TECHNICAL NOTE TN2021_1 – HYPERSPECTRAL IMAGING VS MULTISPECTRAL

Introduction

In this TN we highlight the main differences between multispectral and hyperspectral imaging.

HSI = HYPERSPECTRAL IMAGING

MSI = MULTISPECTRAL IMAGING

RGB = RED GREEN AND BLUE

FWHM = FULL WIDTH HALF MAXIMUM

> *The full width half maximum defines the spectral resolution of a system, more precisely, in this context, its ability to sperate to spectral peaks from each other.*

Article

Very often, when discussing with customers, we need to explain the differences between hyperspectral cameras from multispectral ones. A common definition is stating that hyperspectral cameras have more than 100 bands, whereas multispectral ones have less. But this definition does not take into account the width of the spectral range, neither the sampling. That means that if a camera covers the spectral range 400 – 600 nm with 50 bands, it would not be considered as hyperspectral, whereas if it would cover 400 – 800 nm, with same sampling (meaning this time 100 bands), it would be considered as hyperspectral. We find this discrepancy not relevant, and prefer to speak about spectral resolution (FWHM), highlighting the ability of a camera to separate two consecutive spectral peaks from each other. In this (not perfect) attempt of definition, we would consider that a hyperspectral camera provides smooth and most resolute spectra, whereas the ones provided by multispectral devices are more alike stairs or saw teeth like without abilities to depict acute spectral signatures.

To illustrate this, the sorting of shells among almonds will be studied. This is a very usual application, and this case study makes echo to another one which we already published on our SPECIM website (here: HSI vs RGB cameras). In fact, a RGB camera, can be seen to some extend, as a multispectral device.

We first made a review on multispectral cameras available on the market. For most of them, the spectral range is limited to 400 – 1000 nm, and the amount of bands is often 4 or 5. Those are crucial limitations for many applications.

1. **limit on the spectral range**
   Spectra are shaped by reflection, absorption or emission features which are tightly related with the molecular composition of scrutinized material. The below table is well known, and highlights the spectral bands where each of the most common molecules have their electromagnetics resonance overtones. As can be seen, the spectral range 700 – 2500 nm is necessary for many applications. Especially for those related to food quality assessment and plastics sorting, the range 1100 – 1700 nm is mandatory. Consequently, it highlights that cameras limited to 400 – 1000 nm are not the most relevant for those applications.
   As we saw on our first study (here: HSI vs RG cameras), RGB cameras did not perform well on sorting nuts and pistachios, whereas the FX10 provided better results, and the FX17, best sorting capabilities.

