TECHNICAL NOTE_TN2021_10 - ROTARY SCANNER USAGE WITH MWIR OR LWIR HYPERSPECTRAL CAMERA

Introduction

In this TN, information about using SPECIM thermal cameras on rotary scanners is documented.

MWIR = MID WAVE INFRARED (2700 – 5300 NM)

LWIR = LONG WAVE INFRARED (8000 – 12000 NM)

RS50 = ROTARY SCANNER ABLE TO CARRY UP TO 50 KG

VNIR = VISIBLE NEAR INFRARED (400 – 1000 NM)

SWIR = SHORT WAVE INFRARED (1000 – 2500 NM)

FOV = FIELD OF VIEW

SNR = SIGNAL TO NOISE RATIO

CO2 = CARBON DIOXYDE

O3 = OZONE

Article

Hyperspectral cameras covering the thermal spectral range such as FX50 and FX120 can provide very useful information when used with a rotary scanner (RS50) for a large range of applications. Those are usually related to gas detections, as well as geological analysis.

Figure 1: FX50 on a RS50 for outdoor data acquisition

The usage of these thermal cameras however needs to be cautious, and several factors have to be taken into account for a good data collection.

1. Those cameras can not really be radiometrically calibrated in advance as it is for other cameras covering the more conventional VNIR – SWIR spectral range (400 – 2500 nm). Indeed, FX50 and OWL are sensitive to thermal radiations, and a small temperature drift in the optics would have a large influence on the radiometric behavior of the camera. If a calibration would be done in the lab, under well controlled conditions, the computed radiometric matrix will not be optimized on data acquired in another environment. We acknowledge that for both cameras, the optics is temperature stabilized, within a casing. This is suitable to keep the radiometric behavior of the camera constant over few minutes (the time to acquire a single data set). But not much longer than that.
   Besides, the dark noise of these camera is very dependent on the used integration time. If the calibration would be done at a certain integration time, only data acquired with the very same integration time could be corrected.
2. Since these cameras can not be radiometrically calibrated in the lab, it needs to be done while acquiring the data. To do so, before or after the acquisition of each data cube, a black body needs to be placed in front of the camera, covering its full FOV. Reference data are acquired at two different temperatures, with the same integration time chosen to acquire the hyperspectral image. The two temperatures are set so that it covers the range of temperature of the observed scene (or areas of interest). If for example one is capturing a data cube of an outdoor scene, which temperature range is between +10 and +25 degrees C, then the temperatures setting for the dual point calibration of the black body needs to be at the corresponding ca. +10 and +25 degrees C.
3. In order to ease this process, SPECIM has developed a special mount for those cameras, where a dual black body can be mounted. Also, with SPECIM acquisition software, an automatic workflow can be defined so that for each captured image, a dark image (closing the shutter) and a dual point temperature calibration data set are taken.

Figure 2: FX120 on a RS50 with the dual black body mount

4. When the camera is used on the rotary scanner, it is very easy to control the rotation speed. We recommend to scan the scene in a slow speed, about 10 times slower than the usual ratio keeping speed. While preprocessing the data, the user can average the frames to improve the SNR of the data.

Few hints:

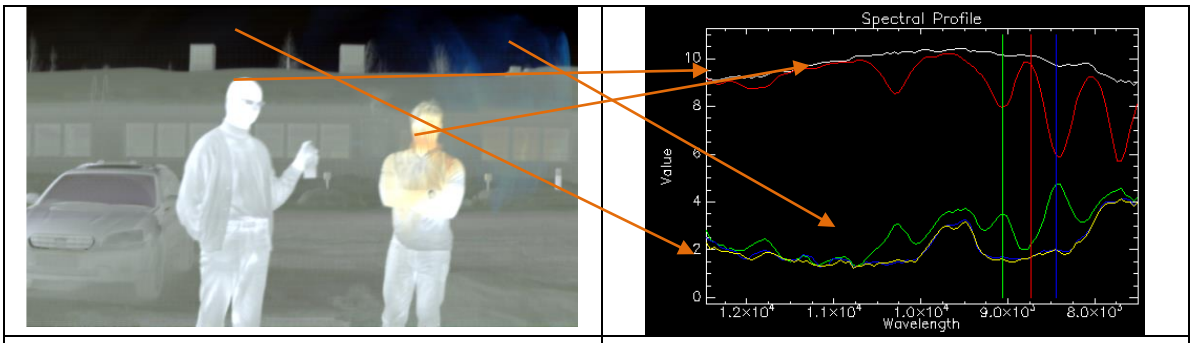
- Focus: adjusting the focus of these camera is tricky to do on the field. The low signal makes it difficult. We recommend the user to adjust the focus in the lab prior to the use in the field. If the user intends to use the camera on a long distance, adjusting the focus at 6 – 7 m would allow object to be sharp at infinity.
- No white reference tile is placed in the scene for reflectance conversion or data check. However, a black body can be placed in the scene for data quality control.

