PHASOR-BASED ANALYSIS OF HYPERSPECTRAL IMAGES FOR PLANT DISEASE DETECTION

DEPARTMENT OF PHYSICS "G. OCCHIALINI"

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UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

CONTENT

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INTRODUCTION

GOAL : Developing an AI-based technique to detect plant diseases from hyperspectral images

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Applications:

- Agricolture 4.0

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GOAL : Developing an AI-based technique to detect plant diseases from hyperspectral images

Applications:

- Agricolture 4.0
- Remote Sensing
- Increase Efficiency

EXPERIMENTAL SETUP

In collaboration with
University of Pisa

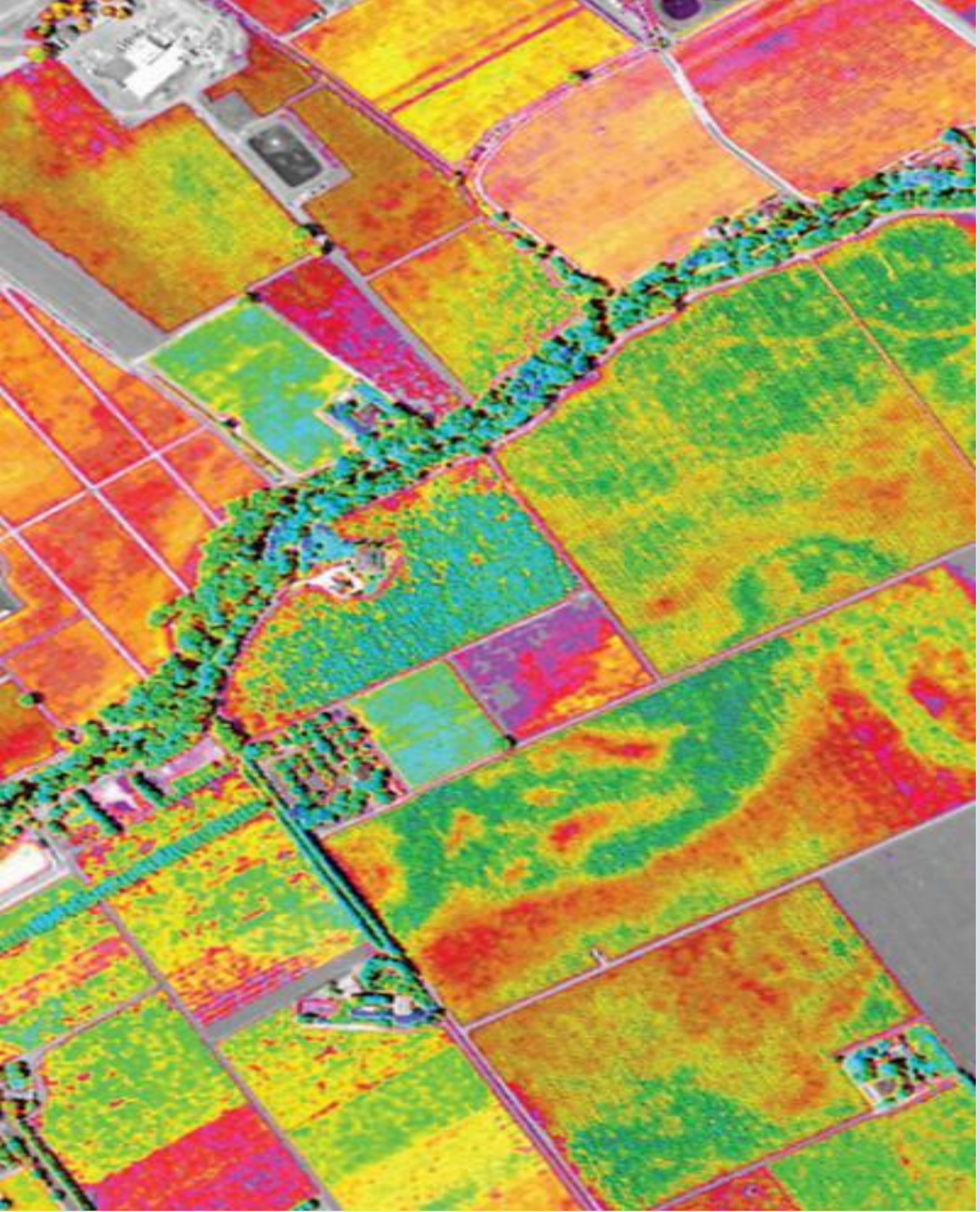
CLASSES ANALYZED

Two main classes are considered from the **Cultivar Bingo varieties**

- **NO TREATMENT**
- **SYSTEMIC TREATMENT**
- **TRICHODERMA TREATMENT**

HEALTHY

INFECTED



DATA ACQUISITION & PREPROCESSING

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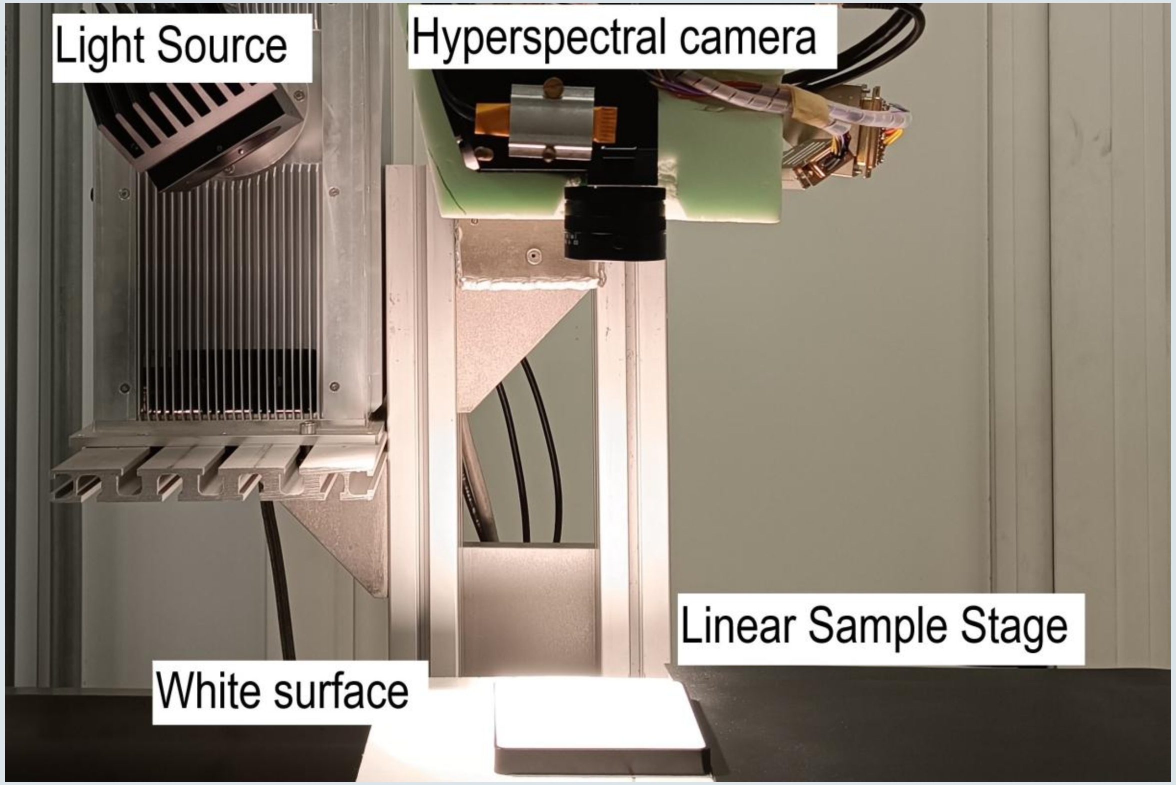
DATA ACQUISITION

Images were acquired with the «**HyIce**» spectrometer



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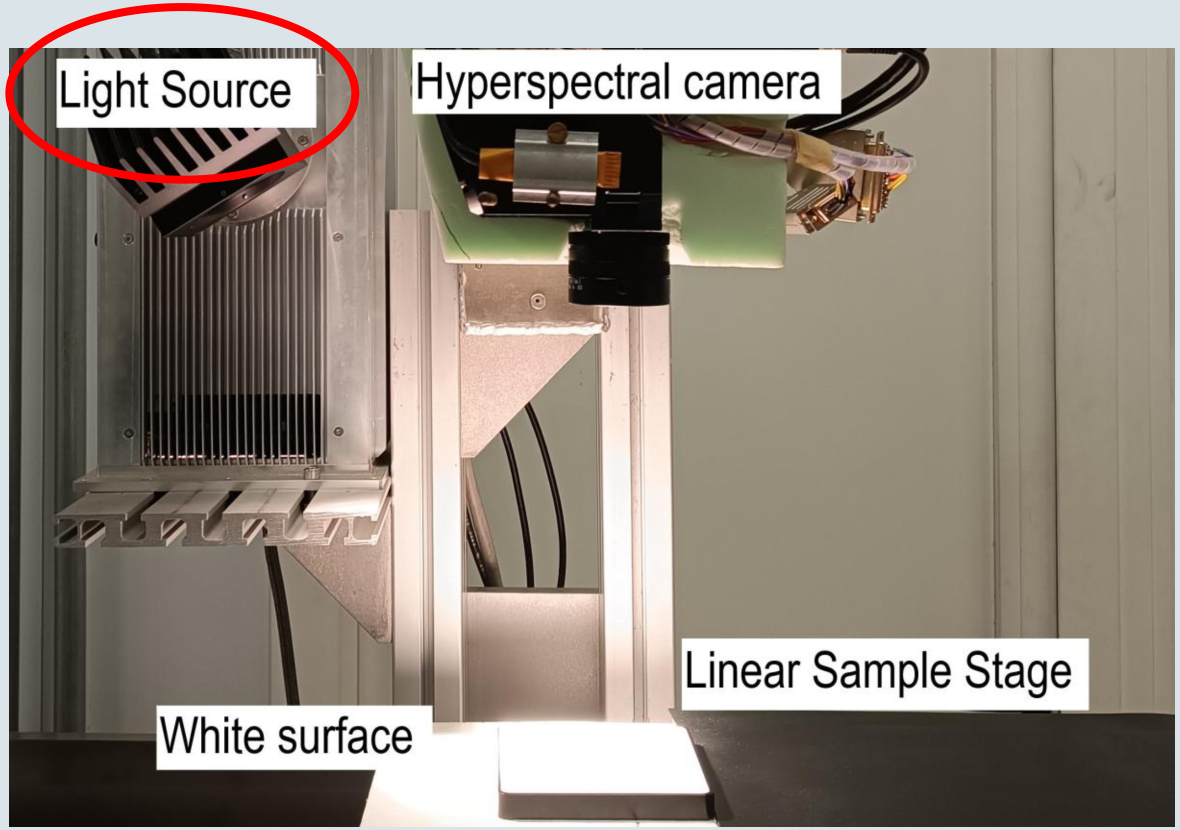
For more details: https://doi.org/10.1016/j.coldregions.2018.07.005



Light source) Halogen stable lamp 600W

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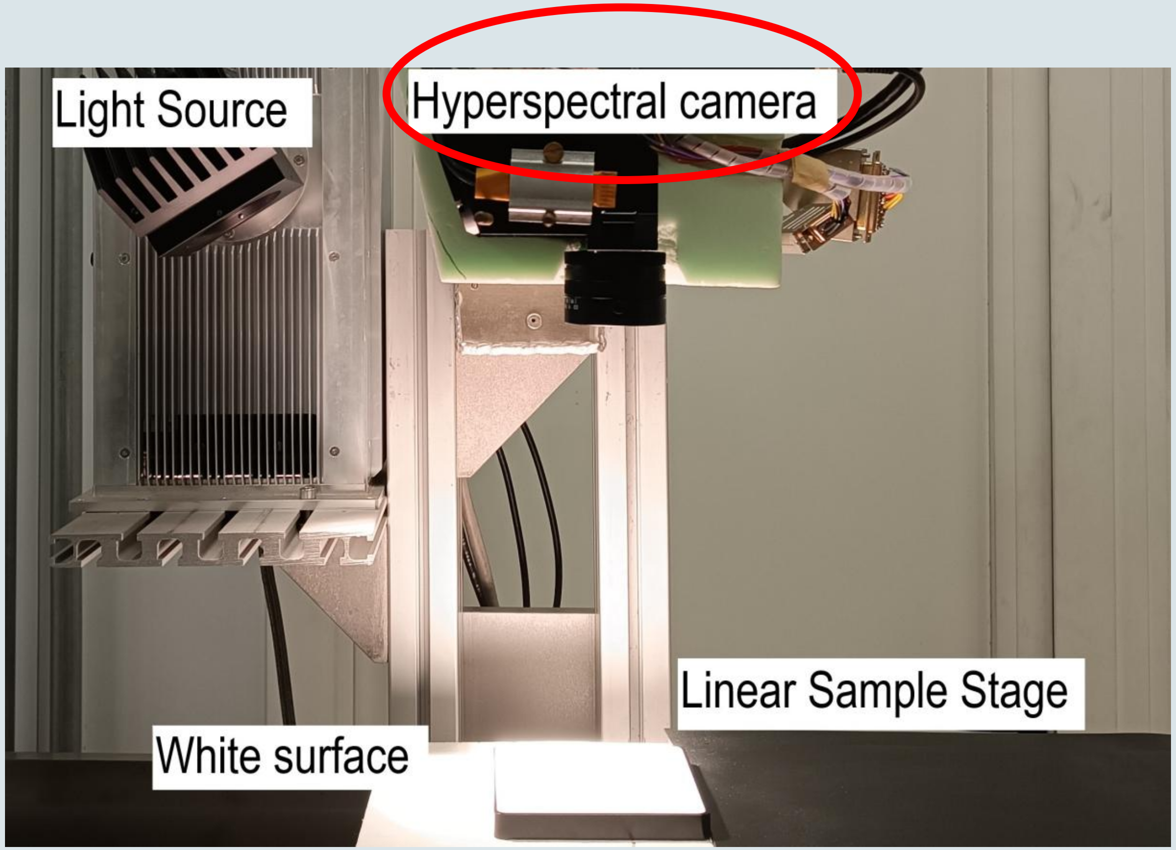

Light source) Halogen stable lamp 600W

Hyperspectral Camera) HeadWall Hyperspec® VNIR

It is the core of the system and collects wavelengths in the VIS-NIR range [380 - 1000 nm] with spectral resolution of 2-3 nm

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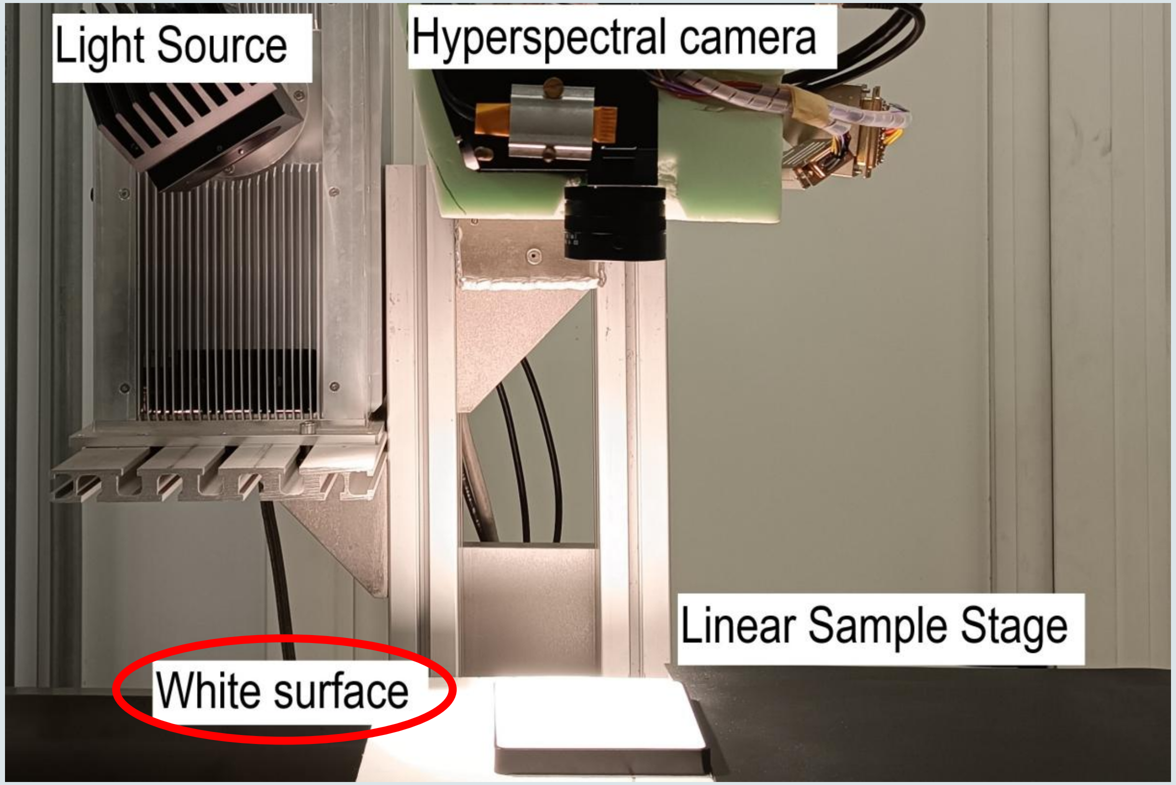

