Métaprogramme DIGIT-BIO
Axe 2 : Phenotypes prediction

PhD 01/05/2022 ➤30/04/2025

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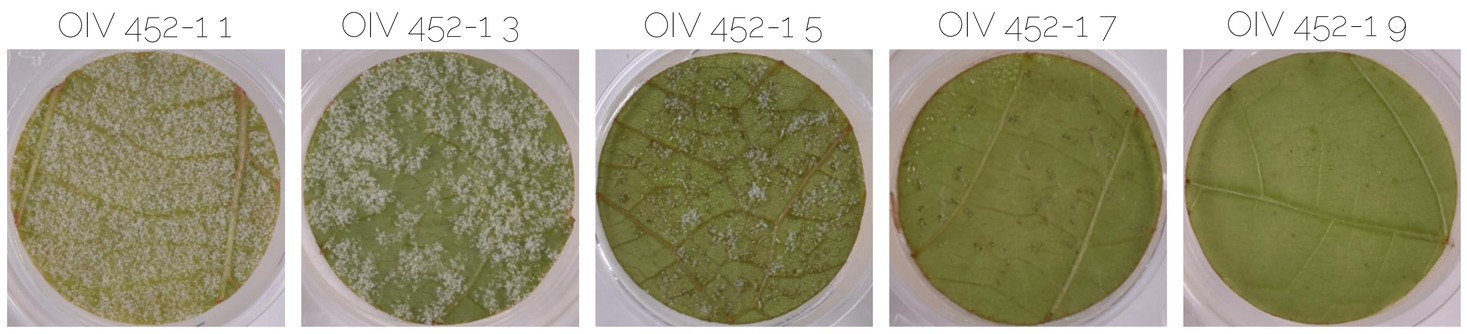
Phenotyping grapevine resistance to downy mildew: deep learning as a promising tool to assess sporulation and necrosis.

•Introduction/ Context - Downy mildew is a plant disease that affects all cultivated European grapevine varieties. The current strategy to control this threat relies on repeated applications of fungicides. The most eco-friendly and sustainable alternative solution would be to use bred-resistant varieties. Some wild *Vitis* species have been used as resistance sources to introduce resistance *loci* in *Vitis vinifera* varieties. The development of a high-throughput machine learning phenotyping method is now essential for identifying new resistance *loci*.

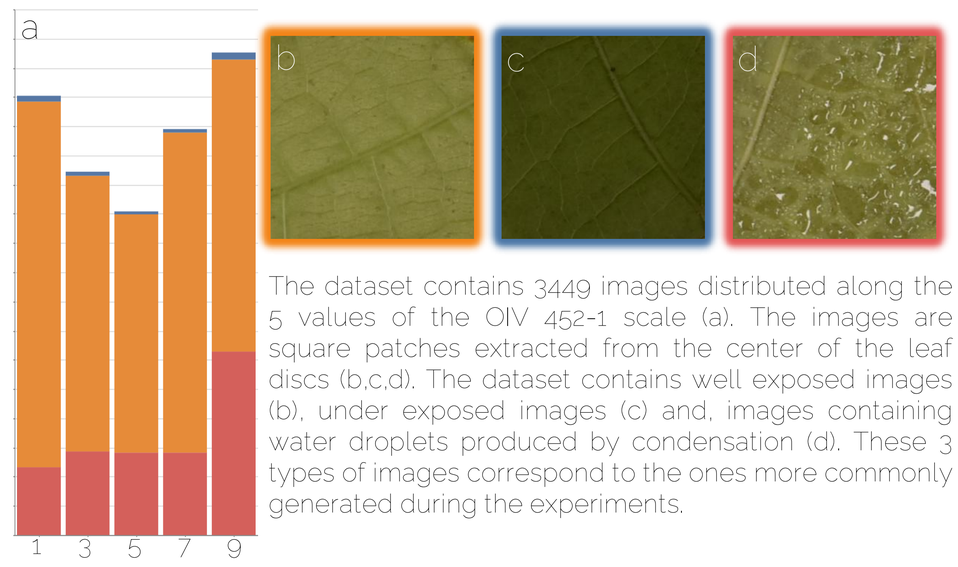
Methods

OIV 452-1, a Standard Scale



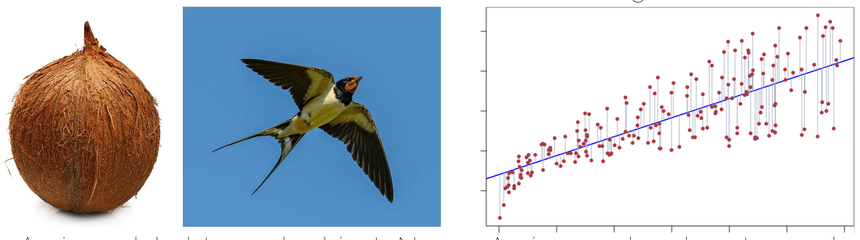
OIV 452-1 is a resistance scale, part of an ontology created by the "Office International de la Vigne et du Vin (OIV), it uses values from 1 very susceptible to 9 fully resistant. The scale merges 2 variables: the pathogen's sporulation and the plant's necrosis, also known as hypersensitve response.

