TECHNICAL NOTE TN2021_2 – FX CAMERAS TRANSFERABILITY

Introduction

FX cameras have been primarily designed for industrial usage. In order to ease their integration into industrial systems, their transferability has been thoroughly taken into account during their designing phase. This TN highlights what to take into account for a successful transfer.

AIE = AUTOMATIC IMAGE ENHANCEMENT

DN = DIGITAL NUMBER

T_INT = INTEGRATION TIME

FOV = FIELD OF VIEW

SNR = SIGNAL TO NOISE RATIO

OEM = ORIGINAL EQUIPMENT MANUFACTURER

Article

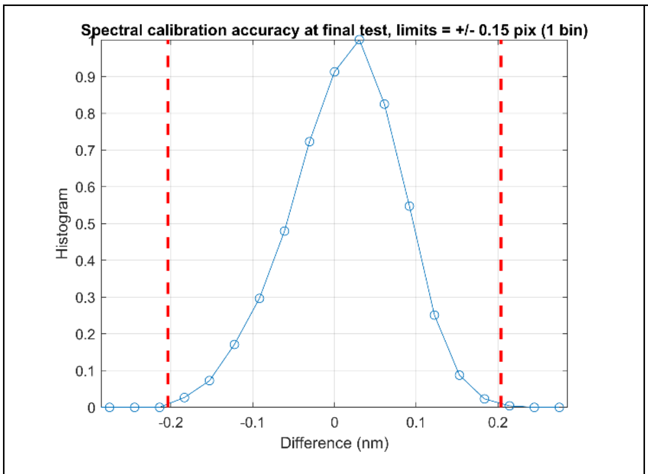
When an OEM, an integrator or a partner choose a FX camera as a key component to build his optical sorter or analyzer, the replacement of a camera needs to be straight forward. Also the sorting model built on one device should be applicable on other machines of the same kind.

As an illustrative purpose, one can say that FX cameras, at a given spectral range, are twins, but not clones. It means that all of them are very similar, but not identical. The aim of this TN is to highlight which parameters need to be considered when transferability is required.

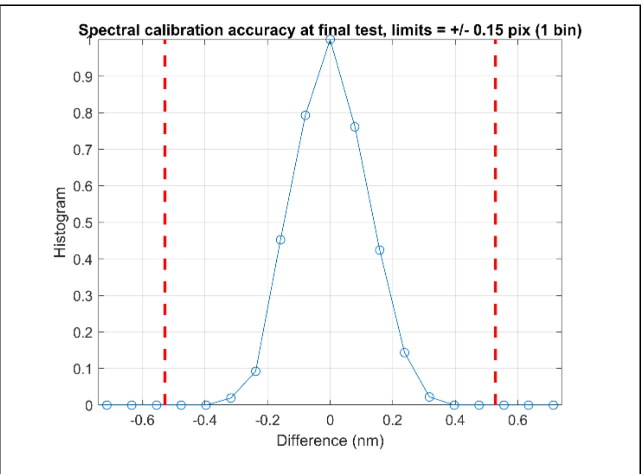
Automatic Image Enhancement (AIE)

For each FX camera, an AIE routine is run in real time to correct the smile and keystone (see our TN about smile and keystone), and to unify the spectral calibration of each unit. This means that all FX camera (at a given spectral range) provides data with identical spectral bands. This is a great improvement from the user point of view, as typically, each push broom hyperspectral camera had their own spectral calibration and bands.

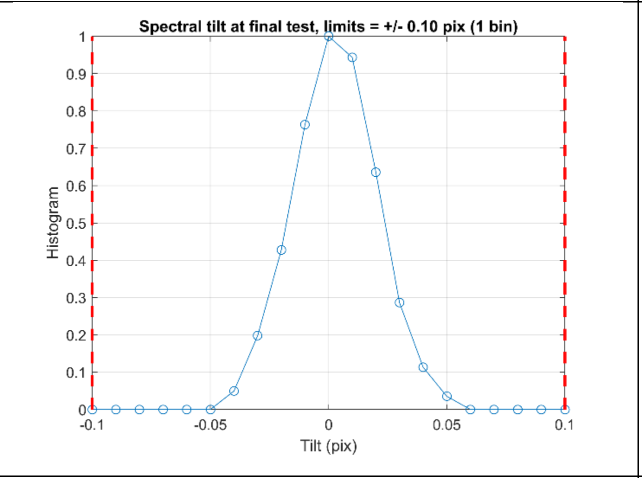
In Fig.1 below, it shows that after AIE correction, smile and keystone (i.e. spatial and spectral deviation over the full field of view and overall spectral range) are well contained below a detector pixel, at ±5% of it, on average. Also, the unified spectral calibration between each device is as precise as ±0.2 nm.