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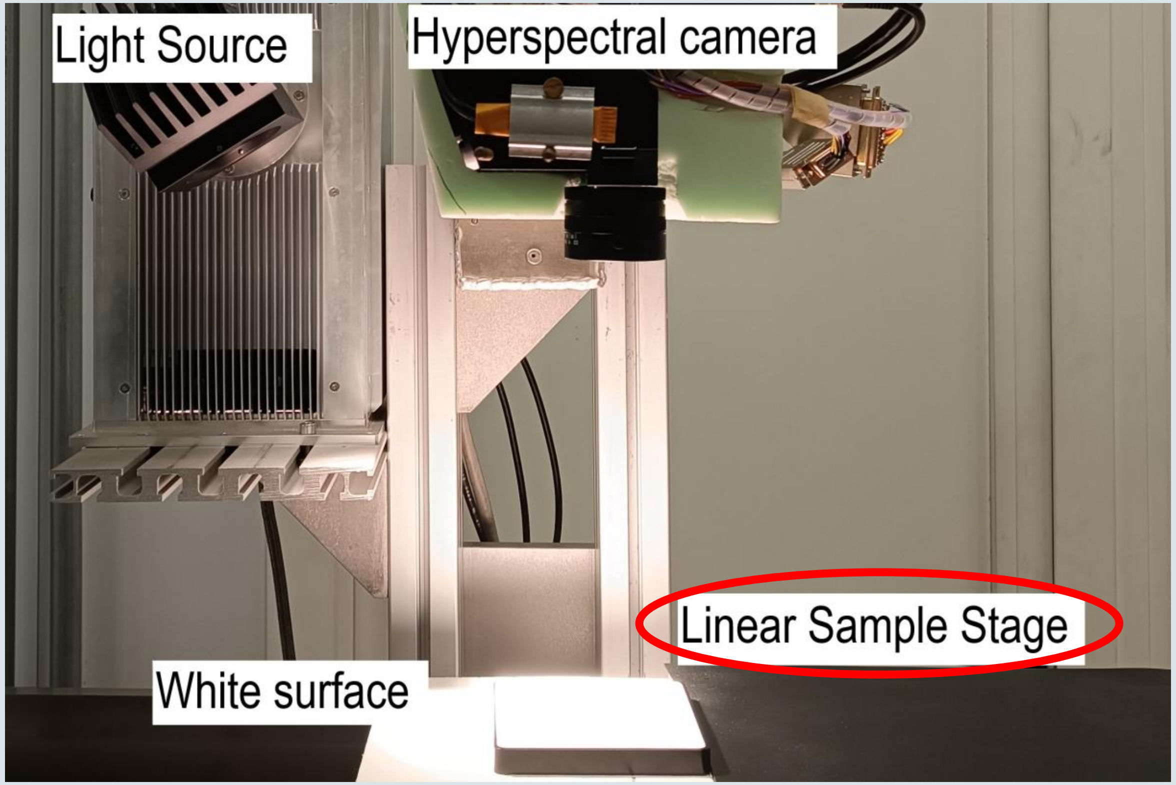

Light source) Halogen stable lamp 600W

Hyperspectral Camera) HeadWall Hyperspec® VNIR

White Surface) Lambertian Spectralon® panel

Linear Stage) high-precision linear stage

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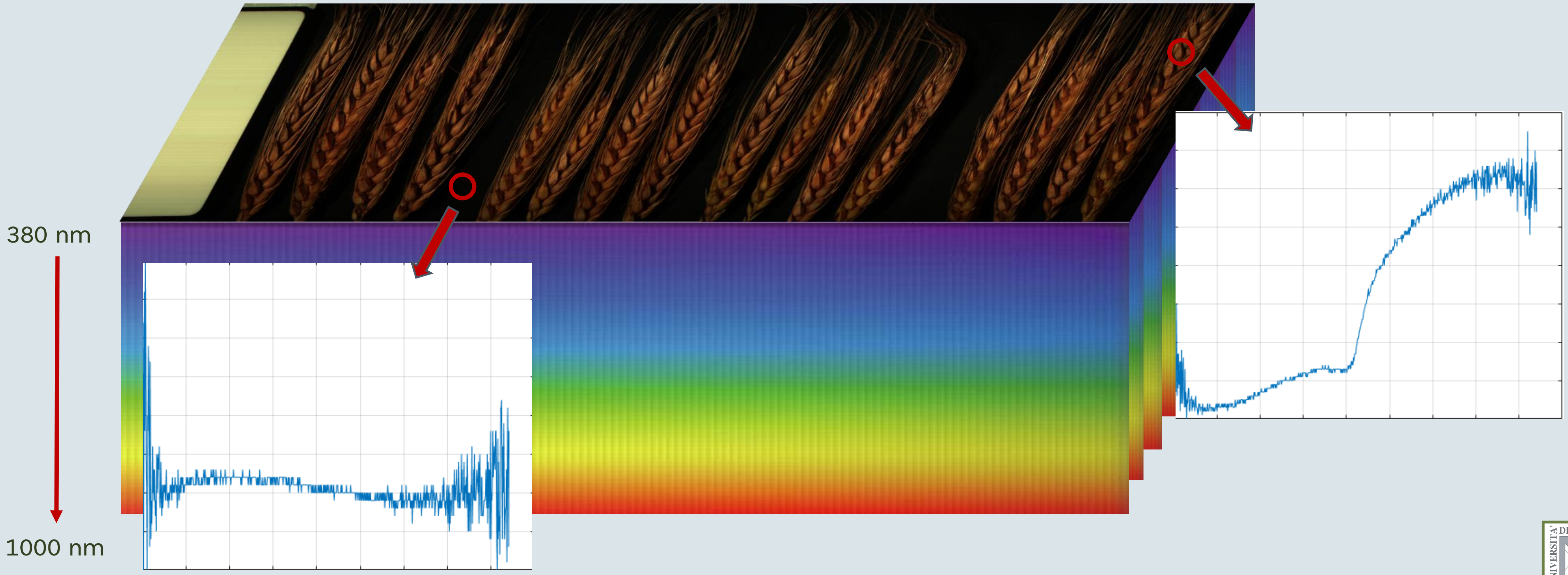

DATA PREPROCESSING

The data were prepared for the analysis:

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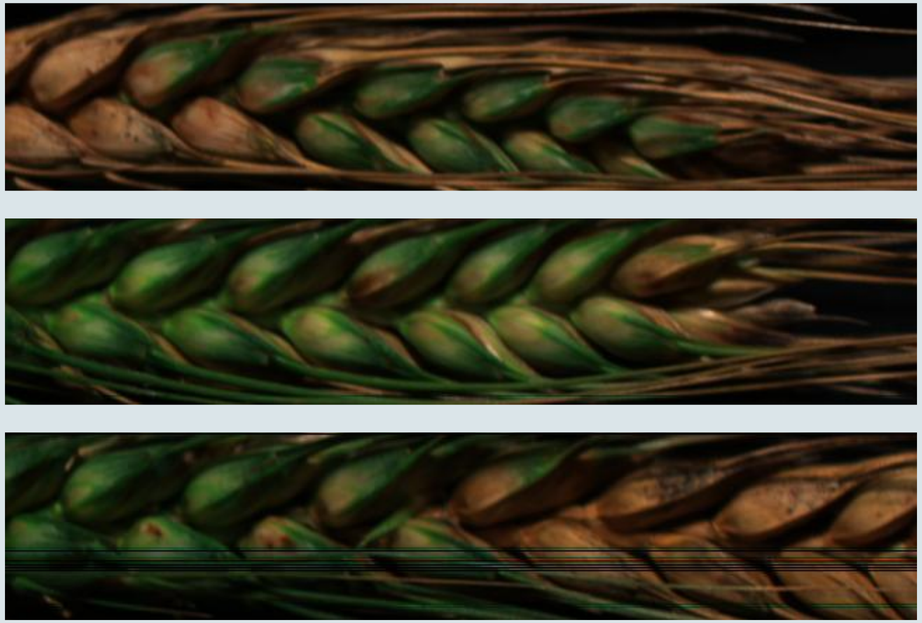


R	G	B
669 nm	554 nm	472 nm

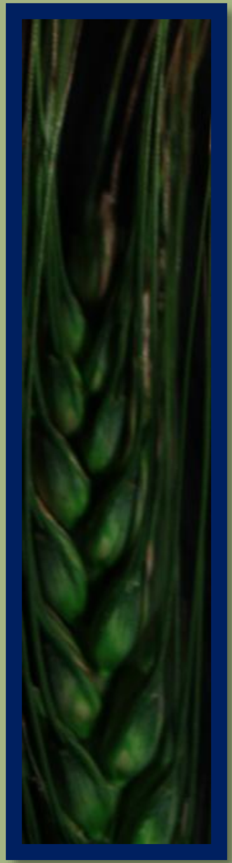
ANALYSIS

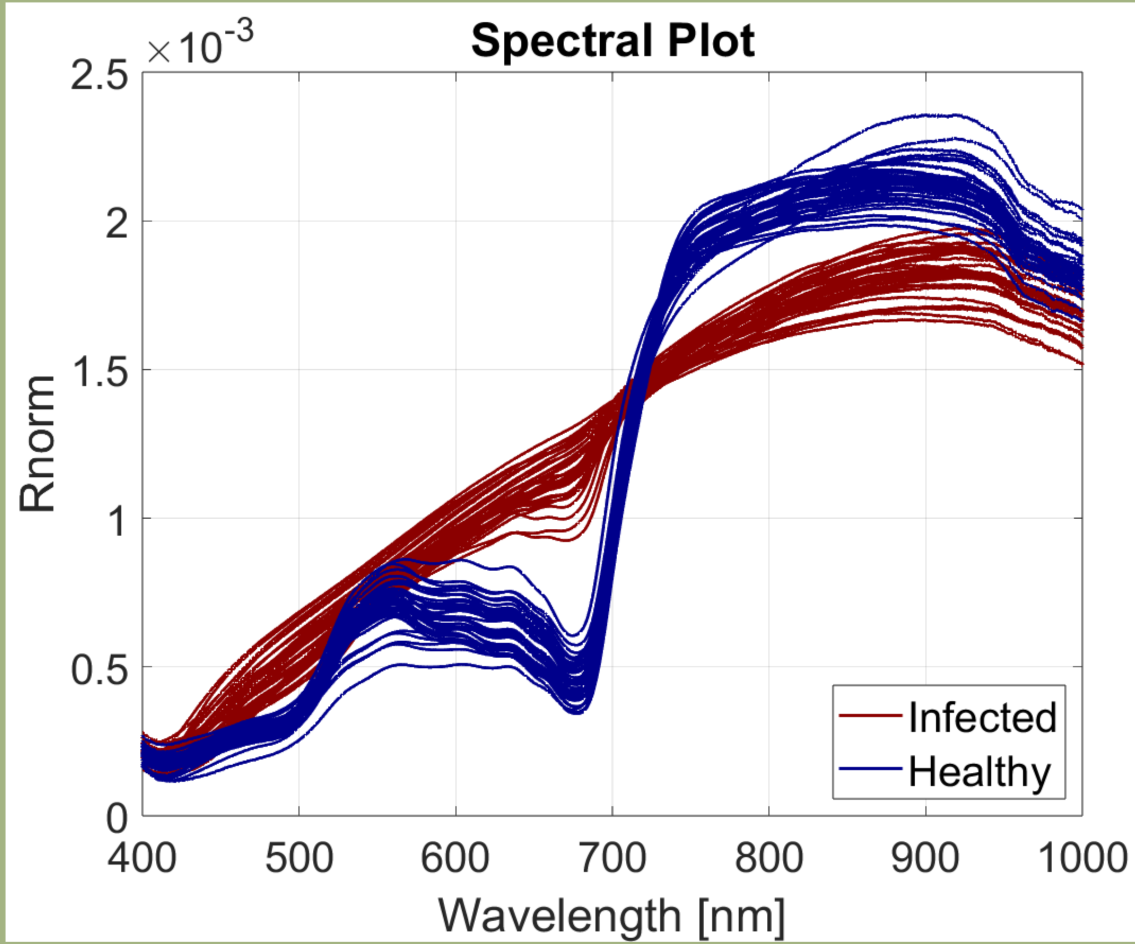
SPECTRA

PHASOR PLANE

TEXTURE

SPECTRAL RESULTS





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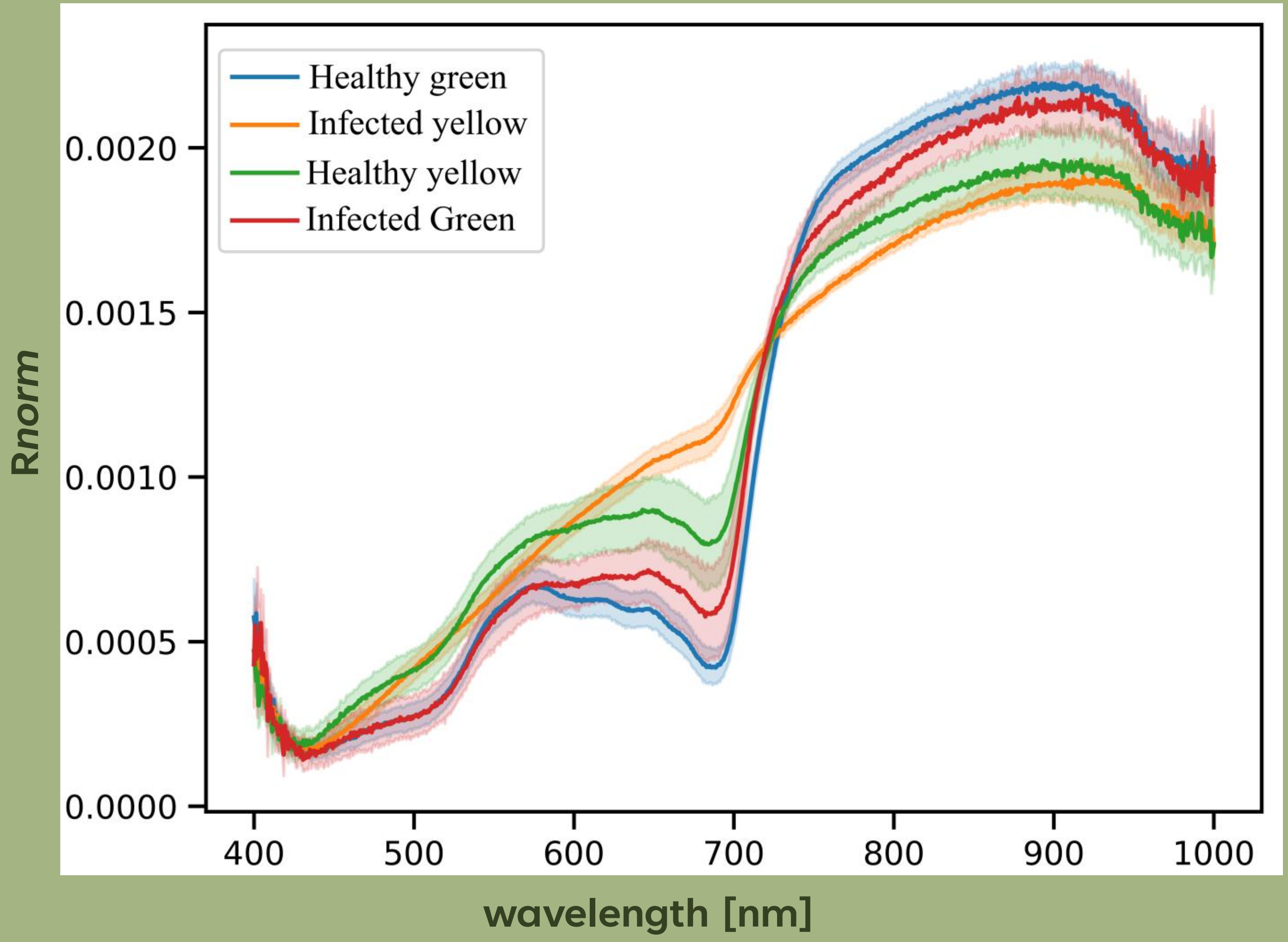

