Chapter 14

A Practical UAV Remote Sensing Methodology to Generate Multispectral Orthophotos for Vineyards:

Estimation of Spectral Reflectance Using Compact Digital Cameras

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ABSTRACT

This paper explores the use of compact digital cameras to remotely estimate spectral reflectance based on unmanned aerial vehicle imagery. Two digital cameras, one unaltered and one altered, were used to collect four bands of spectral information (blue, green, red, and near-infrared [NIR]). The altered camera had its internal hot mirror removed to allow the sensor to be additionally sensitive to NIR. Through on-ground experimentation with spectral targets and a spectroradiometer, the sensitivity and abilities of the cameras were observed. This information along with on-site collected spectral data were used to aid in converting aerial imagery digital numbers to estimates of scaled surface reflectance using the empirical line method. The resulting images were used to create spectrally-consistent orthophotomosaics of a vineyard study site. Individual bands were subsequently validated with in situ spectroradiometer data. Results show that red and NIR bands exhibited the best fit (R^2: 0.78 for red; 0.57 for NIR).

1. INTRODUCTION

1.1. Use of Compact Digital Cameras in Remote Sensing

The low cost and high availability of compact (point-and-shoot) digital cameras has led to usages beyond that of recreational or professional capture of natural color photography (Dean, Warner, & McGraw, 2000). Digital camera ease of operation, speed of image capture, efficient processing, and lightweight

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design lend utility to aerial image capture (King, 1995). Coupled with an unmanned aerial vehicle (UAV) to create an unmanned aerial system (UAS), digital cameras can inexpensively provide very high spatial and temporal resolution data for research in soils (Levin, Ben-Dor, & Singer, 2005), tree inventory and biomass (Dean et al., 2000), land management (Rango, Laliberte, Herrick, Winters, Havstad, Steele, & Browning, 2009), and agriculture (Hunt, Hively, Daughtry, & McCarty, 2008; Lebourgeois, Beguye, Labbe, Mallavan, Prevot, & Roux, 2008; Lelong, Burger, Jubelin, Roux, Labbe, & Baret, 2008; Ritchie, Sullivan, Perry, Hook, & Bednarz, 2008) including viticulture (Smit, Sithole, & Strever, 2010; Turner, Lucieer, & Watson, 2011). See Everaerts (2008) and Watts, Ambrosia, and Hinkley (2012) for informative reviews on UAV and UAS technology. Camera system design for UAV-based remote sensing varies by the nature of the images to be captured; as evidenced by studies that alter digital cameras for their specific needs, while others employ cameras with off-the-shelf configurations. With or without modification, digital cameras remotely record spectral information of a target of interest (Dean et al., 2000; Levin et al., 2005; Ritchie et al., 2008). Levin et al. (2005) utilized an unaltered digital camera (UDC) to record the spectral properties of soils with three spectral bands of blue, green, and red. Most digital cameras, however, have the ability to sense wavelengths beyond the visible spectrum with minor alteration (Cheng & Rahimzadeh, 2005).

A typical digital camera has the following vital components: a sensor (either a charge-coupled device [CCD] or a complementary metal oxide semiconductor [CMOS]) made up of an array of sensor elements or sensels (each of which later become picture elements or pixels in the captured image), a Bayer filter (or other color filter), a lens, and a hot mirror. This study focuses on the CCD sensor, which senses light and converts this spectral information into digital numbers (DNs), typically with 8-bit radiometric resolution (0-255). The Bayer filter is responsible for splitting the incoming visible wavelengths into separate bands so brightness for each can be recorded (i.e., blue, green, and red; stored in reverse order and referred to as RGB). The lens de-magnifies the scene to properly represent physical objects and their geometric relationships within a captured image. The hot mirror is an internal spectral filter that limits detector sensitivity to visible wavelengths (i.e., the sensor will not record energy in the near-infrared [NIR] region). In most cases the hot mirror wavelength cut-off is somewhere around 670-690 nm (Dean et al., 2000; Ritchie et al., 2008), whereas most CCDs have a spectral range up to 900 nm (Dare, 2008; Lelong et al., 2008). Therefore, the hot mirror forces the CCD to sense only the desired portions of the spectrum to more easily replicate the visible light range for natural color photography. For studies that require NIR sensitivity, the hot mirror can be removed and replaced with clear glass to allow the CCD to sense NIR wavelengths (Cheng & Rahimzadeh, 2005). In the case of vegetation studies for instance, NIR sensitivity is important to be able to monitor differentials in crop health, thus the hot mirror must be replaced (Dare, 2008; Ritchie et al., 2008). System designs must be creative to integrate the NIR band usually by use of two cameras. Ritchie et al. (2008), for example, employed an UDC combined with an altered digital camera (ADC) to gather four spectral bands for analysis (UDC—blue, green, red; ADC—NIR).

Image format is another important image acquisition consideration when using digital cameras as remote sensors. Image format is important because compression of images alters the way DNs are computed and stored (Dean et al., 2000). RAW and TIFF image formats are presumed to be better because they do not alter the image (Cheng & Rahimzadeh, 2005; Lebourgeois et al., 2008). RAW and TIFF images are made up of unprocessed, uncompressed pixel data as captured by the CCD. The downsides to such measurements are increased file size and capture time (Lelong et al., 2008). An alternative to RAW and TIFF formats is JPEG, which has proven adequate for scientific analyses (Hunt, Cavigelli,

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