping is an efficient method to extract morphological features of plants (e.g., height, area, perimeter, etc).
- It has also shown that the area extracted from plant images can estimate plant growth rate.

Thank you