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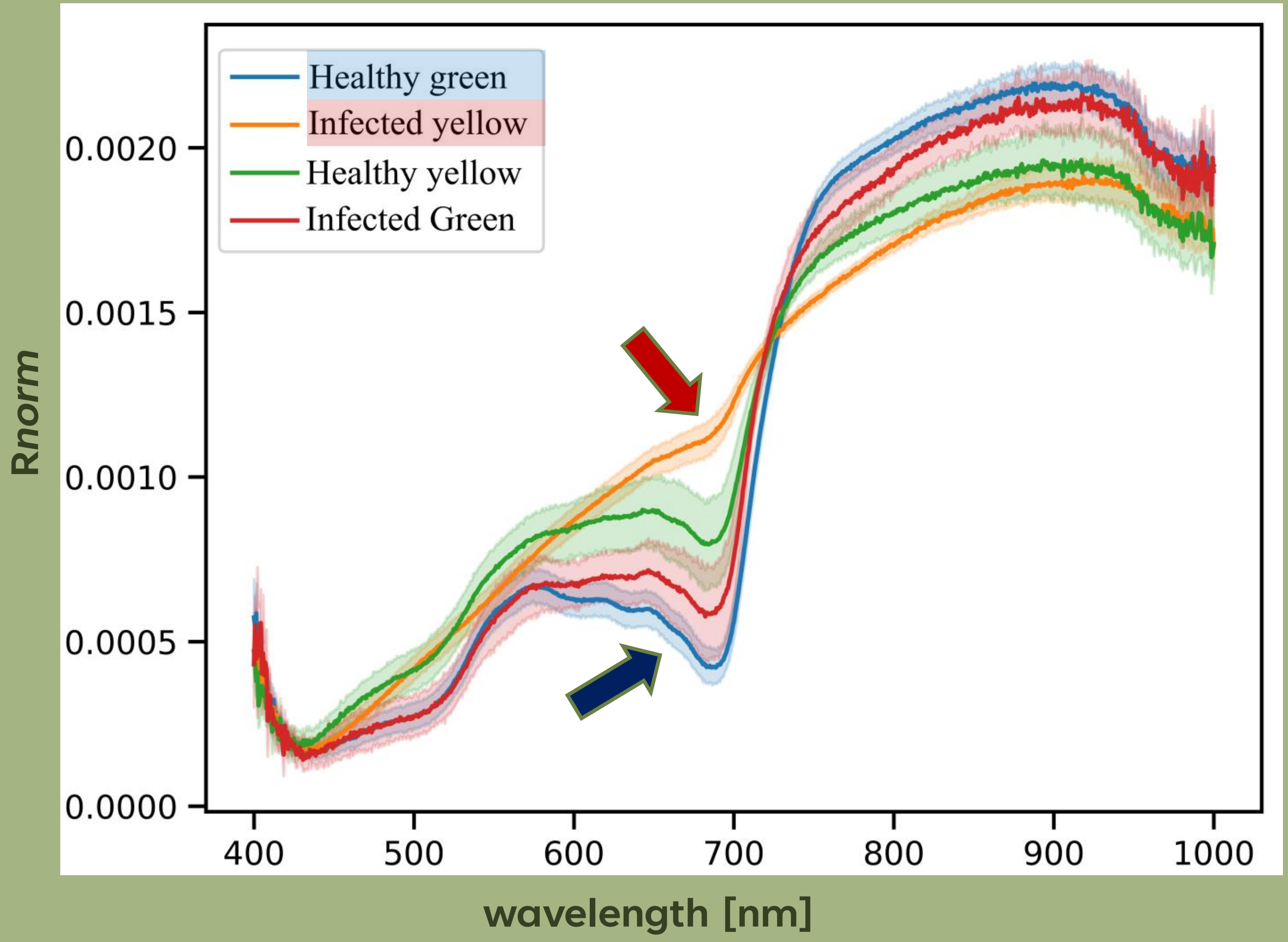


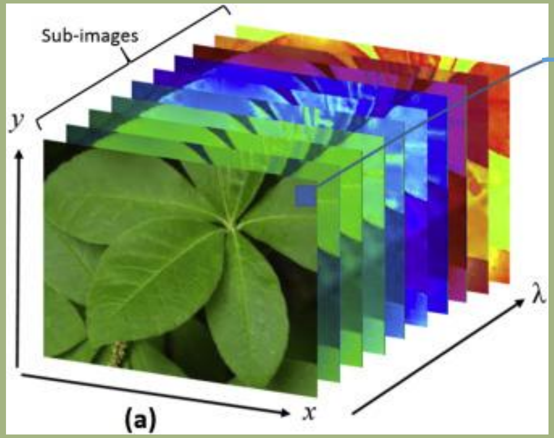
ANALYSIS

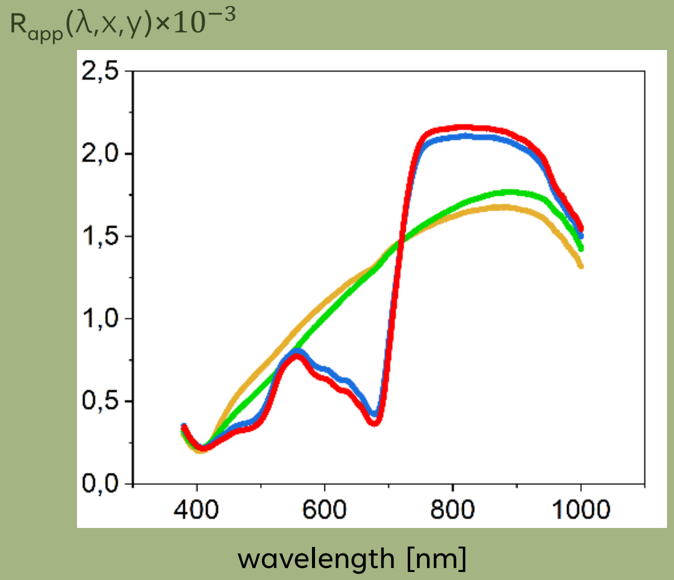
SPECTRA

PHASOR PLANE

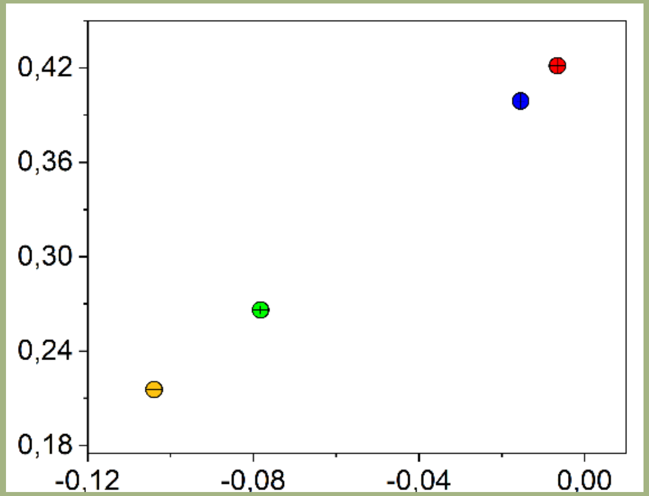
TEXTURE

PHASOR PLANE - EXPLAINATION





DFT



Each R_{app} spectrum is projected onto the phasor plane as a single point (g,s)

Discrete Fourier Transform (DFT)

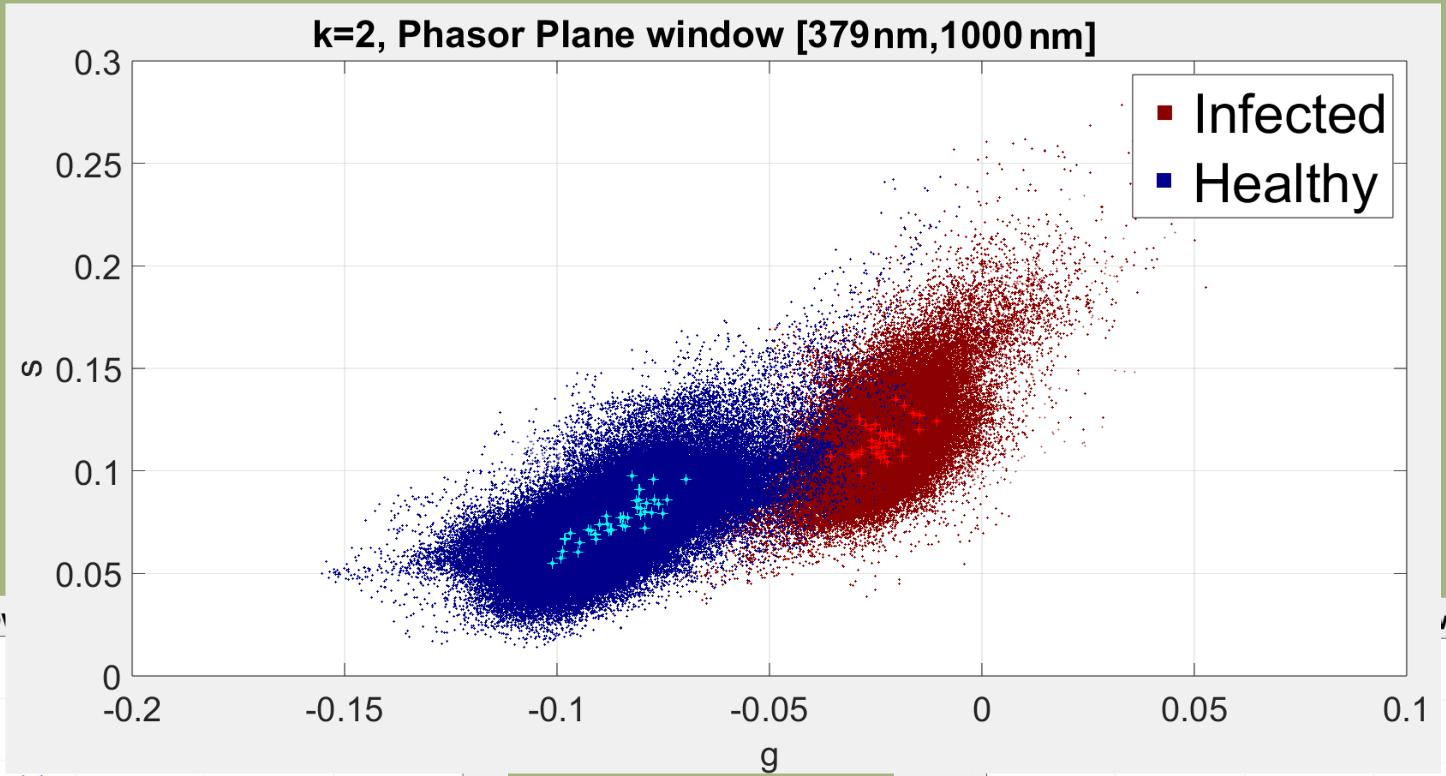
$$g(k) = \frac{\sum_{\lambda_s}^{\lambda_f} R_{app}(\lambda) cos\left(\frac{2\pi}{\tau} k\lambda\right)}{\sum_{\lambda_s}^{\lambda_f} R_{app}(\lambda)}, s(k) = \frac{\sum_{\lambda_s}^{\lambda_f} R_{app}(\lambda) sin\left(\frac{2\pi}{\tau} k\lambda\right)}{\sum_{\lambda_s}^{\lambda_f} R_{app}(\lambda)}$$

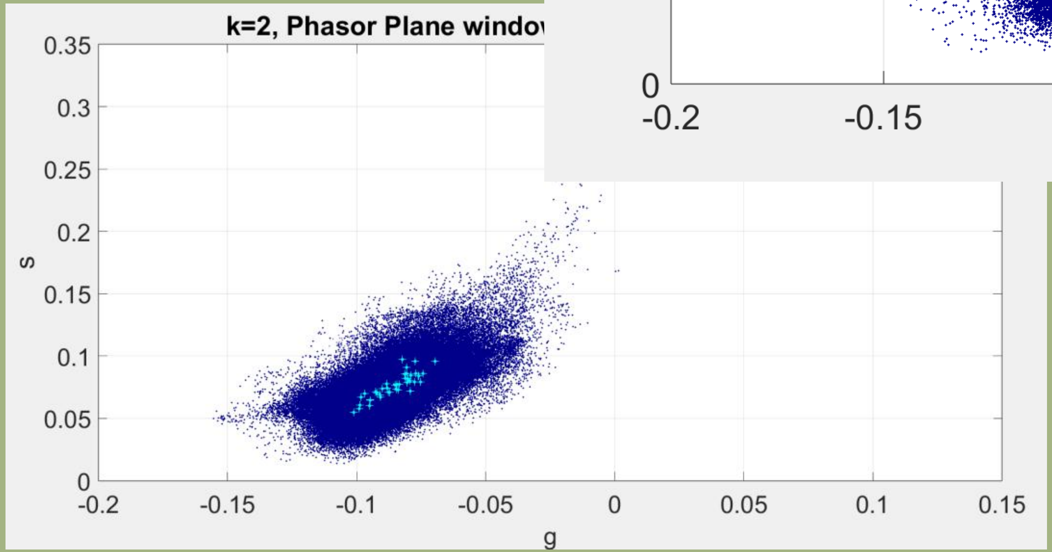
k = harmonic; τ = number of spectral channels

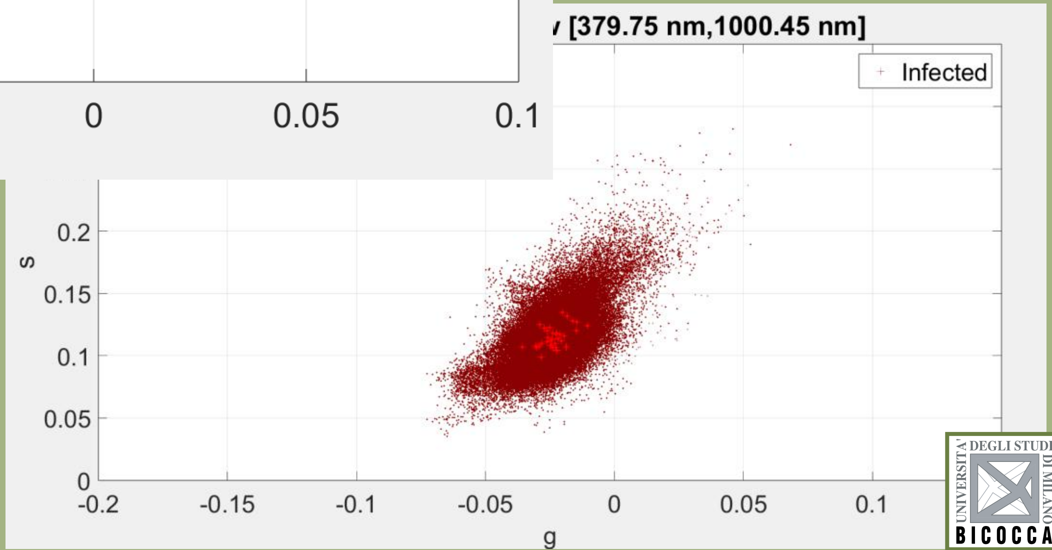
λ_s=starting wavelength λ_f=final wavelength

