TECHNICAL NOTE TN2022_7 – FX SMILE AND KEYSTONE

Introduction

This TN defines two key parameters in hyperspectral imaging: smile and keystone. This article is written within the context of FX camera and their embedded real time correction.

FOV = FIELD OF VIEW

AEI = AUTOMATIC IMAGE ENHANCEMENT

Article

Smile and keystones are two types of optical aberrations which strongly impact the accuracy and the usability of pushbroom hyperspectral cameras. The smile is a spectral distortion and is a property of the solely spectrograph, whereas the keystone is a spatial distortion and is strongly affected the front objective.

Fig.1 below illustrates this:

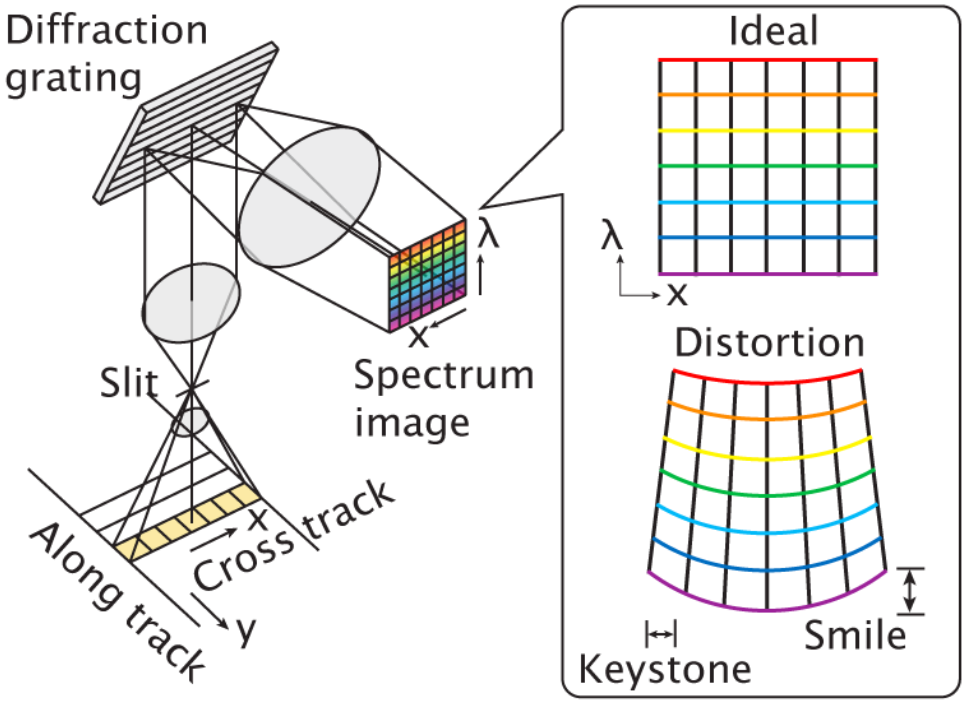

Figure 1: Smile and keystone on a pushbroom hyperspectral sensor.
Source: www.yokoya1985.sakura.ne.jp

- **Smile**

As illustrated in Fig.1, the smile can be seen as a spectral shift of the sensor over its entire field of view (FOV). In practice, this means that if the user images an homogeneous target over its entire FOV, the spectra measured at the middle and on the side of the FOV have an offset. In a sorting application, this may have dramatic consequences: if for instance a sorting model built with data from the middle of the "image" (i.e. middle of the conveyor belt), it will not necessarily work in other location (i.e. at the side of the belt). Fig.2 shows its effect on data acquired with a low performing spectrograph, mounted on a camera detector with very small pixels. We can clearly see a spectral shift between the center and the side of the image of ca. 2 pixels.