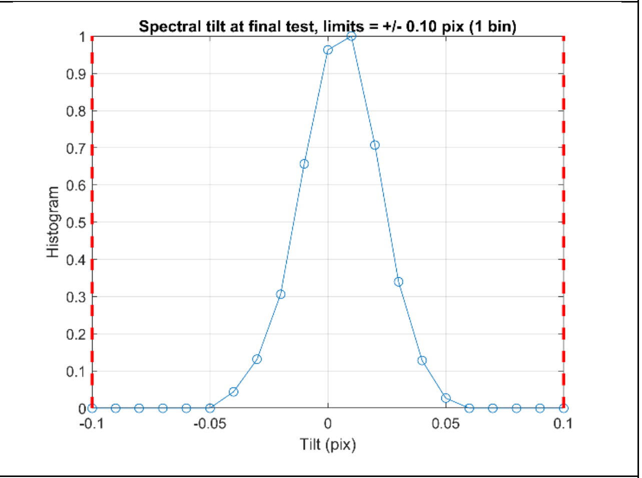
FX10 wavelength accuracy



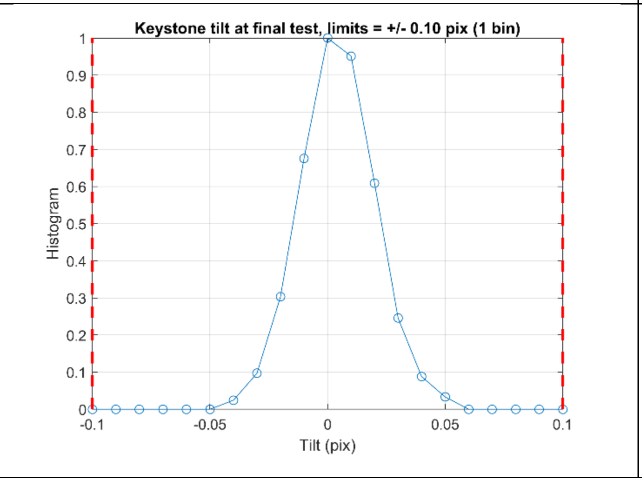
FX17 wavelength accuracy



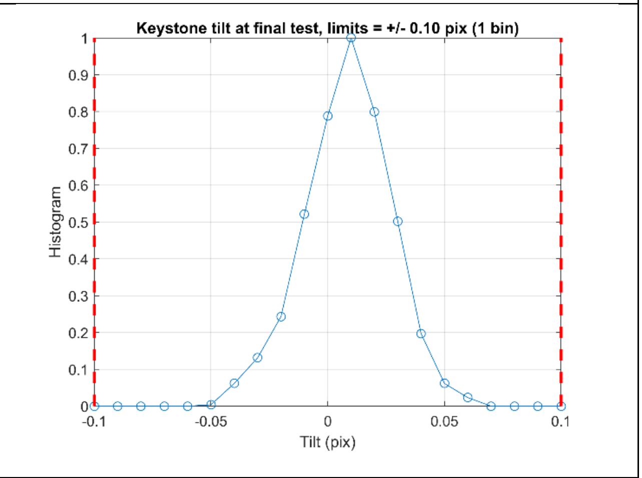
FX10 smile



FX17 smile



FX10 keystone



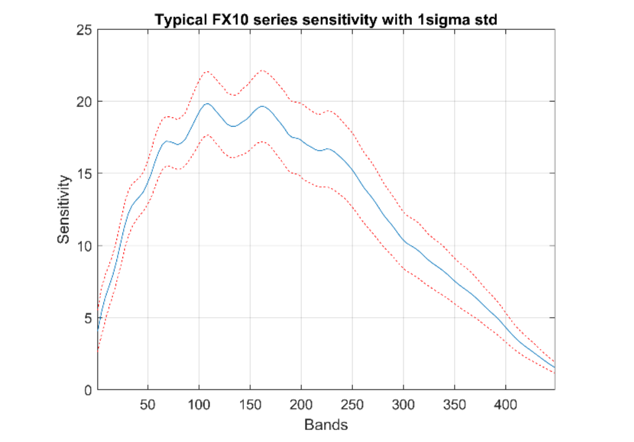
FX17 keystone

Figure1: wavelength accuracy, smile and keystone after AEI routine, for FX cameras.