PHASOR PLANE - RESULTS

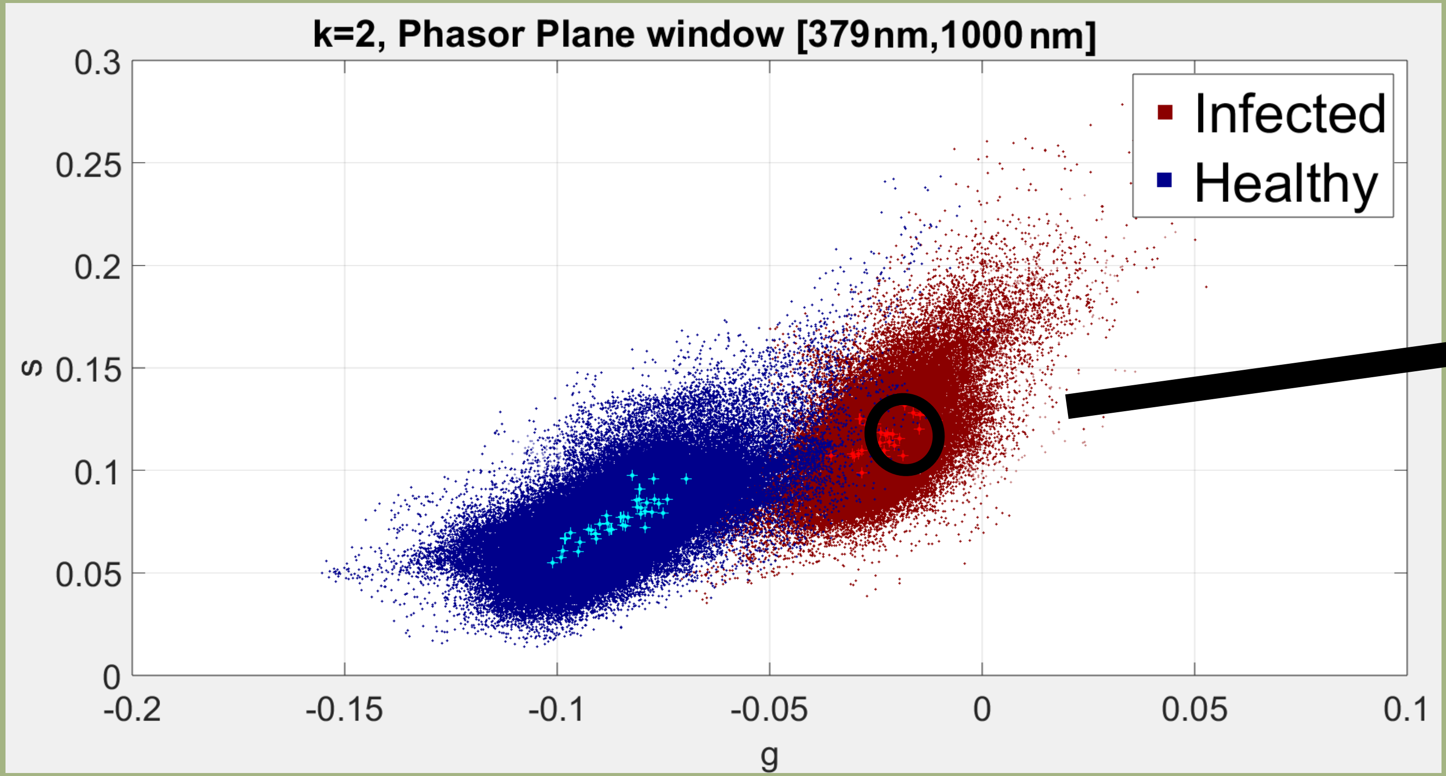
Whole Spectrum analysis with selected caryopses





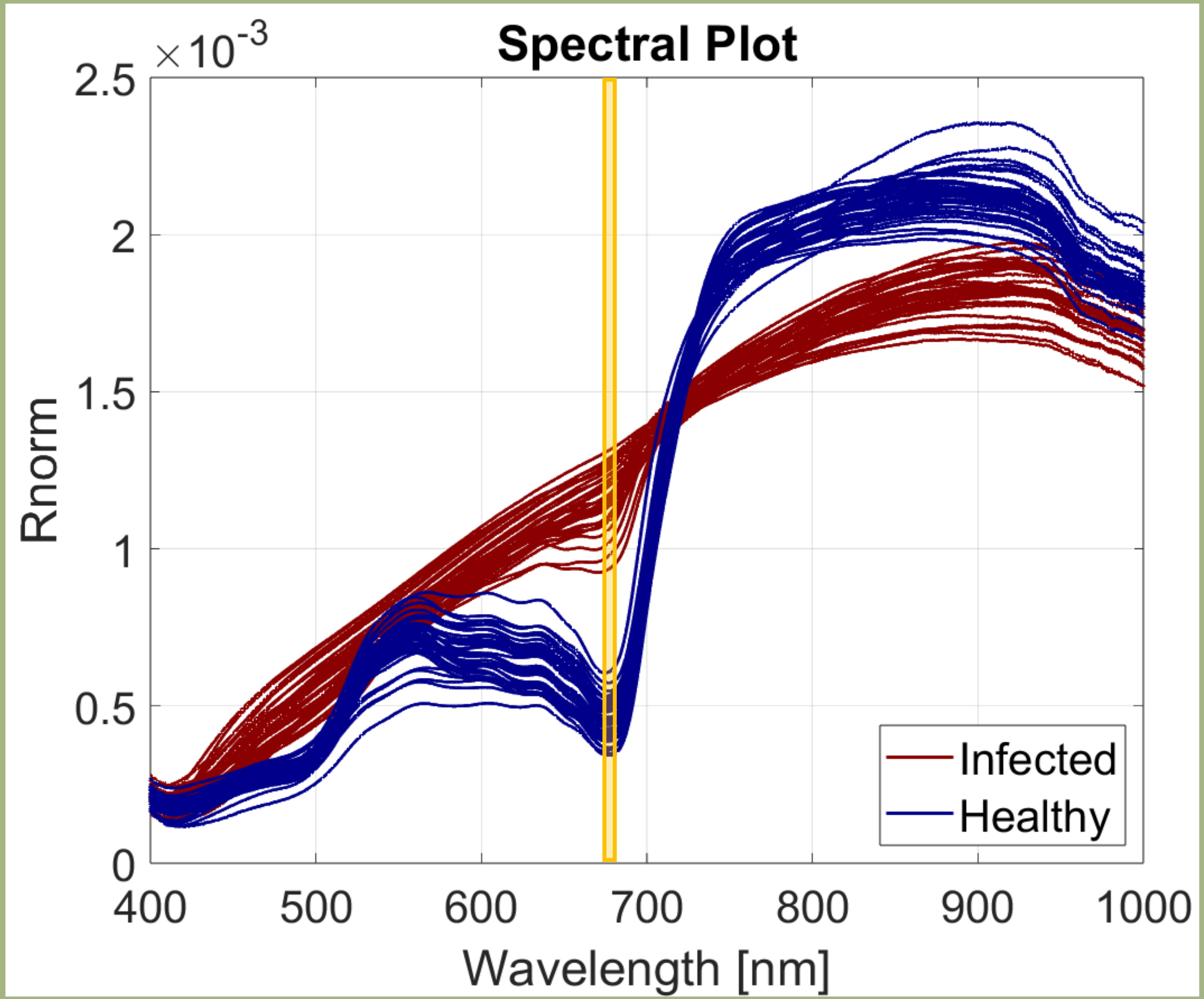


PHASOR PLANE - RESULTS

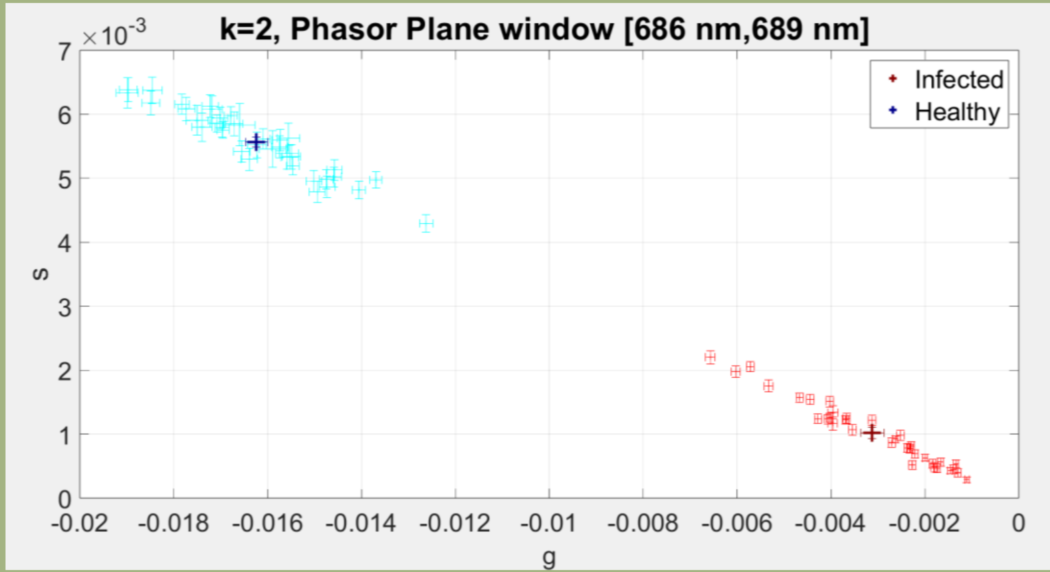


Infected

PHASOR PLANE – RESULTS AT DIFFERENT WINDOWS



Windows width: 3.5 nm



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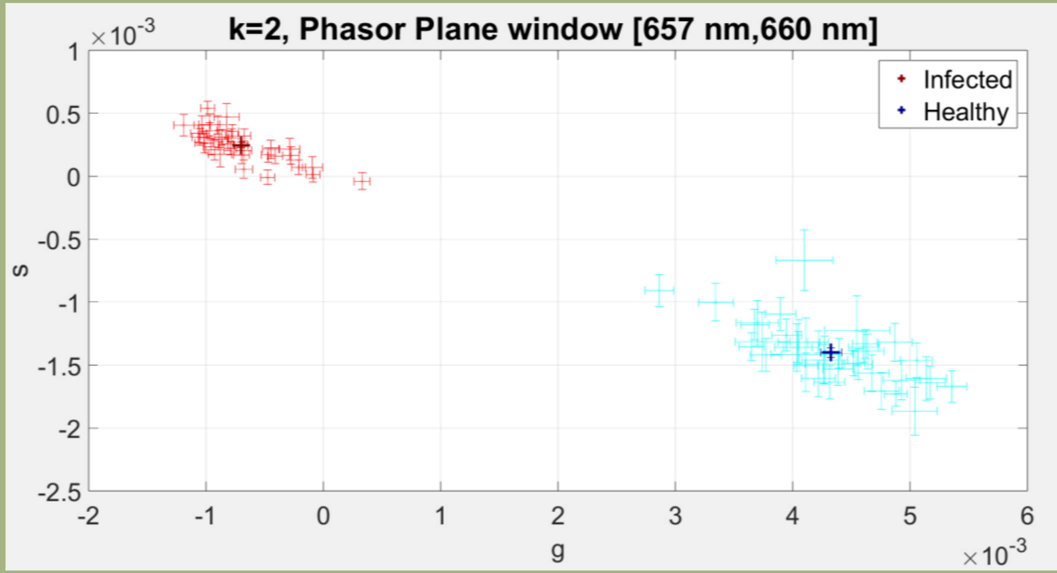

