CALIBRATION ALGORITHMS FOR AN IMAGING SPECTROMETER

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ABSTRACT

Airborne and spaceborne imaging spectrometers are widely used in order to monitor the complex structure of the planet Earth. The precise observation of physical, chemical, and morphological parameters of the sensed target require an accurate calibration and characterization process; this is mainly true if users want to detect the variability over time and space of material characteristics. Imaging spectrometers sense the spectral of materials by using either charge-coupled-device (CCD) or complementary-metal-oxide-semiconductor (CMOS), each constituted of a large amount of detector elements or pixel (usually in the range of a million). Manual laboratory calibration and characterization of such an amount of pixels would require an enormous effort in terms of time for both measuring and interpreting the results. On the other side, it is also true that not all the detector elements must be calibrated and characterized because the physical behavior of some parameters (e.g. linear or quadratic trend) might be used in order to retrieve the missing coefficient through interpolation. Nevertheless, detector non-uniformities, as for instance smile and keystone as well as point-spread-function (PSF) width variations, require the detector to be characterized at a certain number of pixels such that those "anomalies" can be correctly represented. As a rule of thumb, given a detector with *s* spatial pixels and *b* spectral pixels, a good compromise would be to calibrate and characterize at least $1/10^{th}$ of the overall number of detector pixels. If a calibration laboratory allows automatic control of the instrumentation (e.g. linear stage, rotary stage, electrical folding mirror, monochromator) then such goal can be achieved. Moved by this idea, we implemented a hardware/software utility that interface the airborne prism experiment imaging spectrometer (APEX) with the light stimuli provided by the calibration home base (CHB), a laboratory belonging to the German space agency (DLR) and located next to Munich. This utility can drive, upon initial setting of both instrument and instrumentation parameters, the full characterization process almost completely automatically. A full automatic run is allowed for spectral calibration, across-track and along-track geometric calibration, and relative radiometric calibration.
Nevertheless, manual intervention is still needed for particular kind of measurements that require the installation of mechanical holders (e.g. polarization filters, spectral filters, reflectance targets); this happens, for instance, during the measurement of straylight inside and outside field-of-view (FOV) or characterization of the degree of polarization.
This implemented and tested utility allows an intrinsic increase of calibration accuracy, thanks to the elevate numbers of calibrated and characterized pixels. Furthermore, the main detector non-uniformities can be well characterized and the whole behavior of the CCD or of the CMOS can be completely understood. Beside the fact that all process can be completed in a relative short time (more or less about one week), this approach gives users the advantage of interpreting more accurately the material parameters at every spatial position (e.g. being, for instance, not misguided by the wrong center wavelength). A drawback of such a technique is that a small test campaign shall be carried out before running the global automatic procedure; this is necessary because every kind of sensor responds differently to the provided stimuli because. Thus, small experiments shall be executed for every light source, principally in order to avoid that the detector under analysis goes into saturation during the measurements leading then to wrong results.
As a natural consequence of such a tool, it is clear that users are provided with a higher number of calibration coefficients that are stored in a three-dimensional matrix, called *calibration cube*. The goal of this cube is to give users detailed information about every pixel under analysis; this might be vital in order to lead user applications to the proper outcomes.

This paper presents a software/hardware calibration/characterization utility in all its aspects illustrating both benefits and drawbacks. A case study along with all its relevant results is also introduced, based on the APEX imaging spectrometer. Recommendations and suggestions are also given for customized implementations of this tool.