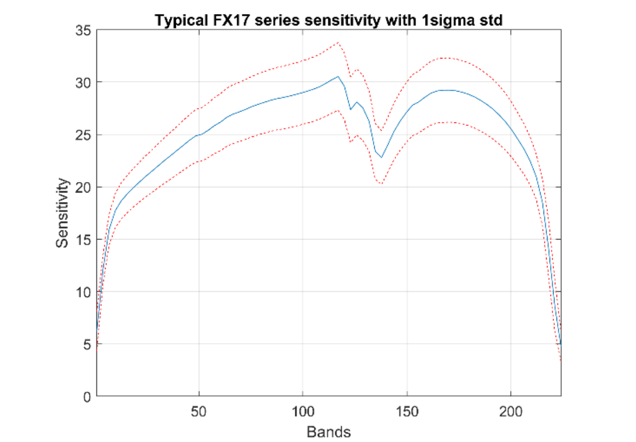
This AIE gives confidence to the user that when a model is built with a certain device, then spectroscopic features will be very similar between devices, and will be located at the same spectral position.

Sensitivity

The sensitivity of devices has not been discussed and did not play any role in the previous section. Here we define the sensitivity as digital signal response to radiance signal input (i.e. DN / [Spectral_radiance x t_int]). It is depending on the Quantum Efficiency (QE) of the detector and the transmission of the optical components. Optically speaking, a camera includes components, one of them being a grating (used as a dispersive element in the camera). The grating efficiency varies due to the manufacturing process, and this contributes the most in sensitivity difference between cameras. AIE routine does not correct this, and the response of the camera deviates between FX units (see Fig.2).



sensitivity of FX10(e)



sensitivity of FX17(e)

Figure 2: sensitivity cures of FX10e and FX17e. FXe camera uses same detectors as FX cameras. Those curves are therefore identical for FX cameras.

If an application, to be transferable, needs to be robust against the spectral response of the camera and its sensitivity, several options are available:

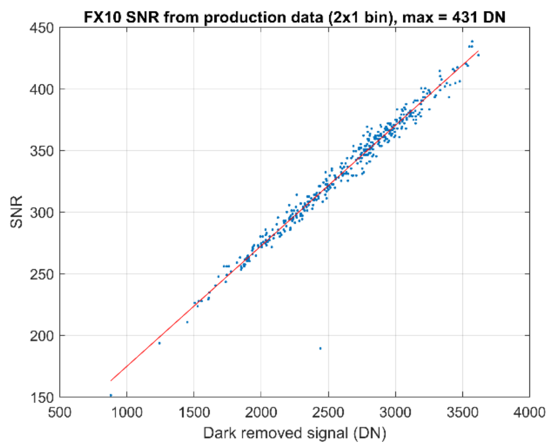
a) radiometric calibration: this calibration allows the user to convert the raw data of the camera, coded in digital numbers (DN), into radiance, which has a unit (mW/sr.cm^2.nm).
b) normalization of the data: raw data are converted into reflectance, by scaling the data in fraction (%) of light reflection in respect to the incoming one. In addition of balancing the measured spectra, when the white reference is taken over the full field of view (FOV) of the camera, spatial non-homogeneity of the illumination can also be corrected.
c) certain preprocessing steps could also augment the transferability of FX cameras by removing any device sensitivity effects. For example, the first derivative of spectra would remove any offset in their intensity.

When an application is performed over a conveyor belt, we always recommend to base the data processing model on reflectance data (point b above), with a white reference tile covering the full FOV of the camera.