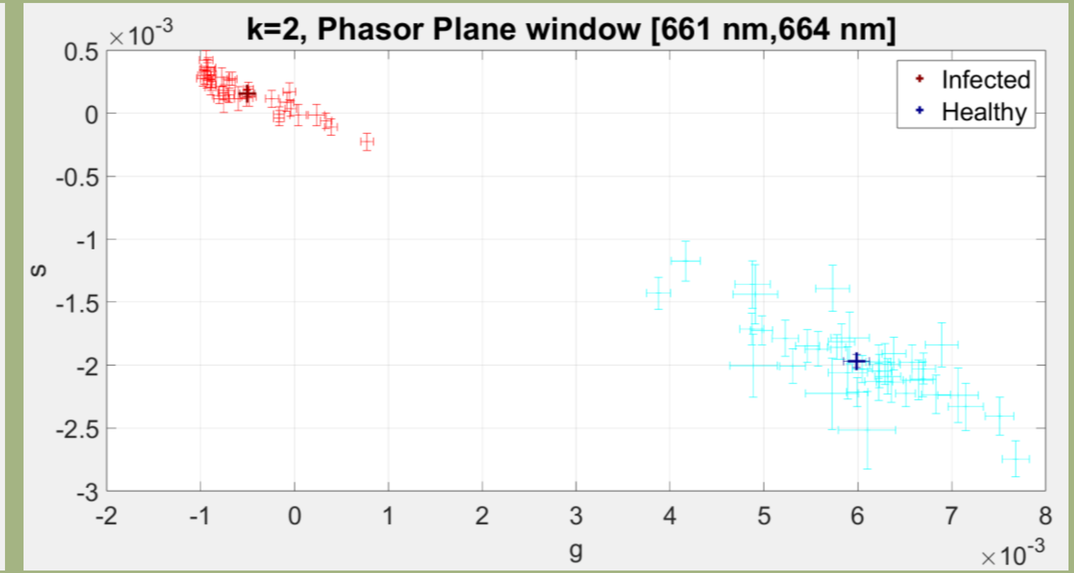

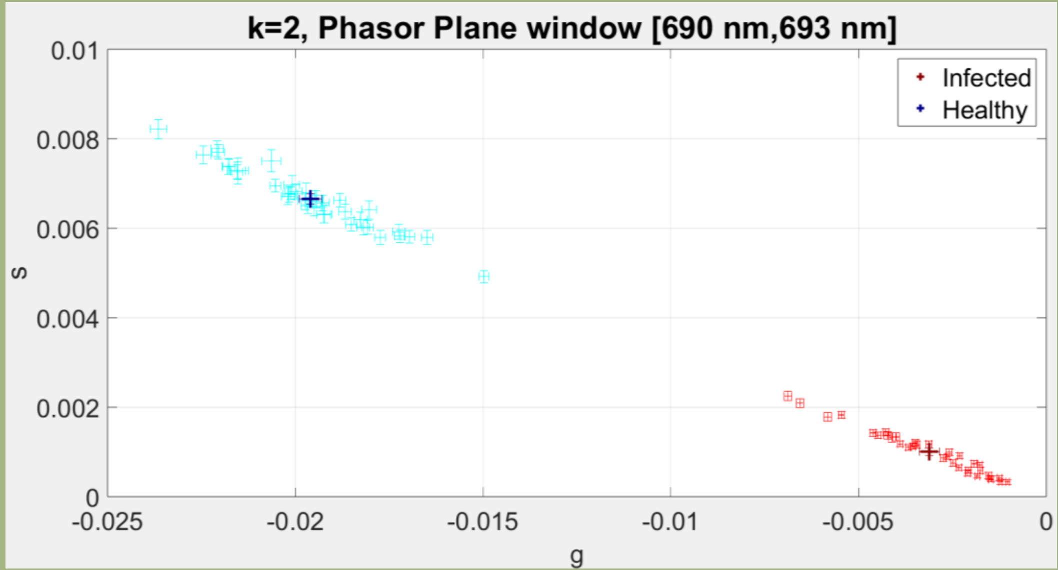

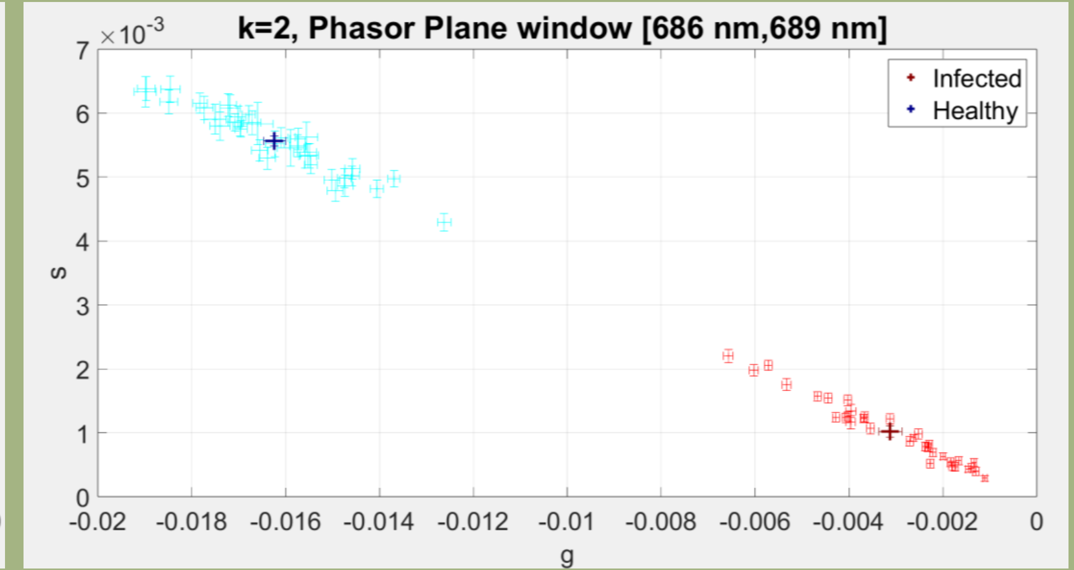

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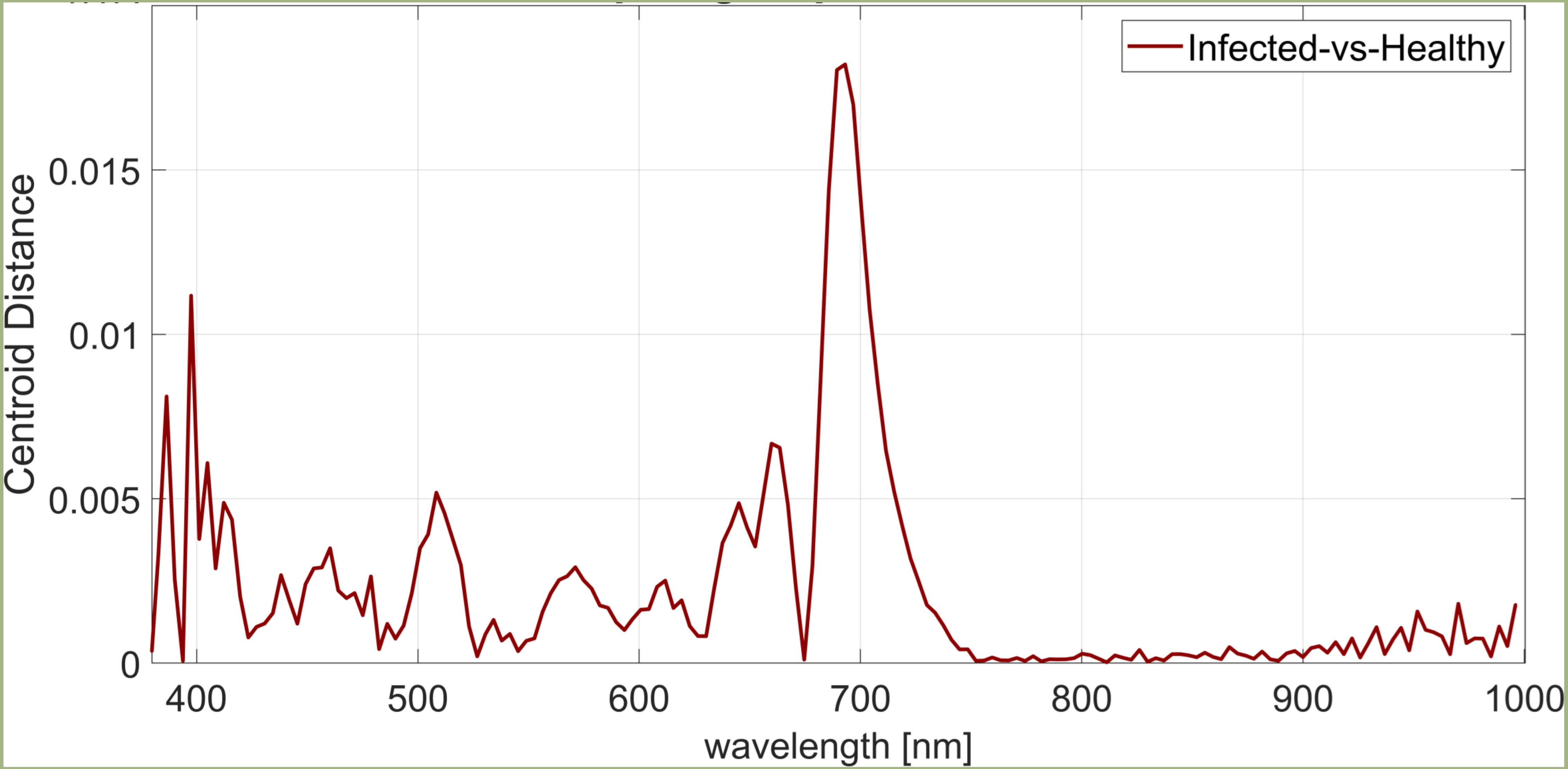
PHASOR PLANE – RESULTS CENTROID MEAN



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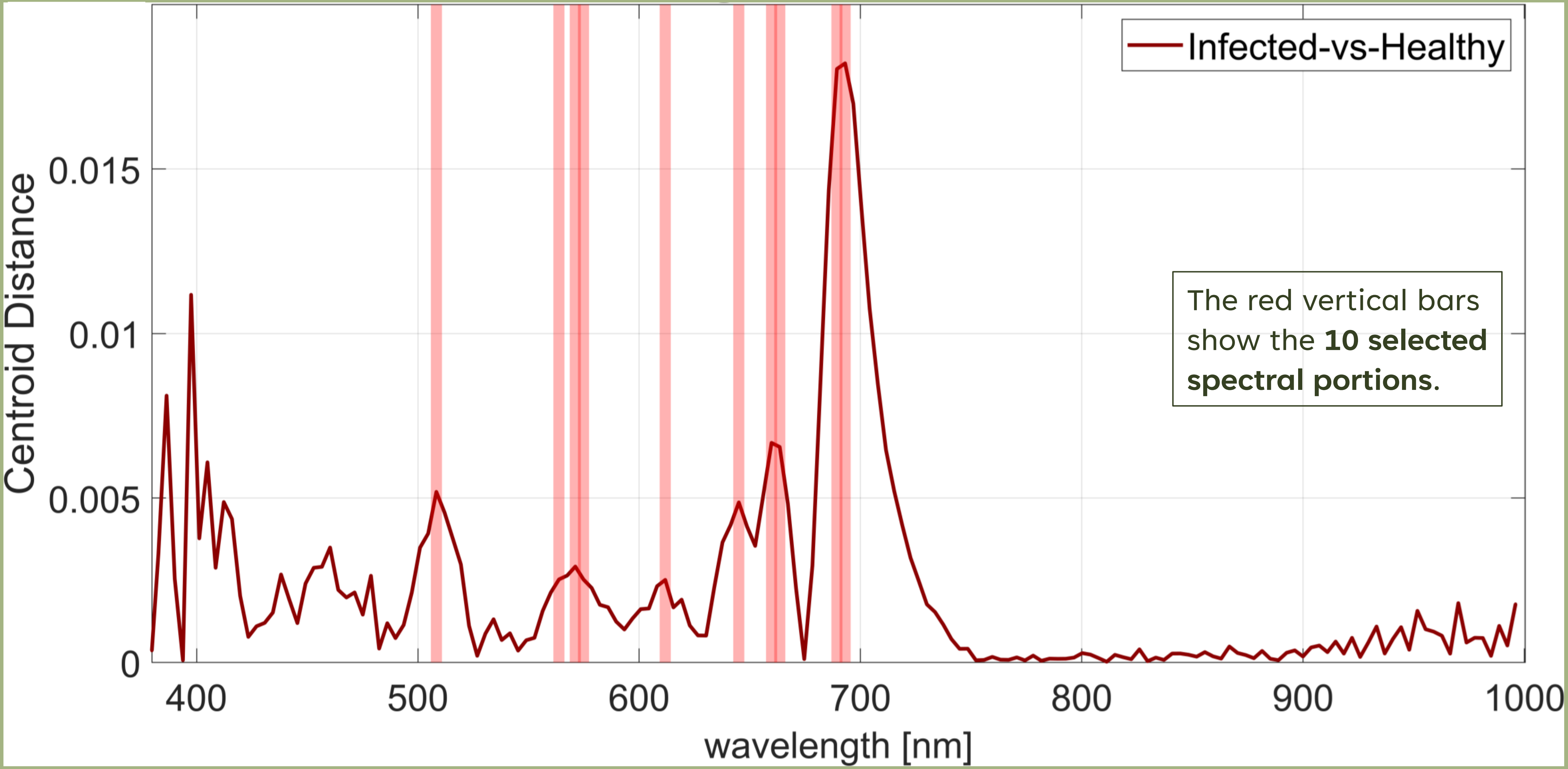

The red vertical bars show the **10 selected spectral portions**.

ANALYSIS

SPECTRA

PHASOR PLANE

TEXTURE

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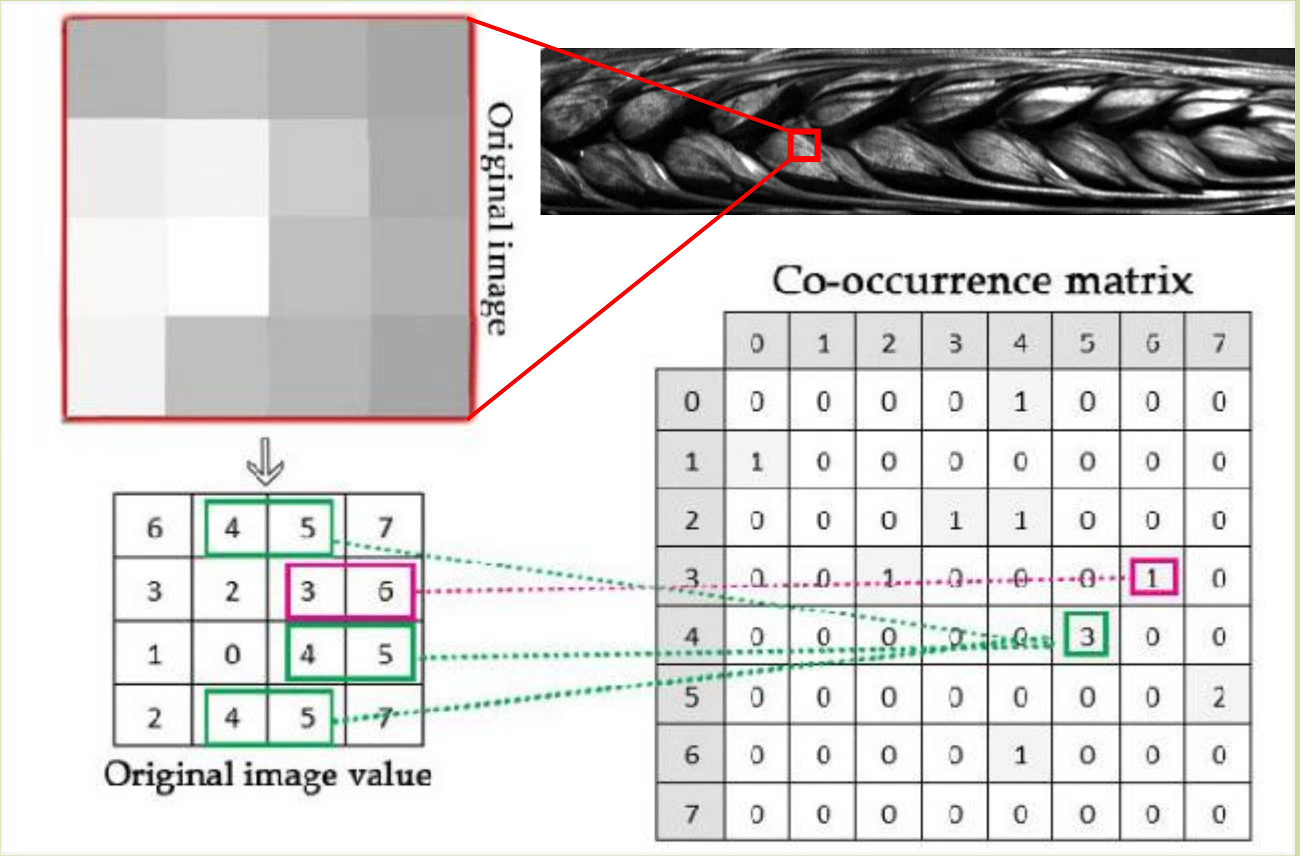
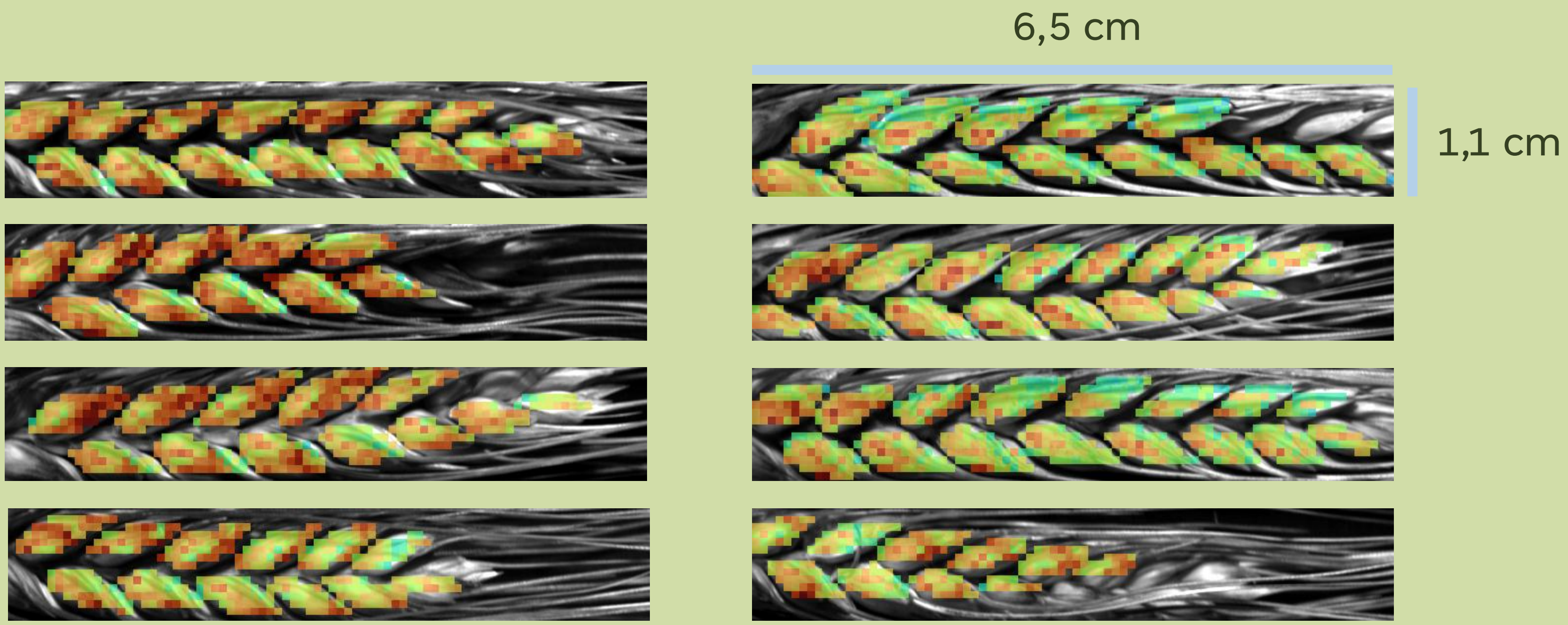
GRAY - LEVEL CO-OCCURRENCE MATRIX (GLCM)



