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MUSIC: A NEW HYBRID ATMOSPHERIC CORRECTION TECHNIQUE FOR SOLAR REFLECTIVE HYPERSPECTRAL IMAGERY

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1. INTRODUCTION

Multispectral and hyperspectral imagery usually require atmospheric correction to remove the influence of the environment on the measurements. The images may then be converted in reflectance units. There are generally two different classes of algorithms that attempt to transform at-sensor radiance or raw images into reflectance. One class consists of first principles methods that rely on physical knowledge of how the environment interacts with the surface to produce radiance. These are sometimes referred to as model-based methods or radiative transfer methods. The other class consists of empirical methods which are usually variants of the empirical line methods (ELM) or other in-scene methods. Both classes of algorithms have benefits and drawbacks. The radiative transfer methods such as FLAASH, 6S and ATCOR4 [1,2,3] can achieve high accuracy but require sophisticated computer codes that are computationally time consuming, require accurate characterization of the atmosphere, and generally do not perform well in less than ideal environmental conditions (overcast, dust) or when the sensors characteristics are not accurately known. The Empirical Line Method based algorithms are computationally fast, can be very accurate, and do not rely on well calibrated sensor but since they require a-priori knowledge of in-scene elements, they are not suitable for all applications. The QUAC algorithm [4], that we may call an empirical-statistical approach, eliminates the main drawbacks of the ELM algorithm by not requiring a-priori knowledge of in-scene elements. Instead, it relies on an empirical observation that the mean of many scene endmembers (assuming that the scene is diverse enough) is constant and known a priori. In a more recent paper the QUAC authors [5] reported that they had to make some adjustment to the algorithm (excluding some additional types of background) because their assumption about the mean of scene end-members being constant was not always holding. Even with adjustments, algorithms like QUAC that rely very heavily on statistical hypotheses may fail on the inevitable statistical exceptions.

In this paper we present a new method that we have developed for correcting hyperspectral images in the reflective bands that we call MUSIC (for Matching of Underlying Spectra for In-scene Correction). It is a hybrid method, meaning that it uses elements of first principles methods and of the ELM methods in order to achieve the transformation of a radiance image into a reflectance image. The next section describes the method and provides some insight into the validation that we conducted.

A patent application for MUSIC has been filed in the United States and in the Canadian patent offices [6]

2. MUSIC ALGORITHM

Figure 1 illustrates the different steps of the MUSIC algorithm. MUSIC is a two pass approach. The first pass steps are aimed at obtaining an approximate reflectance that allows matching in-scene spectra to elements of a spectral library. We first compute a top-of-atmosphere (TOA) reflectance image and then we remove some bad or unwanted pixels before performing an endmember extraction. Endmember extraction algorithms are more effective when applied to a normalized image such as a TOA reflectance image where solar illumination is removed. Then we correct the obtained in-scene endmembers using simplified radiative transfer technique. This technique uses an analytic single layer two-stream method for downwelling diffuse flux approximation. An aerosol retrieval as well as a water vapor retrieval based on a three band ratio are also performed. The method performs a simplified molecular transmittance correction based on standard atmosphere absorption data and water extinction tables. Although the resulting correction is less accurate than full first principles methods, it allows a far greater computation speed. It must be noted that only the endmembers (i.e. a handful of pixels) are corrected leading to an even greater computation speed.

The approximate reflectances obtained in first pass are then used for the second pass steps of MUSIC. These first pass reflectances only needs to be accurate enough to allow matching of the endmembers to elements of a spectral library containing a wide variety of spectra. The matching is performed with a metric that emphasize the correspondence of the spectra in shape and amplitude. The matching score is then used to perform a weighted linear regression to obtain correction gain and offset. Optionally, the black level can be derived from the image or the radiative transfer model to anchor the linear regression for zero signal level. The resulting spectral gain and offset is then applied to the entire image to obtain the output reflectance.