Dataset



The dataset contains 3449 images distributed along the 5 values of the OIV 452-1 scale (a). The images are square patches extracted from the center of the leaf discs (b,c,d). The dataset contains well exposed images (b), under exposed images (c) and, images containing water droplets produced by condensation (d). These 3 types of images correspond to the ones more commonly generated during the experiments.

Neither Classification Nor Regression

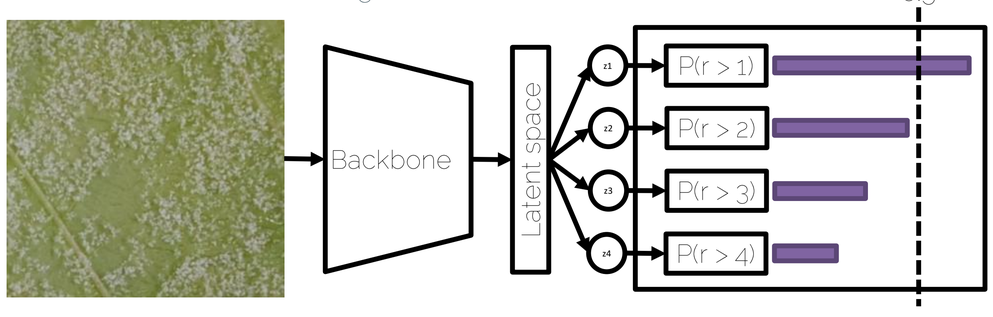


Assign a label to each object. No ordinal relationship between classess. All errors are equal

Assign real value to each object. Ordinal relationship between objects.

Something completely different

Rank-Consistent Ordinal Regression (CORN)



Rank-consistent ordinal regression (Shi et al. 2023) allows to assign class labels to samples like a classification while introducing a magnitude of error like a regression.

$$OIV = (\sum_{j=1}^{K-1} \mathbb{1}(\hat{P}(y^{[i]} > r_j) > 0.5)) * 2 + 1$$

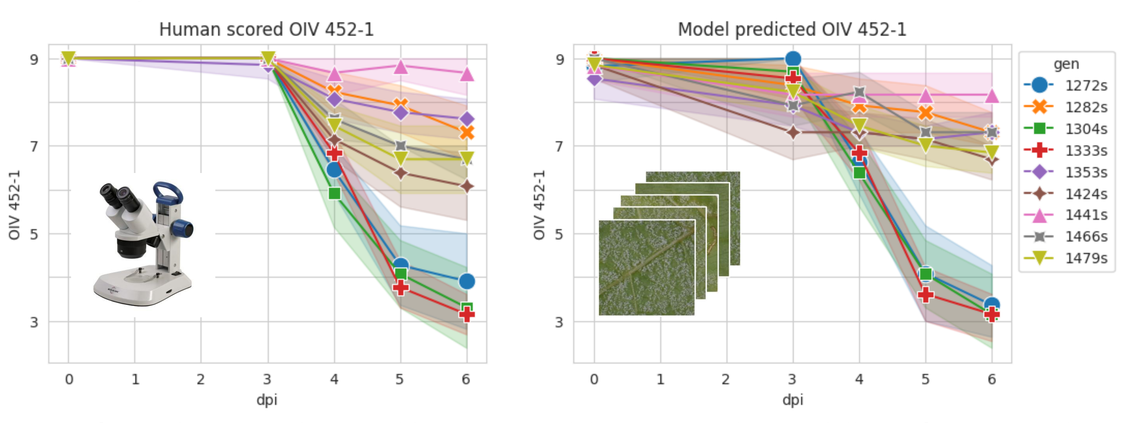
Results

Metrics

Actual label \ Predicted label	1	3	5	7	9	F1-score
1	109	4	0	0	0	0.9277
3	13	68	12	0	0	0.7556
5	0	15	63	5	0	0.7545
7	0	0	9	76	19	0.78136
9	0	0	0	28	96	0.8033

The model obtained an MSE of 0.203 on the test dataset. Thanks to the ordinal regression there are no errors over 1 class value.

Genotype differentiation experiment



We performed an experiment with new material to assess the model's performance when differentiating 9 genotypes resistance level to the pathogen. We compared human observations on a stereo-microscope to the model's predictions on low resolution images.

When comparing model and human assessment wirth Tukey HSD tests there is a 97% accuracy.

Conclusion

Perspectives:
•Improve image quality and resolution.
•Extend method to other leaf disc pathosystem with discrete scales.
•Use this method with multiple simultaneous pathogens.

Expected impact:
•Speedup leaf disc annotations by 650 times.
•Replace human annotation thus removing human bias.
•Facilitate transition to high throughput phenotyping.

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