Some values can be calculated:

- Contrast
- Correlation
- Energy
- Entropy
- Homogeneity

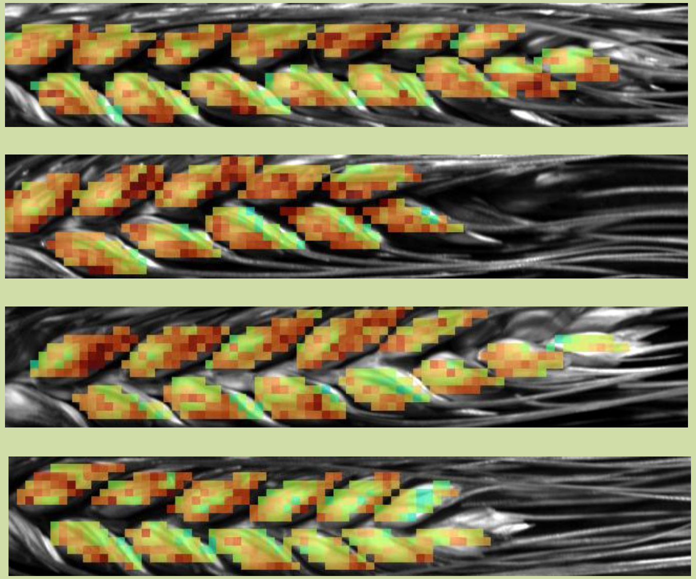
GLCM RESULTS - HOMOGENEITY



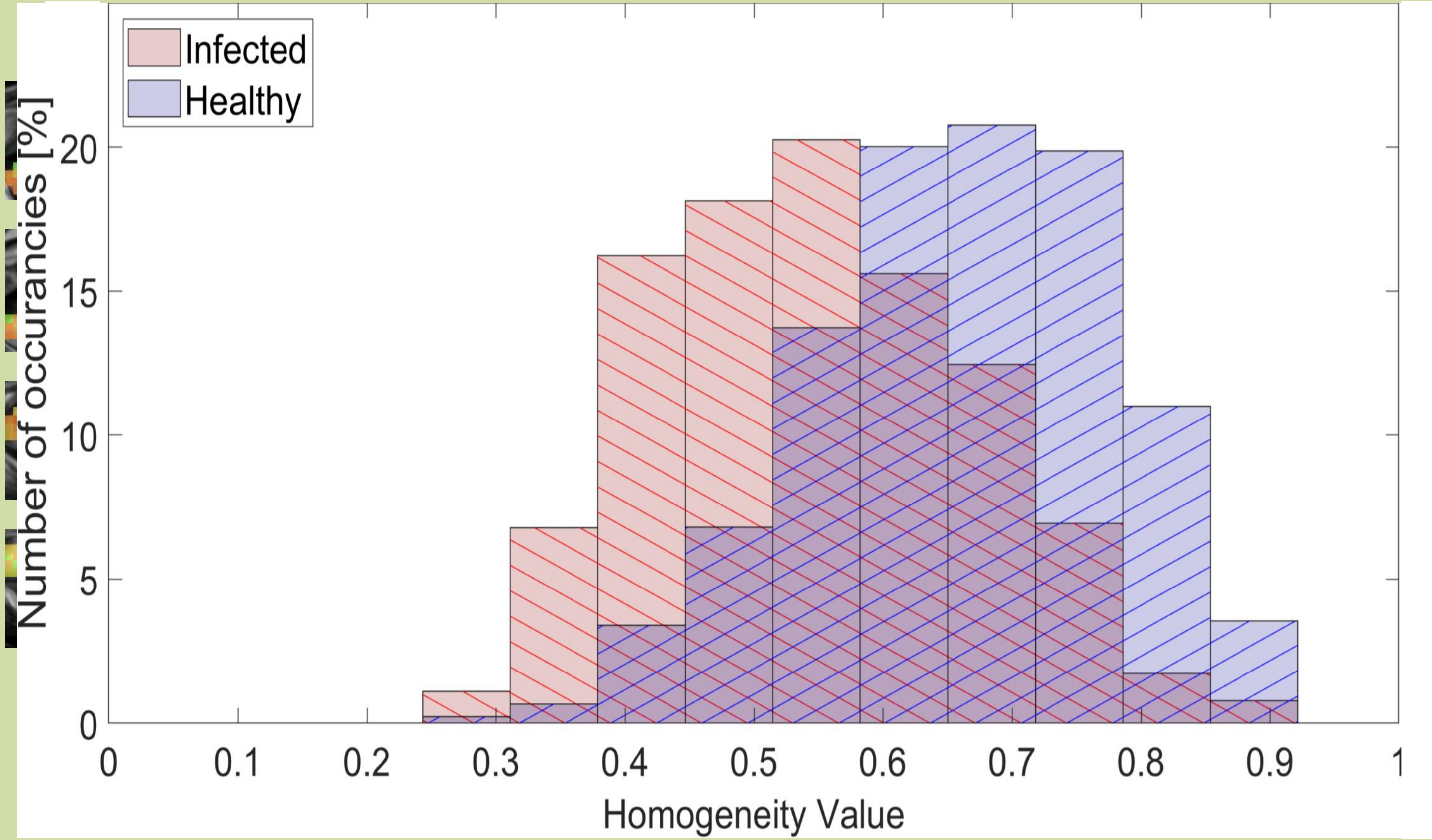
Healthy spikes

Infected spikes

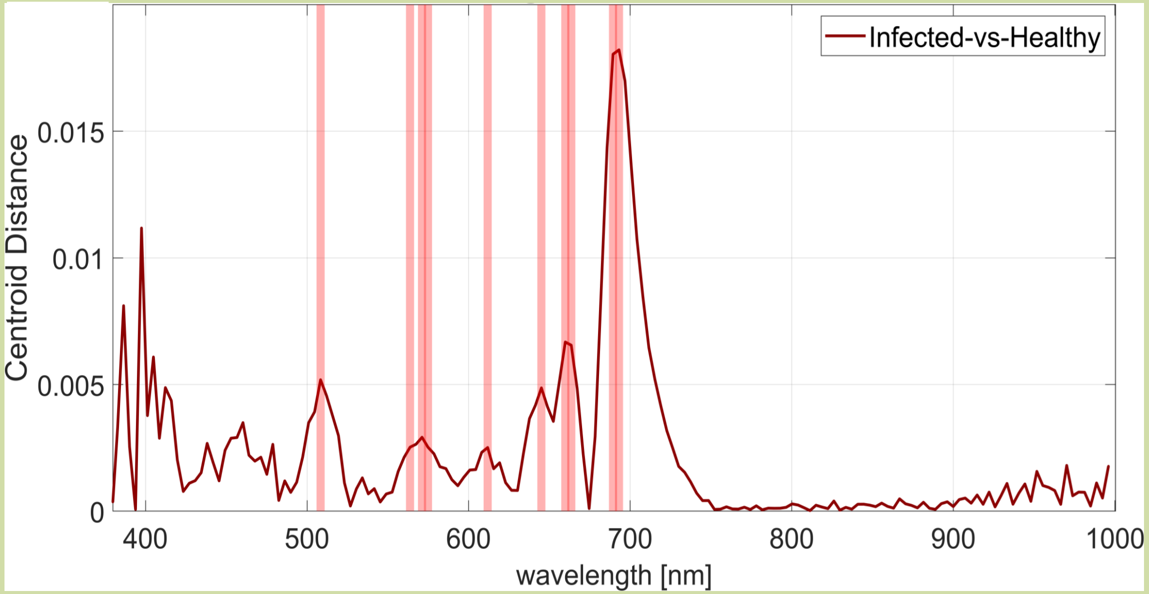
GLCM RESULTS – HOMOGENEITY



Healthy spikes



ANALYSIS RESULTS



20 phasor features

+

- **Contrast**
- ~~**Correlation**~~
- **Energy**
- **Entropy**
- **Homogeneity**

40 texture features (4 for each λ)

MACHINE LEARNING ALGORITHMS

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DATASETS – TRAINING SET

Dataset:
80% training
20% test

Infected spike

Healthy spike

Table 5.1: Pixel ROI Dataset

class	number of elements
Infected green	1900
Infected yellow	5800
Healthy green	4600
Healthy yellow	1800

Three dataset are utilized:

- **PHASOR-ONLY**
- **TEXTURE-ONLY**
- **ALL FEATURES DATASET**

"INTERNAL TESTING"

20% of the dataset **NOT USED** for training

Infected yellow	5800
Healthy green	4600

MODEL: **Ensemble Subspace KNN –** ***PHASOR Only features***

	Real Positive	Real Negative
Predicted Positive	1187	15
Predicted Negative	18	867

	Real Positive	Real Negative
Predicted Positive	98.5%	1.7%
Predicted Negative	1.5%	98.3%

ACCURACY: 98.3%

1) ● 2) ● 3) ● ● ● 4.a) ● ● 4.b) ● ● ● ● ● 4.c) ● ● ● 5) ● ● ● ○ ○ 6) ○ ○

«EXTERNAL TESTING»

Two tests are performed on the treated spikes

GREEN CARYOPSES ARE CONSIDERED HEALTHY

YELLOW CARYOPSES ARE CONSIDERED INFECTED

Classes	Observations	
Systemic green	2000	30
Systemic yellow	1200	20
Trichoderma green	1400	20
Trichoderma yellow	2700	40

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«EXTERNAL TESTING» RESULTS

BEST MODEL
Ensemble Subspace KNN – *PHASOR Only features*

ROI TEST	Real Positive	Real Negative
Predicted Positive	83.2%	14.6%
Predicted Negative	16.8%	85.4%

ACCURACY: 84.2%

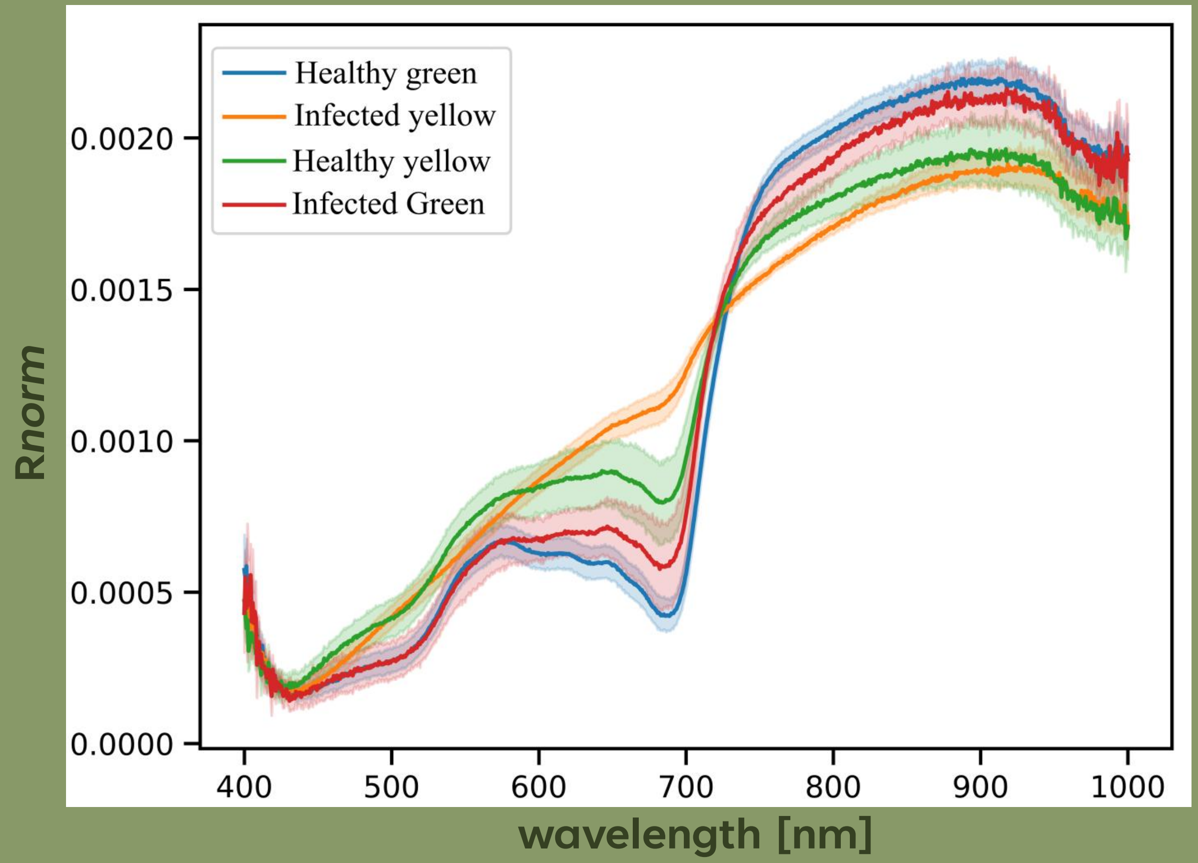
BEST MODEL
Weighted KNN – *PHASOR + TEXTURE features*

BEAM TEST	Real Positive	Real Negative
Predicted Positive	87.3%	4.0%
Predicted Negative	12.7%	96.0%

ACCURACY: 91.5%

MORE CLASSES NEEDED ?

The **mean spectra** of the **references** (healthy green and infected yellow) are **different from** the mean spectra of **other** healthy and infected beams.



CONCLUSIONS

The best results for the accuracy are:

- INTERNAL TESTING 98.3%
- EXTERNAL TESTING PIXEL 84.2%
- EXTERNAL TESTING CARYOPSIS 91.5%

The pipeline schematized:

- Data acquisition and preprocessing
- Feature extraction with Phasor analysis and texture analysis (GLCM)
- Training and Testing

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FURTHER IMPROVEMENTS

- Make trials with different features & classes
- Better evaluate the performances
- Use PCA techniques
- Integrate with remote sensing & on-site application

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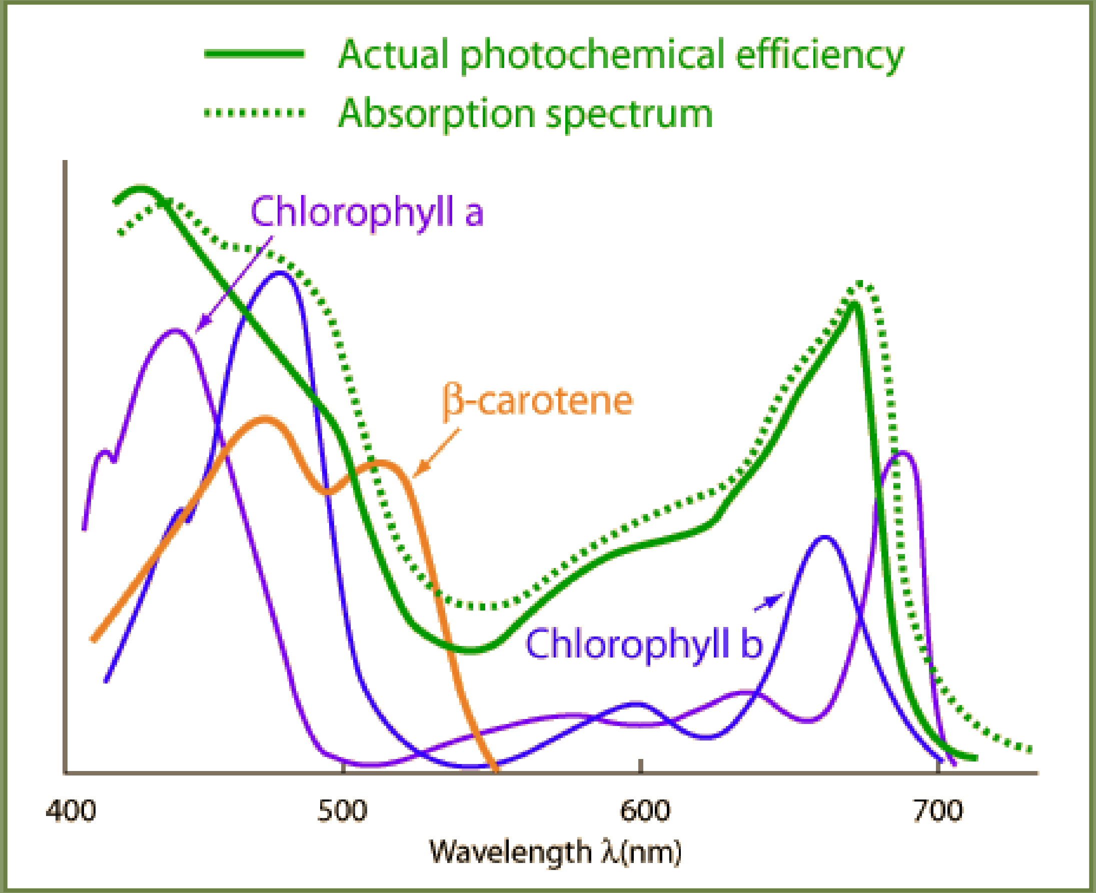
BONUS: ABSORPTION PEAK