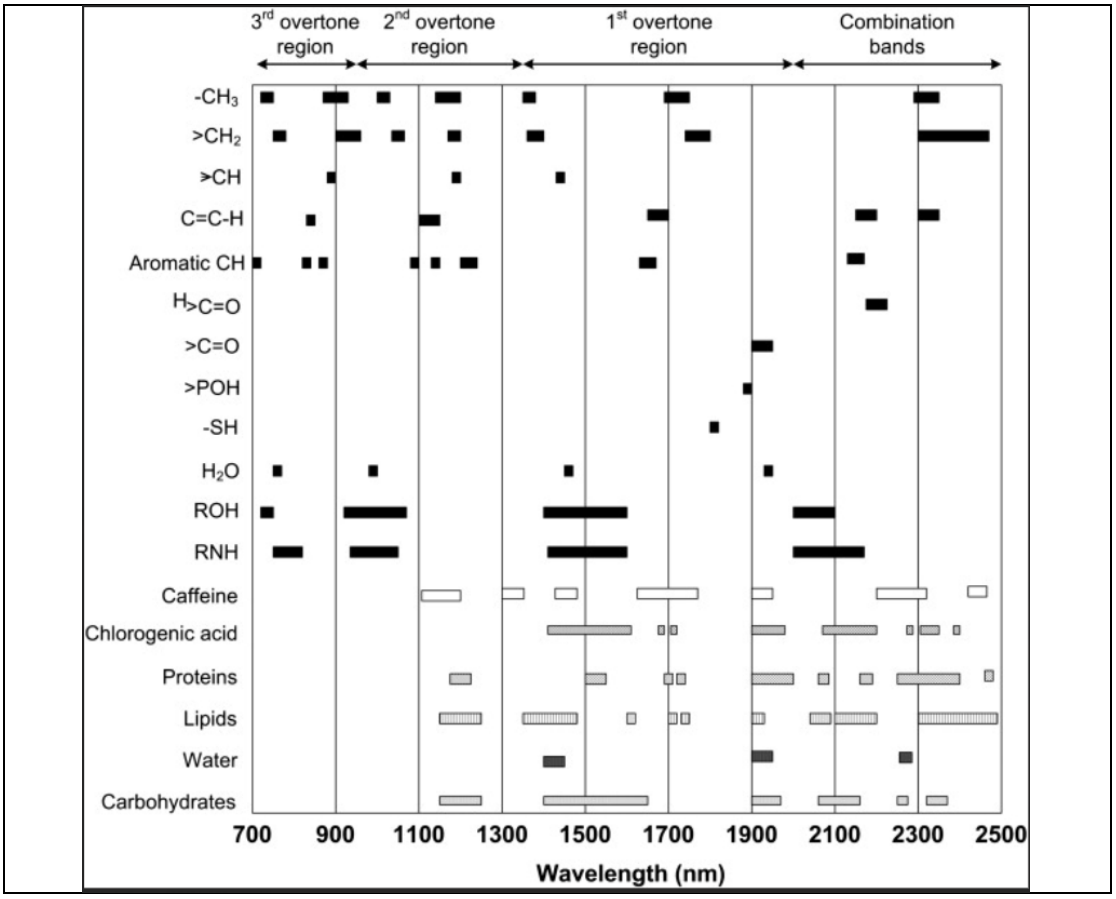
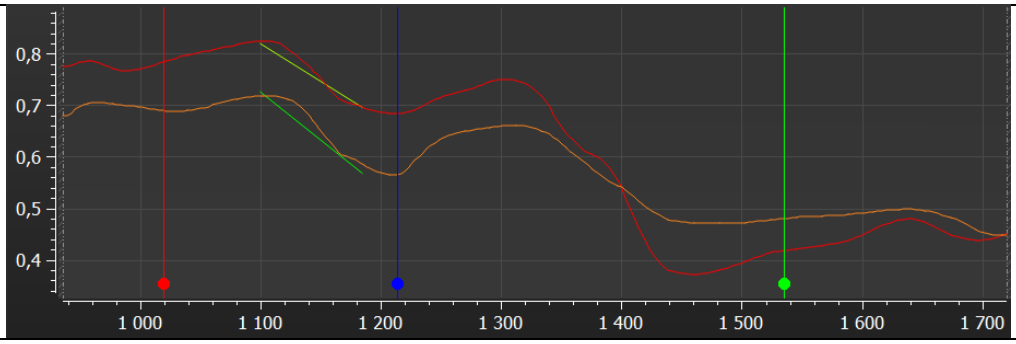


Table 1: Molecular electromagnetics resonance overtones

2. **limit due to the amount of bands**

Taking into account the previous point, we made a comparative study on almonds and shell with FX17 data: with i) all the bands (i.e. 224 bands), and ii) by simulating a typical NIR multispectral cameras, with 2 large bands of 20 nm centred on relevant NIR spectral regions (at 1100 and 1185 nm). As can be seen on Fig.1, spectra sampled with 224 bands are smooth and can depict small but crucial spectral differences between almond and shells. In fact, almonds contain oil, whereas shell does not, and related spectral features are clearly visible in the vicinity of 1185 nm.