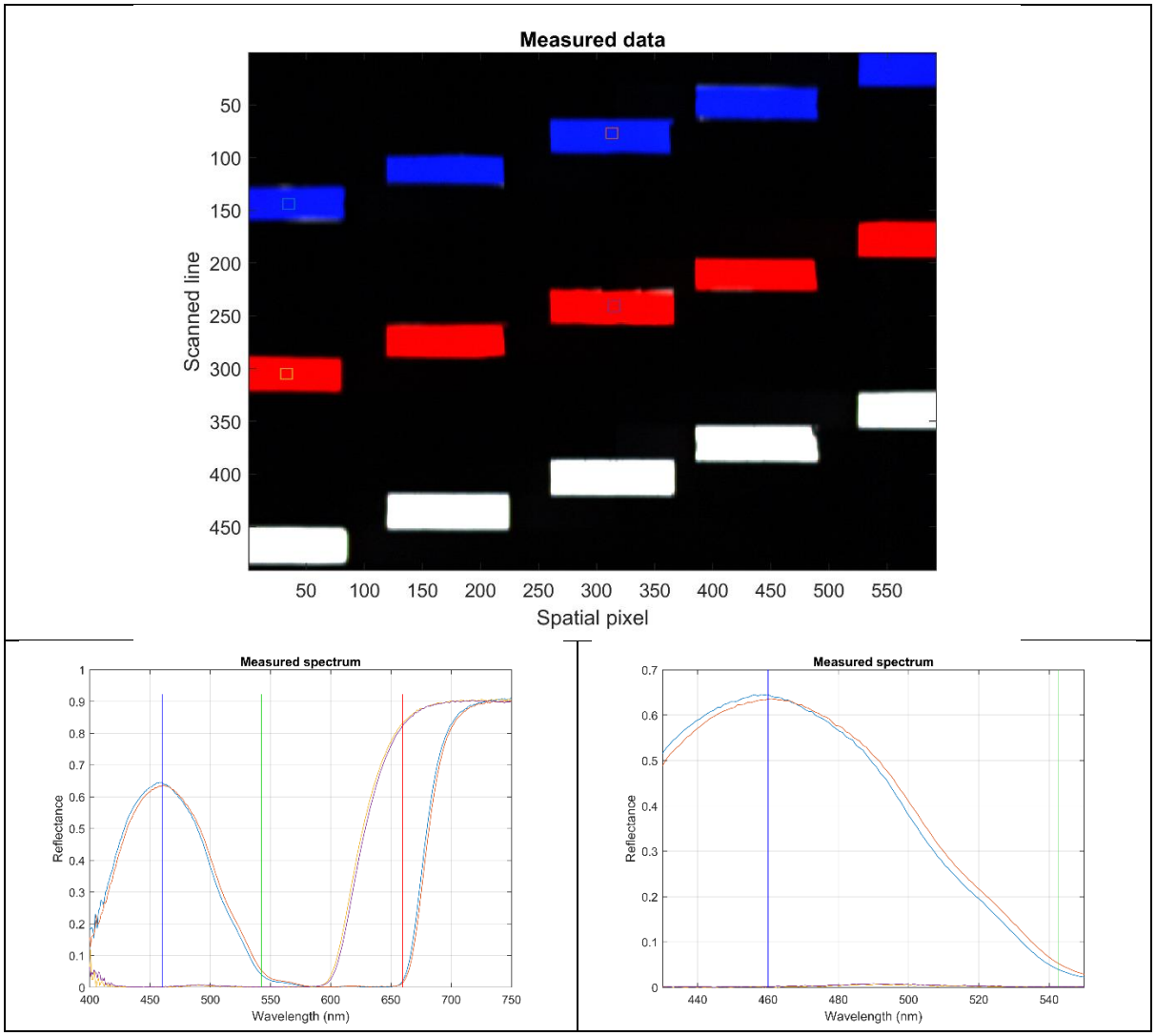

Figure 2: Spectral shift due to smile distortion. The blue, red and white tiles are spectrally similar, respectively per group pf color.

FX cameras have been designed for industrial application, where robustness and model transferability are required. An Automatic Image Enhancement (AIE) algorithm has been designed to correct in real time this smile effect. This AIE correction reduces the smile distortion below ±15% of a pixel (see Fig.3). Those numbers are valid for all FX cameras,

regardless their model (FX10, FX17 and FX50). Besides, it is always recommended to use the FX10 with a spectral binning configuration x2, which would decrease by half the effective smile.

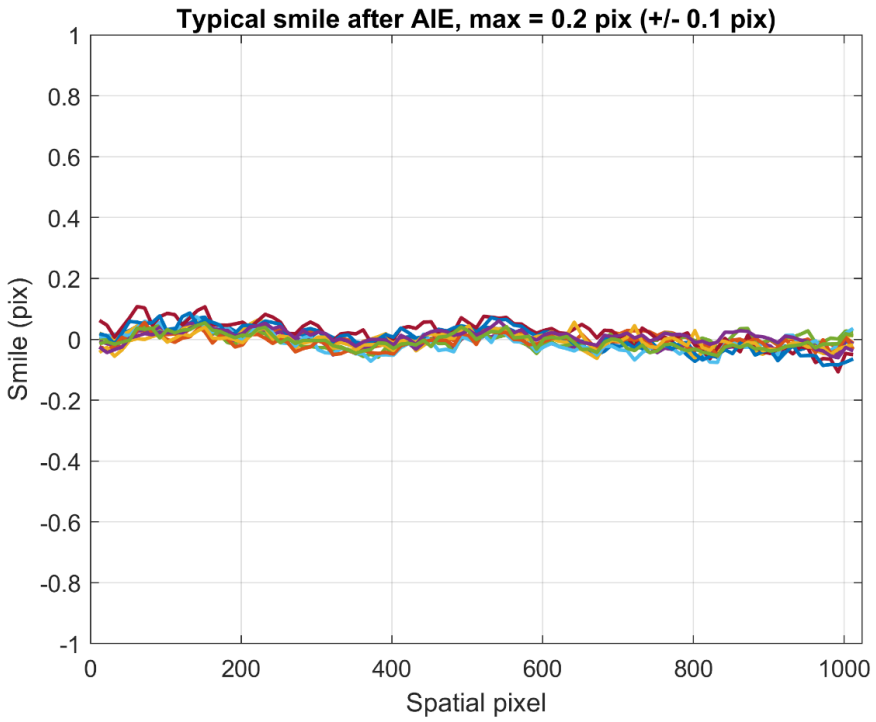

Figure 3: Typical smile after AIE correction, here for a FX10 (which contains 1024 spatial pixels)