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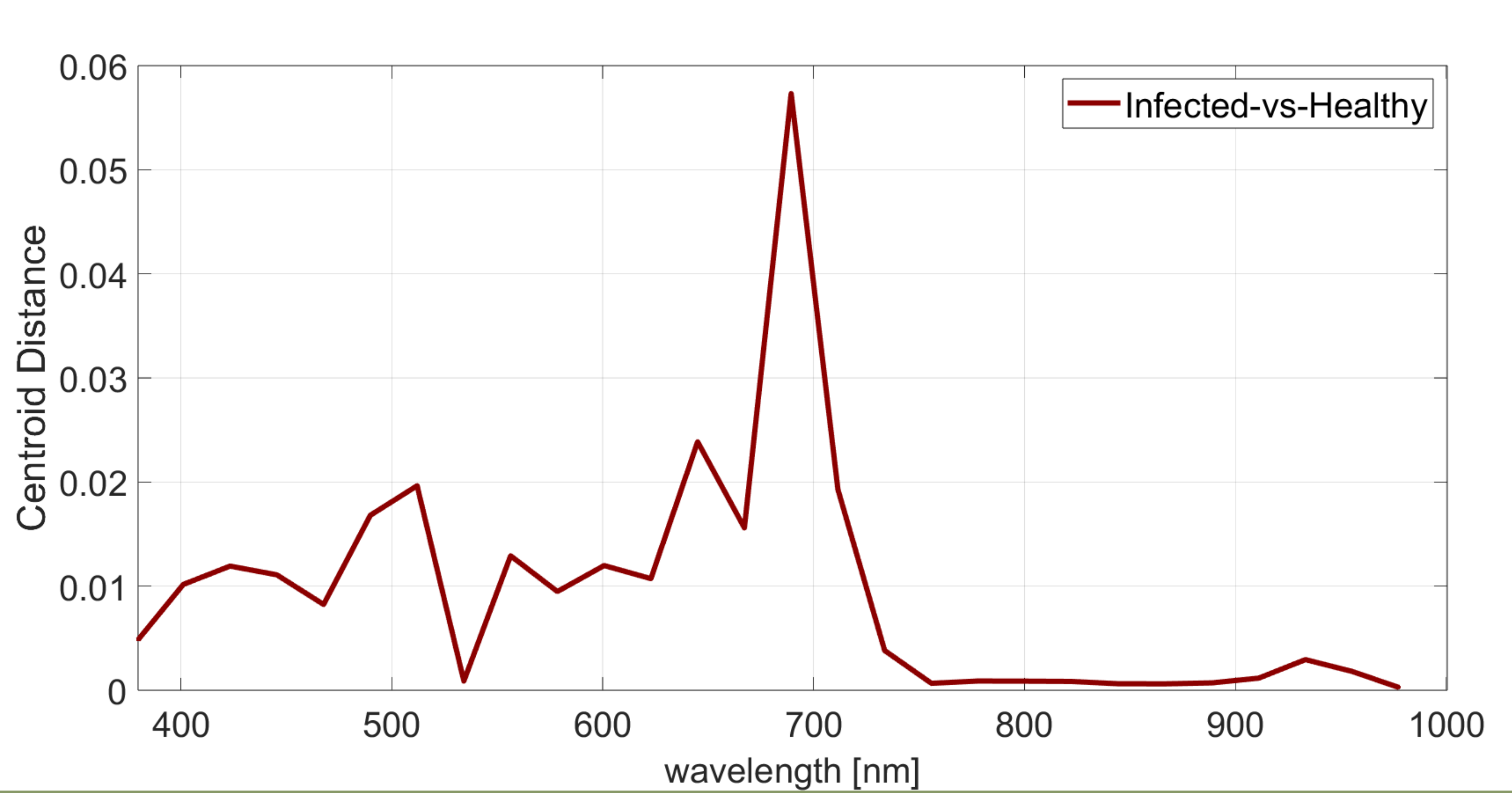
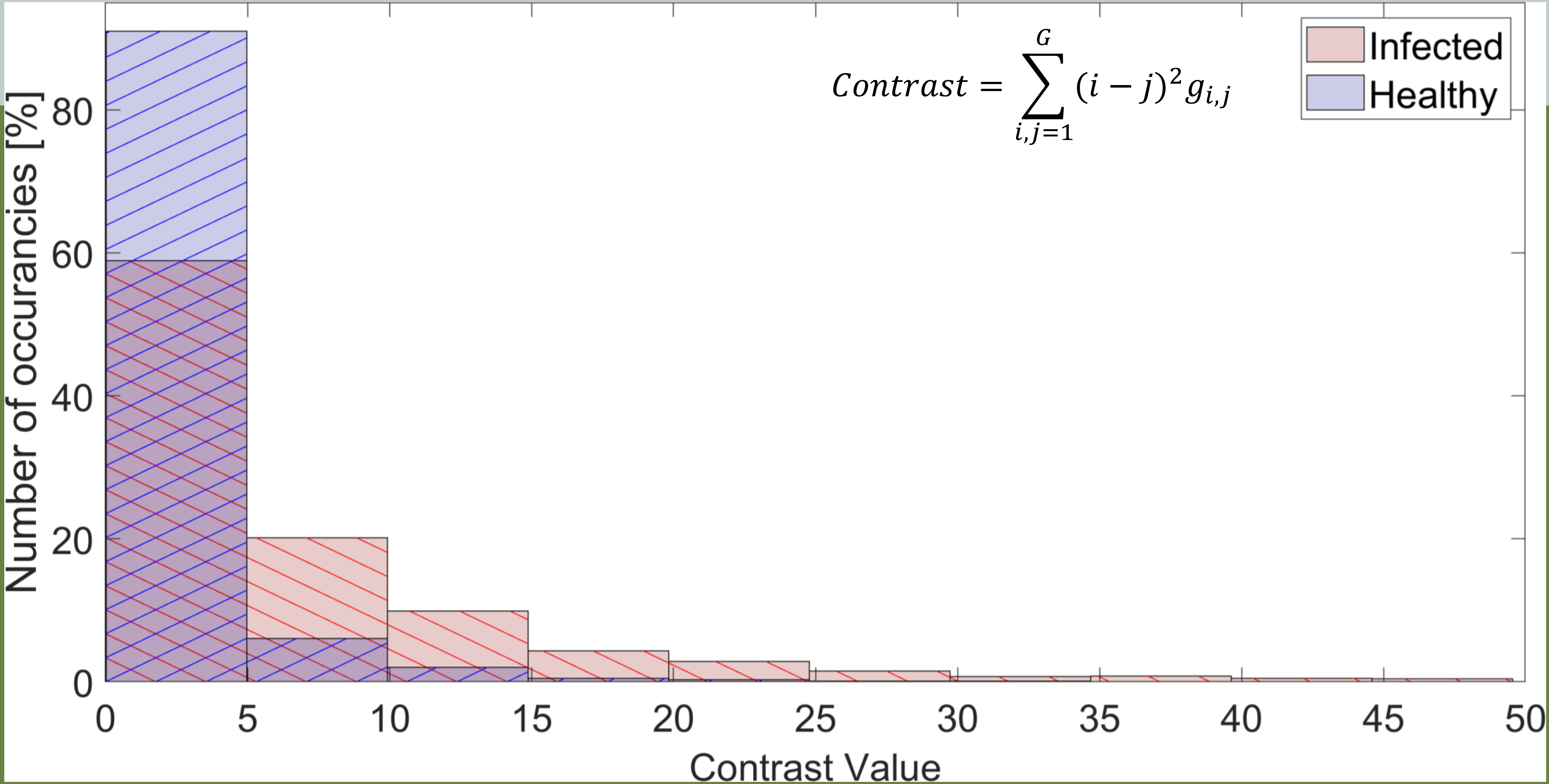
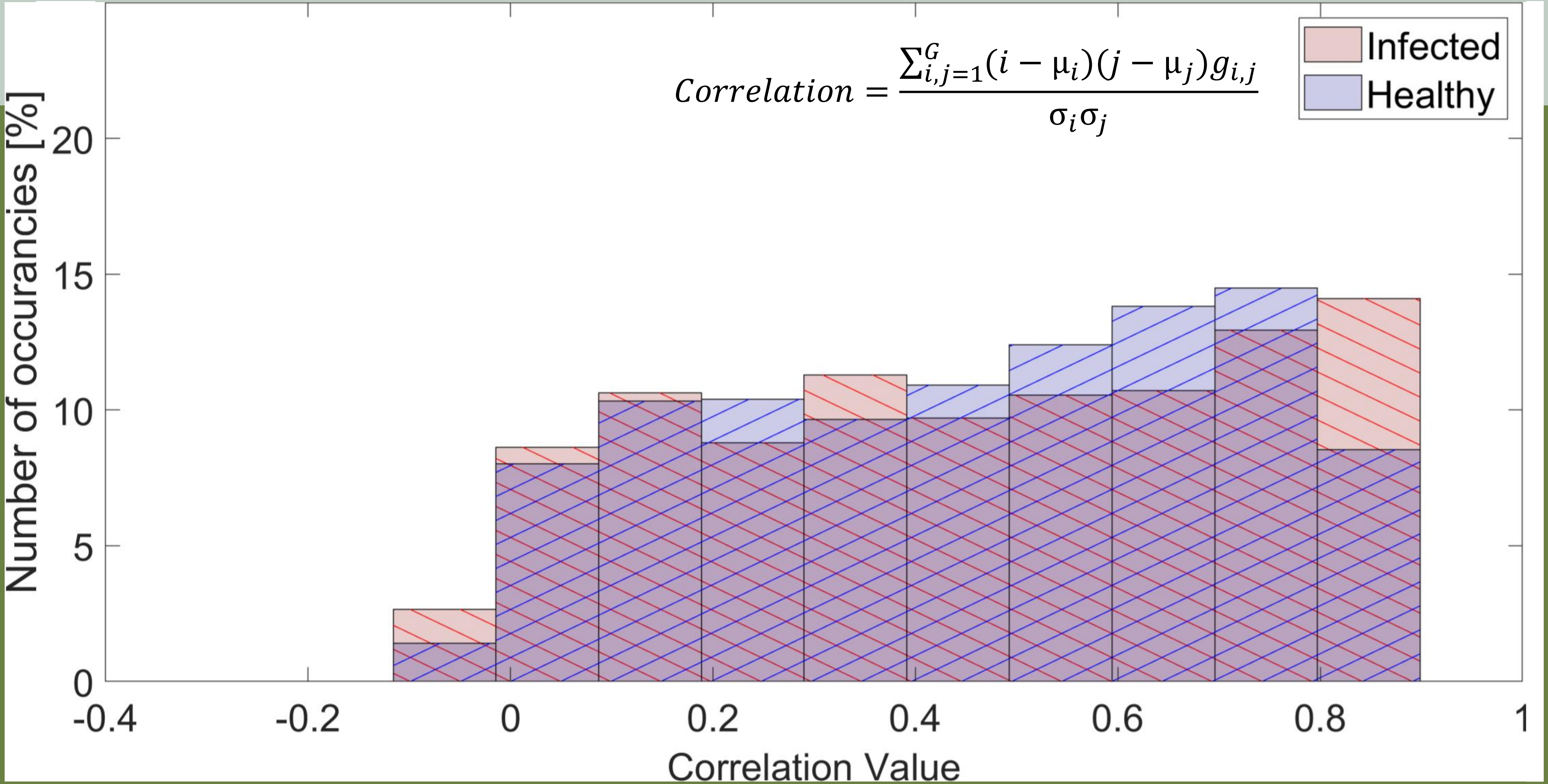
BONUS: DIFFERENT WINDOWS