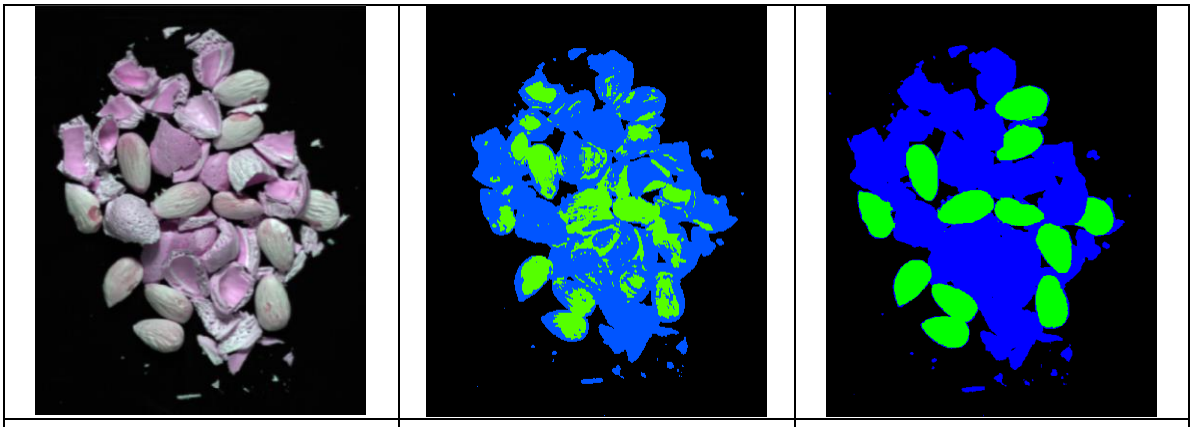


224 bands
Orange and dark green: shell
Red and light green: almond

Figure 1: spectra of shell and almond depicted by 224 and 28 bands.

Besides, with multispectral data, some pre-processing methods are not suitable. For instance, derivative or smoother such as Savitzky-Golay require continuous spectra to perform well, which are not provided by multispectral sensors.

To illustrate these above mentioned points, two models were built on each dataset. The hyperspectral model (224 bands) is much more accurate than the multispectral one. Small pieces of shell are well sorted, and object are not misclassified.



False RGB	Multispectral model prediction	Hyperspectral model prediction

Figure 2: Models based on multispectral and hyperspectral datasets, and related predictions (green for almond, blue for shell).

Also, we acknowledge that only 2 bands over the NIR spectral range is very little to sort almond and shell. But even a larger amount would not warranty a perfect sorting. In Fig.3, the sorting performance of a camera with 28 bands, equally spread over the full spectral range 90 – 1700 nm, are highlighted. Sorting performance are better than with a typical multispectral camera, but not as good as with a full hyperspectral device. Small objects and edges are here misclassified.

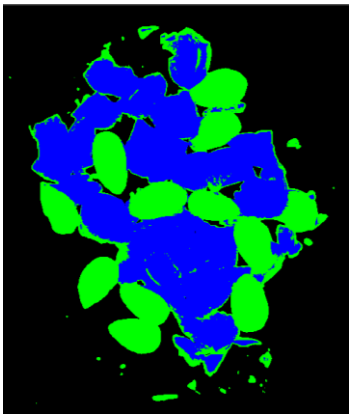


Figure 3: prediction model over a NIR dataset with 28 bands.

Finally, we acknowledge that for some applications, where the full spectral range is not needed, custom made multispectral cameras, with well chosen bands, may perform equally well as hyperspectral devices. However, the user will lose the flexibility offered by hyperspectral sensors (having the possibility to upgrade the machine to sort new types of contaminants or materials). Advantageously, with the FX cameras, the user can freely select relevant bands. The FX cameras can therefore become multispectral, whereas on the opposite, a multispectral camera could never become hyperspectral.

Besides, multispectral cameras are not cheaper, especially if they need to be made custom, with a rather large amount of bands.

Disclaimer

Version history

Version	Date	Author	Comments
1.0	Mar 14th 2022	MMA	