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Sílvia Mas Garcia, Daniel Moura, Faten Ammari, Katell Crepon, Ryad Bendoula

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COMIC  
UMR ITAP  
Silvia Mas Garcia  
Daniel Moura  
Faten Ammari\*  
Katell Crepon\*  
Ryad Bendoula  
\*ARVALIS -Institut du végétal, Île-de-France, France

# Detection of Insects in Wheat Grains: A MCR-ALS and FDA Approach Using Hyperspectral Imaging

The detection of insects present in large grain shipping sites are becoming crucial to reasoning out a possible treatment to protect them from a massive infestation, which could lead to significant financial losses. This study is oriented to show that hyperspectral imaging combined with a multivariate data processing pipeline can be used to detect weevils in wheat.

## Experimental

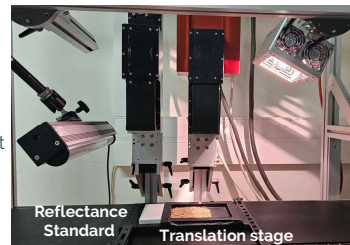
### Setup for Anesthetizing Weevils

Exposition to a gentle stream of CO<sub>2</sub> to induce temporary immobilization without harm.



### Hyperspectral imaging

Hypesx VNIR-1600 Pushbroom 410-985 nm  
Hypesx SWIR 320m-e Pushbroom 965-2500 nm



Halogen light source

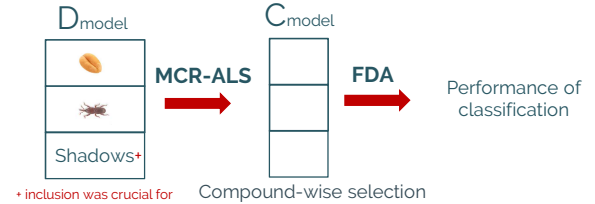
Led light source

### Data set

- **One model image** containing four weevils and several wheat grains. *Weevils are well-separated from wheat grains.*
- **Four test images**, each containing the same quantity of wheat grains with varying numbers of weevils. *Some weevils are hard to visualize*

## Data Analysis

### Model construction\*



\* inclusion was crucial for satisfactory results.

### Model evaluation



### Pre-treatment:

- 1) Cropped region of interest using 'imrect' Matlab function
- 2) Binning by a factor of 4 in x and y for VNIR images
- 3) Spectral Angle Mapper application to extract non background pixels
- 4) Spectral range used: 410-950 nm (VNIR) and 1200-2285 (SWIR)

## Results

### 1. MCR-ALS/FDA model.

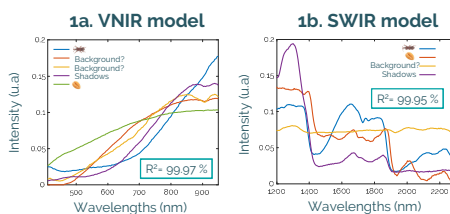


Figure 1. Resolved Pure spectra of both VNIR (a) and SWIR (b) MCR-ALS models.

! MCR-ALS enables to extract some relevant signatures that can discriminate weevils from wheat grains.

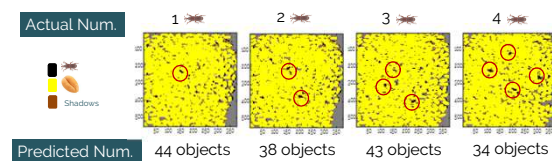
Table 1. Confusion matrices of both VNIR (a) and SWIR (b) MCR-ALS/FDA models, showing the pixel classification for each class.

		1a. VNIR model			1b. SWIR model		
		Predicted Values			Predicted Values		
Actual Values	Background	442	16	20	140	0	0
	Background?	0	408	3	0	128	10
	Shadows	1	19	420	0	12	130

! For both VNIR and SWIR models, the ability to distinguish shadows and wheat grains is lower compared to weevils. Notably, the SWIR model achieves perfect precision for weevils, with no false positives detected, likely due to its more distinctive spectral signature.

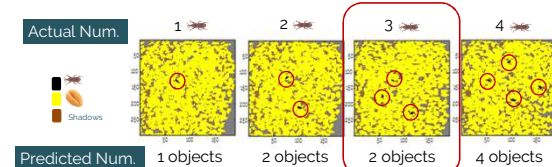
### 2. How many objects have been counted? Where's Wally?

#### 2a. VNIR Test Images



○ ALL have been found  
! High false positives for wheat grains and shadows in the model → object overestimation in test images.

#### 2b. SWIR Test Images



○ ALL have been found  
! No false positives in the model → Good object estimation in test images.

To achieve accurate detection of all 3 objects, lowering the pixel threshold in the 'wareaopen' function is necessary. Reduced accuracy in this image may be attributed to one weevil being well-hidden

Figure 2. Predicted distribution maps of VNIR (a) and SWIR (b) test Images



SWIR hyperspectral images, combined with the MCR-ALS/FDA approach, show strong potential for detecting weevils, even those not visible to the naked eye.



Fusion of images proposed to enhance hidden object detection. Researching optimal anesthesia timing for effective weevil immobilization during imaging.