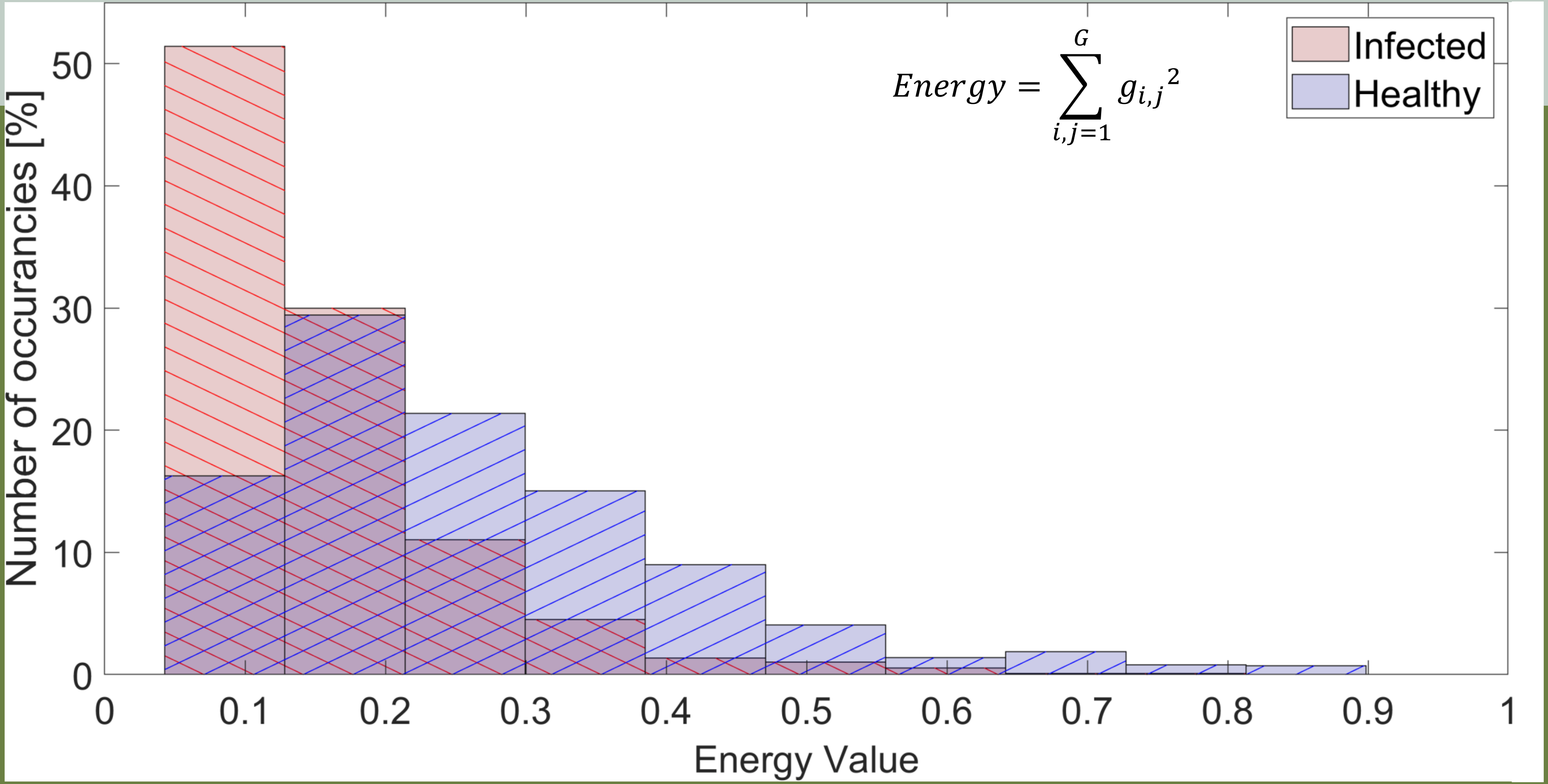
BONUS: GLCM – CONTRAST



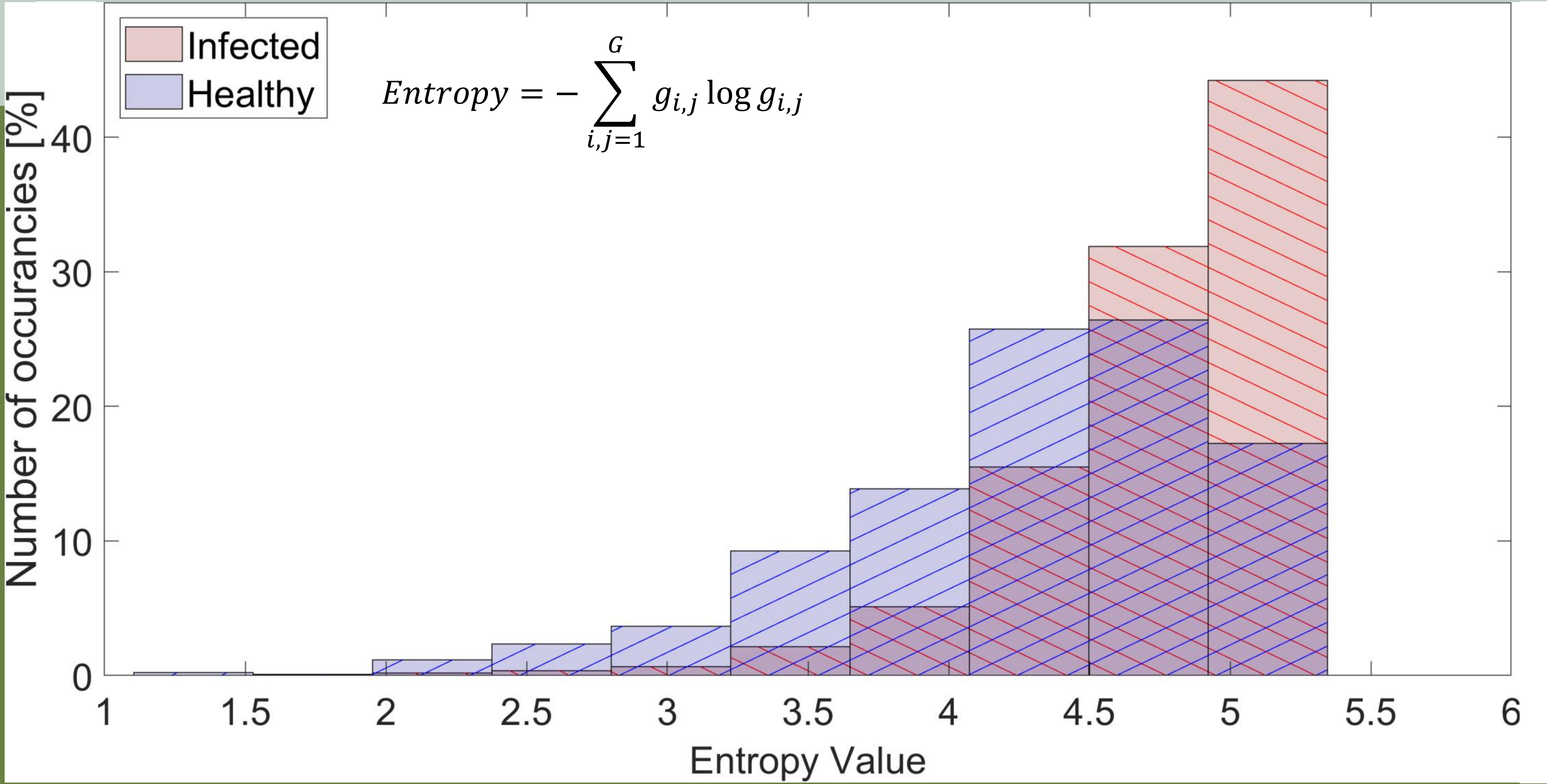
BONUS: GLCM – CORRELATION



BONUS: GLCM – ENERGY



BONUS: GLCM – ENTROPY



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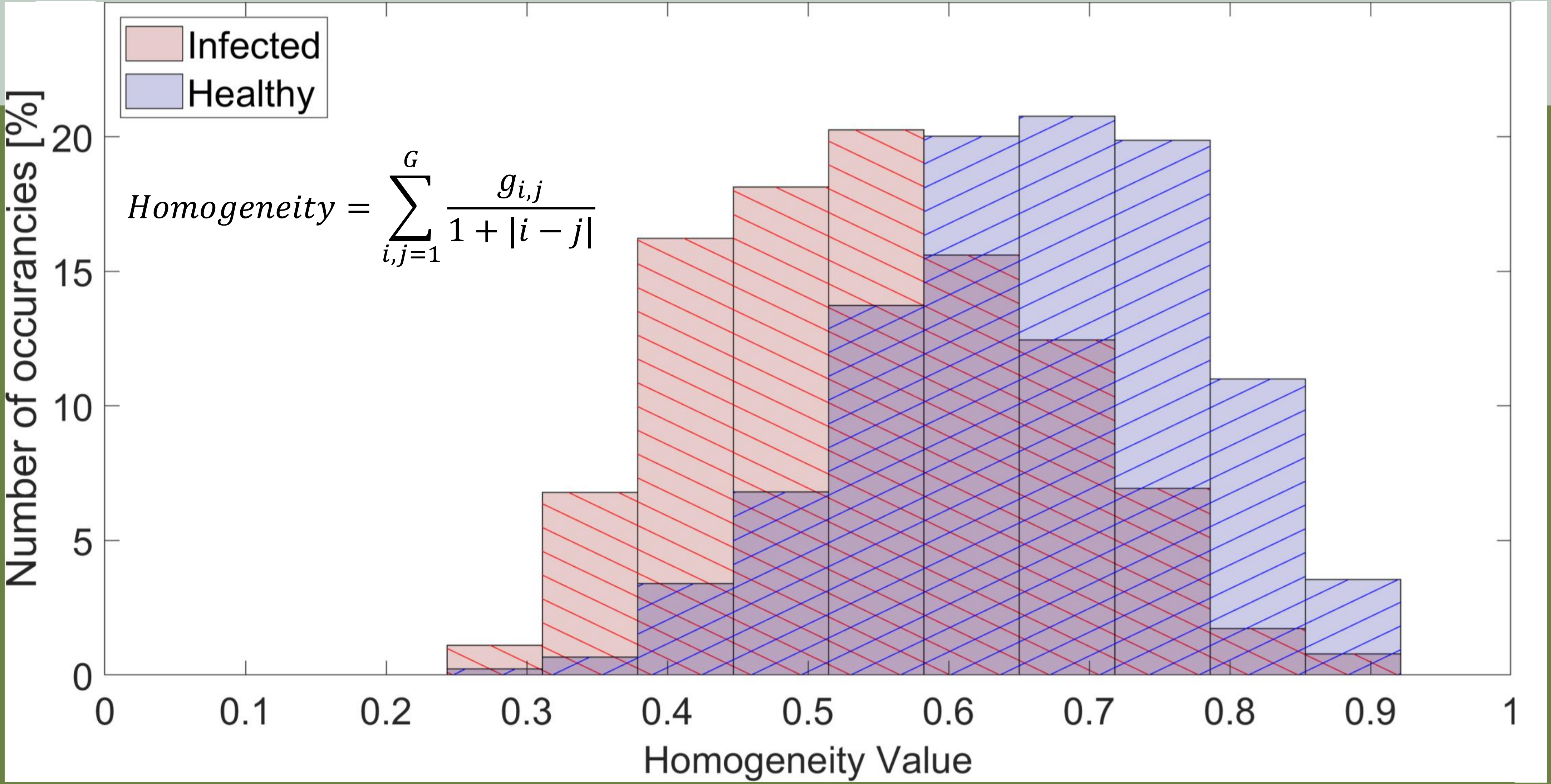
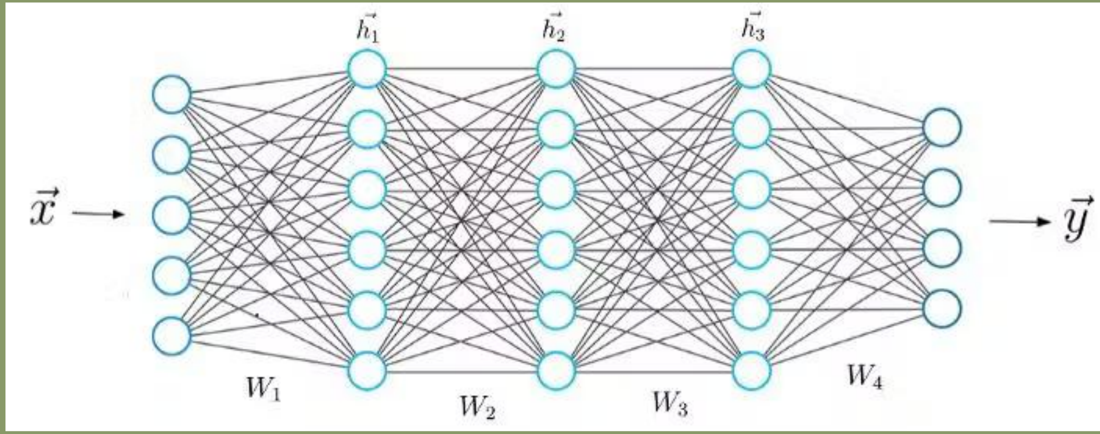
BONUS: GLCM – HOMOGENEITY

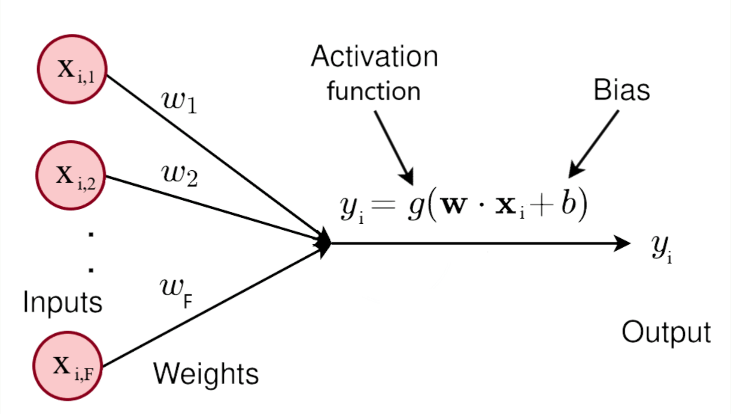


BONUS: MACHINE LEARNING MODELS

Several ML models are trained and tested

- Neural Network (NN)





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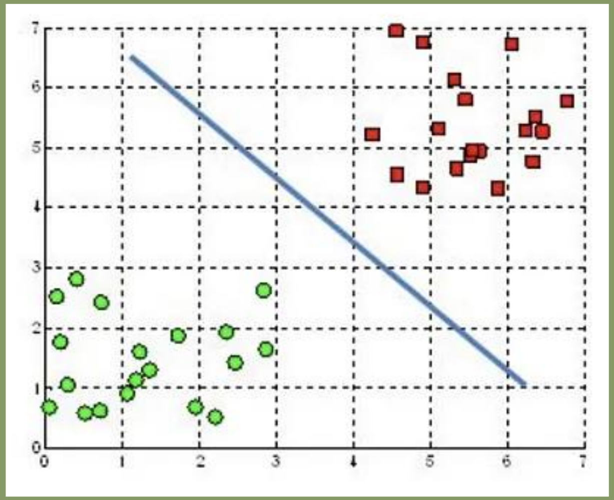

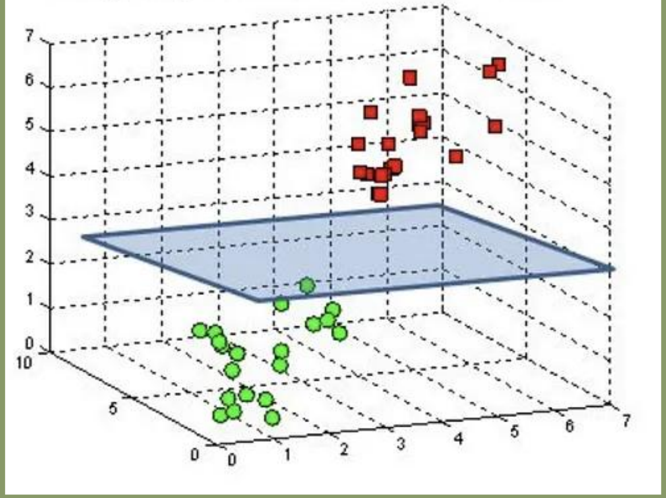

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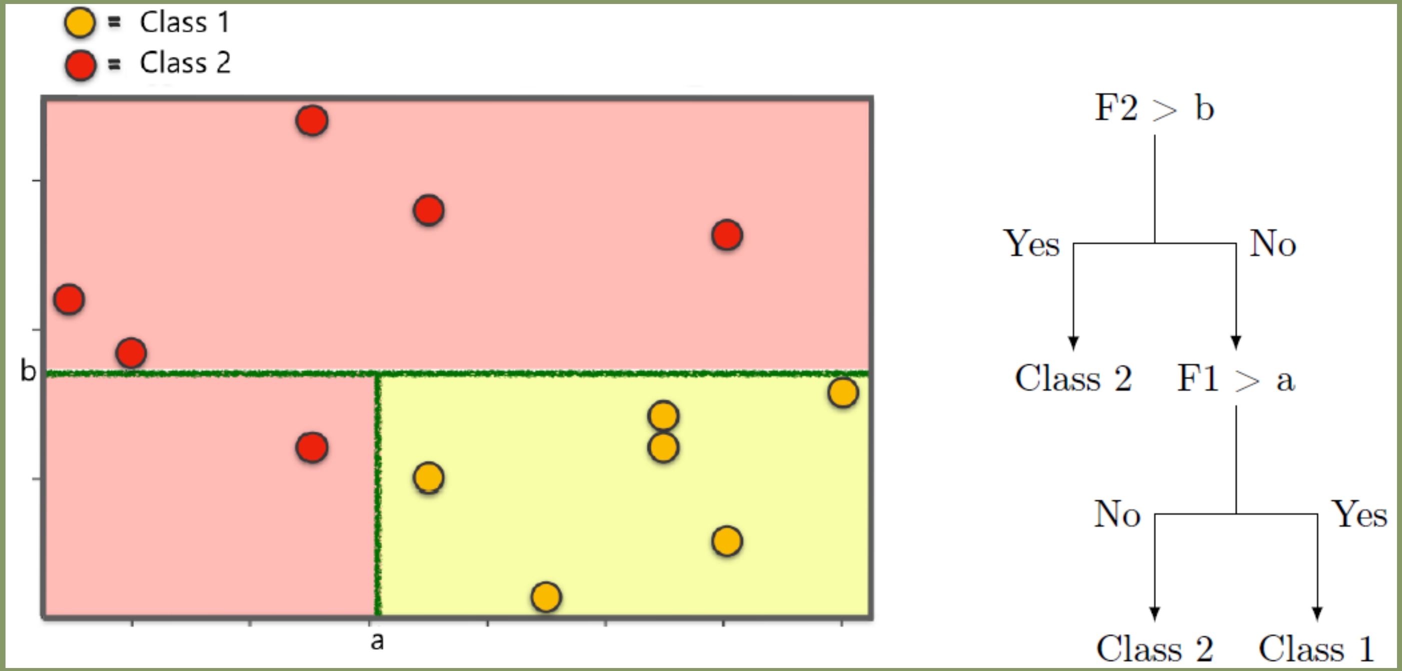
- Support Vector Machine (SVM)
- Trees-based method



BONUS: MACHINE LEARNING MODELS

Several ML models are trained and tested

- Neural Network (NN)
- Support Vector Machine (SVM)
- Trees-based method
- K-Nearest Neighbours (KNN)