23ème Congrès de Chimiométrie, Université de Bretagne Occidentale, Brest, Juin 2022.

Detection and quantification of live rice weevils in wheat grains by hyperspectral imaging

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Keywords: Hyperspectral imaging, rice weevils, wheat, SVM classification, quantification.

1 Introduction

By 2022, the cereal sector has decided to reduce by half the proportion of cereals that may contain chemical insecticide residues [1]. In order to achieve this goal, the development of rapid and reliable methods for insect detection and quantification is essential. Currently, insect detection is done manually by sampling and sieving. This method can only detect high infestation rates above 5 insects/kg [2]. In order to improve detection sensitivity and to reduce sampling errors by analyzing larger amounts of grain, hyperspectral imaging could be a promising alternative. The objective of this study was to evaluate the potential of hyperspectral imaging for the detection and quantification of live insects (rice weevil, adult form) in a batch of wheat.

2 Material and methods

2.1 Plant material

From a batch of wheat (Fructidor variety), 23 different infestation levels were prepared with: 1 insect in 1 to 5 kg per step of 0.5 kg and from 2 to 15 insects/kg per step of 1 insect. Each level of infestation was prepared in three replicates. One sample without insect was also analysed.

2.2 Hyperspectral acquisitions

Sample images were acquired using the LLA's uniSPEC1.7HSI hyperspectral camera in the infrared range (from 950 to 1700 nm). The spectral and spatial resolutions are 3 nm and 320 pixels respectively. To develop supervised models, additional images were acquired: 2 images with only wheat grains, 3 images with only insects, 1 image with impurities (straw, foreign grains, …) and 1 image with the background.

2.3 Image processing

Data processing was carried out with Matlab (version R2019a, The MathWorks Inc., Natick, USA). Figure 1 summarizes the hyperspectral images processing steps.

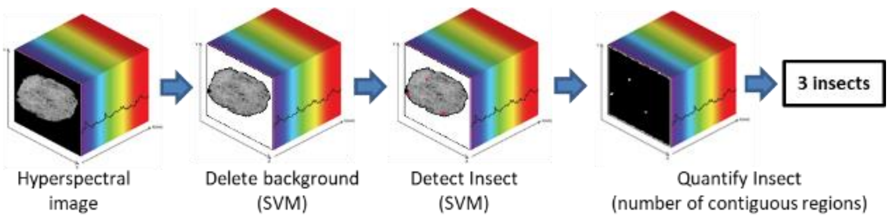
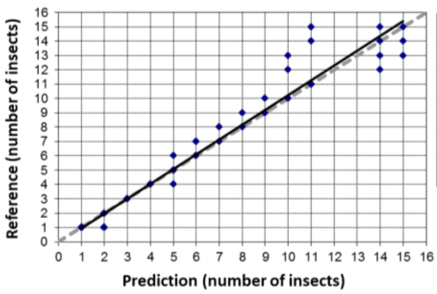


Figure 1 – Hyperspectral image processing steps.

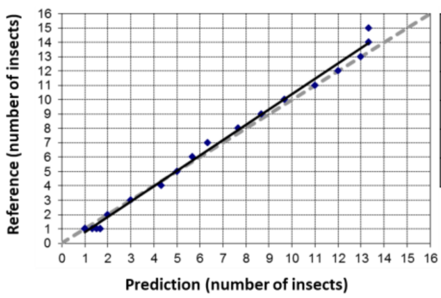
First the background pixels of images were removed by applying a Support Vector Machine (SVM) classification model.
After removing the background, the second step was to detect insects. An SVM model was applied to classify each remaining pixel of the image in two classes: wheat or insect. As impurities are often present in wheat samples, impurity spectra have been added to the wheat class to improve classification performances. To reduce multiplicative and additive effects, spectra were pre-processed with a second order derivative. A selection of 30 discriminative wavelengths was done using Support Vector Machine Recursive Feature Elimination (SVM-RFE). SVM-RFE classifies the wavelengths from the least discriminating to the most discriminating using criteria derived from the coefficients in SVM models [3].
The last step was to quantify insects. Using results of classification models, a 2D binary image was created: 0 for pixels labelled background or wheat and 1 for pixels labelled insect. To quantify the number of insects in a sample, the number of contiguous regions in the 2D binary image was calculated.

3 Results and discussion

The developed insect quantification algorithm was tested on the 65 images with different infestation levels. For each sample, the number of insects predicted by hyperspectral imaging was compared to the number of insects manually put in the sample during its preparation (reference). The performances, shown in figure 2, are very satisfactory although high infestation percentages (above 11 insects/kg) are less well predicted. The uncertainty of quantification is ± 2 insects (2xSEP(C)).



N	65
SEP	0.98
Bias	0.09
SEP(C)	0.98
Slope	1.03
R^2	0.96



N	23
SEP	0.49
Bias	0.08
SEP(C)	0.49
Slope	1.07
R^2	0.99

Figure 2 – Quantification results on the 65 individual samples (on the left) and by averaging replicas of the same infestation level (on the right).

By averaging the predictions obtained for the 3 replicates of each infestation level, the quantification performances are improved (Figure 2). The standard prediction error (SEP) is 0.49 instead of 0.98 and the uncertainty of quantification is ± 1 insect.

4 Conclusion

This study showed the feasibility of using hyperspectral imaging to detect and to quantify live rice weevil (adult form) in wheat. This technology could detect lower percentages of infestations than conventional detection methods and could be used for on-line analyses. In future works, it would be interesting to study other insect species in different forms (adult, larvae…) and other cereals.

5 References

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