Figure 3: False RGB composite based on a FX50 data cube. The black body is clearly visible on the right hand side of the image (bright square).

- We recommend not to use a too high integration time with the OWL nor the FX50. Especially when used outside, it is hard to notice when the signal is saturating the camera. For outdoor measurements, typical integration times with the FX50 would be ca. 2.7 ms, and with the OWL ca. 1 ms.
- Detecting gas is a common thermal hyperspectral application. Nevertheless, there are few factors to take into account:
    - the quantity of the gas along the line of sight (which means the concentration multiplied by length of the line of sight) needs to be sufficiently high to be detected, and the user needs to ensure first the gas is having spectral features in the used spectral regions.
    - the gas needs to be either warmer or colder than the background, but should not be in any case at the same temperature. The figure below illustrates this (Fig.4):
        - the white spectra refers to a “hot” body, and is a reference. The red curve is the spectrum related to a pixel where a cold gas is in front of a hot object. The

spectral features which are observed in red are mixture of the white spectra through the transmission of the gas

- the blue and yellow spectra refer to a cold sky, and this is again a reference. The green curve is a spectrum related to a pixel where a warmer gas is in front of a cold background. Therefore it shows the emission spectrum of the gas.
- the green and red curves are having mirrored spectral features at exactly the same wavelengths as a body which absorbs at a certain wavelength will emit at the same one.



Emissivity image based on OWL data	Emission spectra

Figure 4: emissivity image and spectra based on SPECIM OWL data.

- When one is using the FX50 and FX120 outside, it is always good to keep in mind which type of illumination is provided by the sun through the Earth atmosphere (Fig.5).

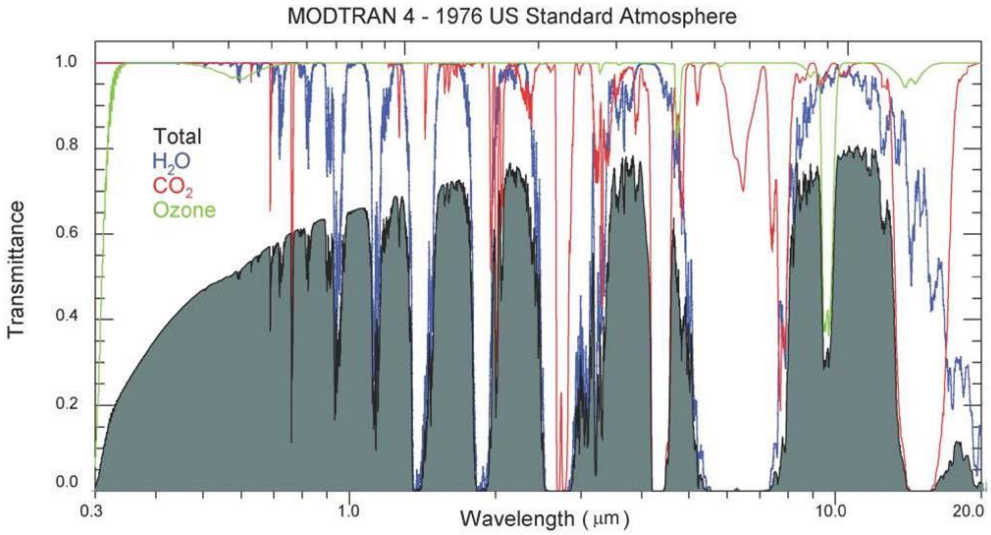


Figure 5: sun emission and atmospheric absorption.

Here we can clearly see that the middle of the FX50 range there is a strong CO2 absorption peak. Concerning the LWIR spectral range, O3 also has a clear influence.

- It is also good to keep in mind that both cameras do not see the same phenomena:
  - for the FX50 camera:

        - at the lower end of the spectral range, when using the camera outside to measure scene at ambient temperature, the sun induced reflected signal is dominating the emission spectrum
        - at the higher end of the spectrum, this is the opposite, the emission dominates the reflectance.
    - for the OWL camera, at ambient temperature, the emission signal is always significantly dominating the sun induced reflectance

These 2 points highlight that FX120 can be used day and night without any effect, whereas this is not true for the FX50.

Disclaimer

Version history

Version	Date	Author	Comments
1.0	Feb 18th 2022	MMA	
1.2	April 26th 2023	MMA	
1.3	Feb 13th 2024	MMA	Updated with FX120