- **Keystone**

Analog with the smile, the keystone can be seen as a spatial mis-registration of the spectrum. It has a very significant effect on what is called spectral purity (the ability of a sensor to measure the spectrum of an object or single point only without being influenced by its surrounding). In practice, an optical system with a high keystone will measure spectra influenced by its environment, which means again for a sorting application that a model can not be built in a robust manner: a shell of a nuts, will not have its contour line sorted as the same way as its center, even if it would be homogenous. This may lead to wrong interpretation of contamination. In Fig.4 below, a homogenous white paper was measured with a poor quality spectrograph mounted on a camera detector with small pixels, and on the side of it a red line of ca. 2 pixels can clearly be seen, revealing the presence of keystone.

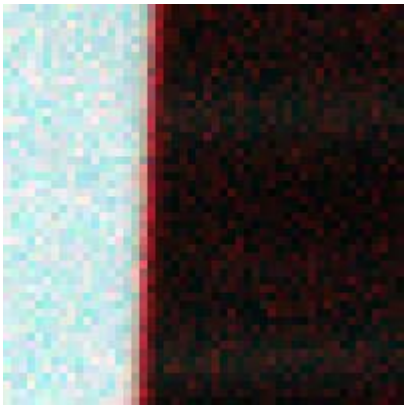

Figure 4: effect of keystone on a sharp paper edge. Red, Green and blue channels were allocated to 900, 550 and 450 nm, respectively.

To limit keystone effects on FX cameras, correction was also implemented within the real time AIE algorithm. It reduces the keystone of all FX cameras below 15% of a pixel (see Fig.5)

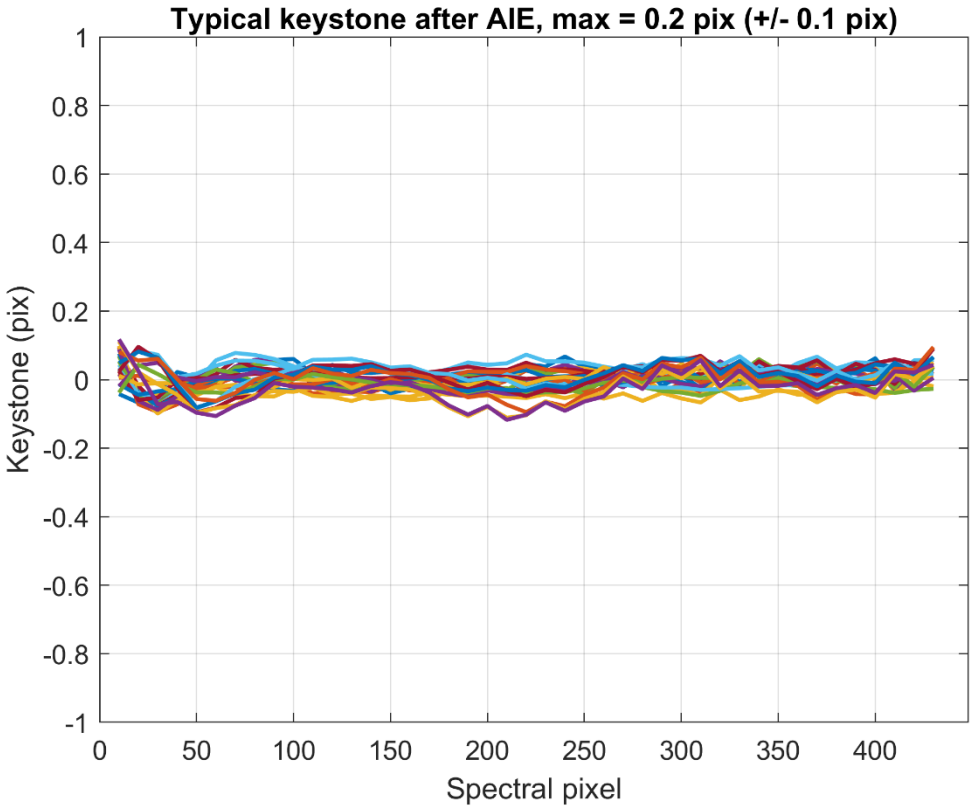

Figure 5: Typical Keystone after AIE correction, here for a FX10 (which contains 448 spectral pixels)

- Conclusions:

Large smile and keystone distortions strongly affect the robustness, transferability and efficiency of sorting models. To limit their effect, their level should be well below the pixel size of the detector on which the hyperspectral system is based. To acknowledge this, SPECIM cameras correct and limit those aberrations in real time, at such level that no effect can be seen.

Disclaimer

Version history

Version	Date	Author	Comments
1.0	Nov 4th 2022	MMA, KKA	