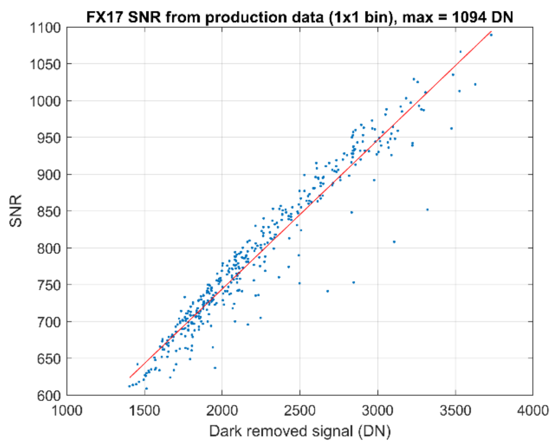
- a model based on raw data will be sensitive to the spectral response of the camera and the illumination
- a model based on radiance data would be sensitive to the illumination
- a model based on reflectance data, with a white reference acquired over the full FOV of the camera would not be sensitive to the illumination neither the spectral response of the camera.

SNR (Signal to Noise Ratio)

The SNR also varies between units of the same type. SNR is a complex (but very interesting) topics, and we encourage to consult our TN about it. As can be seen in Fig.3, the SNR of a camera increases with the signal level. Consequently, the illumination, especially its spectral distribution and intensity, plays an important role. Also, peak SNR value varies from units to unit. Besides, when running an application, the SNR depends on the samples reflectance.



SNR vs signal intensity for FX10 cameras



SNR vs signal intensity for FX17 cameras

Figure 3: SNR vs signal intensity for FX10 and FX17 cameras.

In general, from the SNR point of view, the sensitivity does not matter if exposure time can be set in such that raw signal is maximized.

Line-of-sight

Every FX cameras of the same type are built with same mechanical components. However, due to the tolerance of assembly and the manufacturing of the components, 2 cameras from the same model (for instance two FX10 cameras with same front objective) would not look exactly at the same line. Fig.4 below illustrates it, showing the three possible deviations.

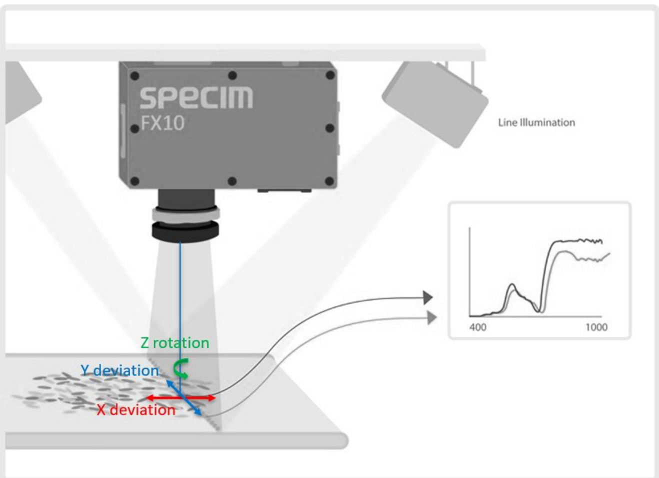


Figure 4: Illustration of a FX10 camera measuring samples over a conveyor belt, with the three possible misalignment axis between FX cameras.

When swapping a camera or when accurate timing between line of sight and some actions are required (e.g. sample ejection), we always recommend to fix the camera on the machine with a three rotation axis mount. This will allow the user to perfectly well adjust the camera position.

Ambient temperature

Specim FX cameras have an operative temperature ranging from +5 to +40 degrees C. However, for some applications which require very accurate, precise and stable data, placing the camera in a temperature stabilized casing is highly recommended. For instance, SPECIM FX50 is often used to sort black plastics, where samples reflectance levels are often ca. 3%. A deviation of the ambient temperature may cause a drift of the camera dark signal, which in turn would hamper the accuracy and stability of the sorting model. We have seen that using the FX50 in a temperature stabilized casing improves significantly the sorting performance of the sorter.

Illumination

This section does not have anything directly related to the camera itself, but should be taken into account when dealing with model transferability. The acquisition of hyperspectral data is directly related to the used illumination and its quality (see TN about illumination). If an illumination is not stable, it is at the expense of system performance and stability. In that case, we strongly recommend to base the model on reflectance data, and the white reference needs to be acquired as often as possible. On the opposite, if the illumination is very stable, the white reference does not need to be acquired very often.

FX cameras are line scan devices. Acquiring the white reference over the full FOV would allow a line by line normalization of the data. This would also correct the spatial non-homogeneity of the illumination.

Also, if possible, the illumination should be chosen so that the spectral regions, on which the sorting model is based, are intense. This would maximize the SNR of the camera on bands which are most significant.

Disclaimer

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Version history

Version	Date	Author	Comments
1.0	Feb 18th 2022	MMA	

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