Some aspects of the MUSIC algorithm also allow performing an effective pixel by pixel water vapor correction in the second pass with a novel approach. Pixel-based water vapor correction is usually associated with the more accurate radiative transfer methods rather than the empirical methods. As well, we have tested a new approach to extract reflectance in shadowed region of a scene. These techniques will be discussed for the conference.

The MUSIC algorithm was validated with a large number of airborne and space-borne hyperspectral images from different sensors (e.g. AVIRIS, AISA, HySpex, SASI, Hyperion (EO-1)). We compared the reflectance computed by MUSIC and QUAC algorithms with the reflectance obtained by FLAASH. The metric (Spectral Distance) / (number of bands)$^{1/2}$ (basically the definition of the standard deviation between results of two algorithms) was used for comparison. Our validation shows that most images corrected by MUSIC are on average within 5% of FLAASH while QUAC is within 10%. In other words, MUSIC is twice as accurate as QUAC when FLAASH corrections are used as a baseline. The computation speed of MUSIC and QUAC are similar. When available, MUSIC was also compared to ground truth data. Figure 2 compares reflectance spectra from an Aviris image processed by MUSIC, FLAASH and QUAC.

3. CONCLUSION

A new hybrid atmospheric compensation algorithm has been devised that attempts to utilize benefits of both first principles and empirical methods. Compared to first principles approaches, the new MUSIC algorithm is computationally fast, requires only an approximate characterization of the atmosphere while achieving results with similar accuracy. On the other hand, while being almost as fast as empirical methods, it does not require prior knowledge of image elements.

4. REFERENCES

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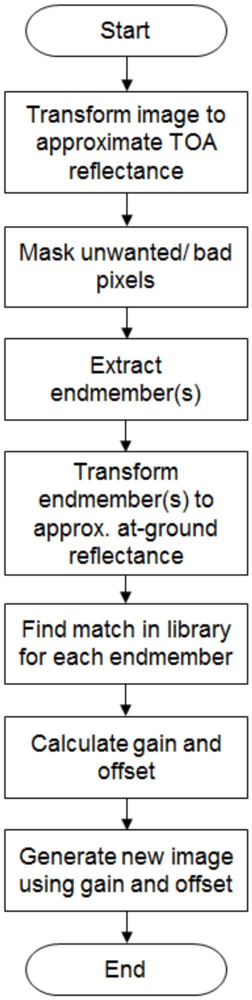

Figure 1: MUSIC algorithm processing steps

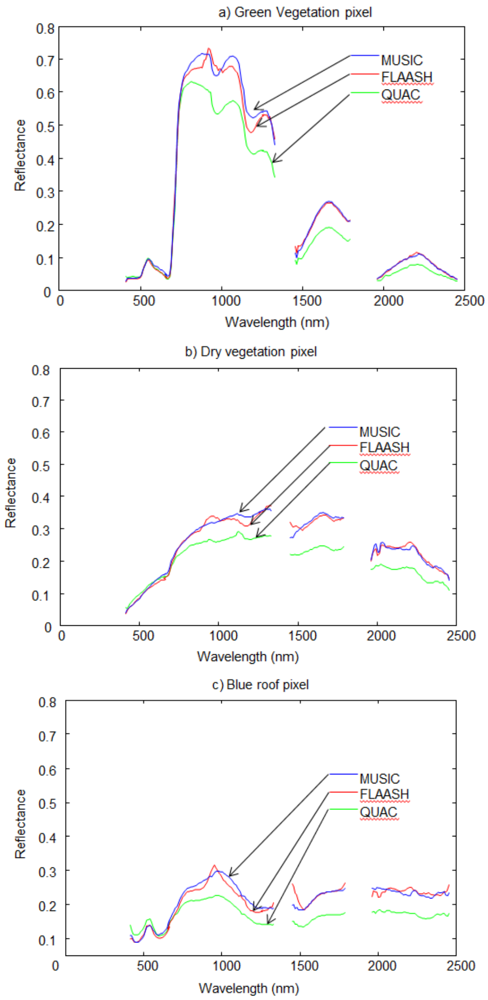

Figure 2: Comparison of reflectance spectra extracted by MUSIC, QUAC and FLAASH from an Aviris image