Retrieval of Spectral Reflectance of High Resolution Multispectral Imagery Acquired with an Autonomous Unmanned Aerial Vehicle: AggieAir™

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Abstract
This research presents a new semi-automatic model for converting raw AggieAir™ footprints in visible and near-infrared (NIR) bands into reflectance images. AggieAir, a new unmanned aerial vehicle (UAV) platform, is flown autonomously using pre-programmed flight plans at low altitudes to limit atmospheric effects. The UAV acquires high-resolution, multispectral images and has a flight duration of about 30 minutes. The sensors on board are twin cameras with duplicate settings and automatic mode disabled. A white Barium Sulfate (BaSO4) panel is used for reflectance calibration and in situ irradiance measurements. The spatial resolution of the imagery is 25 cm; the radiometric resolution is 8-bit. The raw images are mosaicked and orthorectified and the model converts their digital numbers (DN) to reflectance values. Imagery, acquired around local solar noon over wetlands on the Great Salt Lake, Utah, is used to illustrate the results. The model generates high quality images and the results are good. The reflectance values of vegetation in the NIR, Green and Red bands extracted at the test locations are consistent. The image processing, reflectance calculations, accuracy issues, with the proposed method are discussed.

Introduction
In the recent past, various unmanned aerial vehicle (UAV) platforms equipped with a myriad of devices have been used to gather data in different bands for an array of applications. It is an area of remote sensing that has become very active, and UAVs are rapidly becoming the preferred platform for development of remote sensing applications (Watts *et al.,* 2012). Earth orbiting satellites and manned aircraft remote sensors have the advantage of covering large areas, but the high operating cost of such instruments limits the availability of timely information for specific areas of interest (Hakala *et al.*, 2010). Remote sensing applications require more sustainable, affordable, user-friendly systems which are compliant with various levels of changes in technology. Zhang and Kovacs (2012) state that low altitude remote sensing platforms, or UAVs address most of these issues, and can be a potential alternative to satellite imagery given their low cost of operation, high spatial and temporal resolution, and flexibility in image acquisition programming. UAV imagery provides the ability to quantify spatial patterns, and is used in rangeland monitoring and mapping to quantify patches of vegetation and soil not detectable with piloted aircraft or satellite imagery (Laliberte and Rango, 2009). UAV data have been extensively used in forest fire applications (Merino *et al.*, 2006, Ambrosia *et al.*, 2003), wetland management and riparian applications (Zaman *et al.,* 2011, Jensen *et al.*, 2011), precision agriculture (Primicerio *et al.*, 2012), agricultural decision support (Herwitz *et al.*, 2004). Field reflectance data from UAV platforms are also increasingly being used for image classification and predictive models (Berni *et al.*, 2009). But the accuracy issues related with conversion of the information acquired by the sensors on board these UAVs into useful data remains a widely discussed topic. The small UAV systems have low payload capabilities and are commonly equipped with lightweight, low-cost digital cameras, which may complicate the image processing procedures. Additionally, the chemical basis for making a filter used on these cameras is proprietary and there is variation in filter spectral transmittances among various digital cameras (Hunt *et al.*, 2010), which calls for a specific radiometric and geometric calibration (Hruska *et al.,* 2012) to produce reliable data. Several UAV imaging systems require custom designed applications for photogrammetric processing and creation of orthomosaics to handle the large number of small-footprint images acquired by the UAVs with a rather unstable platform (Du *et al.,* 2008; Laliberte and Rango, 2008; Wilkinson *et al.*, 2009). This paper discusses processing of data obtained from a new UAV system, AggieAir™, which uses off-the-shelf Canon PowerShot SX100 cameras as sensors.

UAV imagery has spectral information in the form of digital numbers which have noise arising from changing view, illumination geometry, and instrument errors. Huang *et al.*, 2002 demonstrate the necessity of converting DN to at-satellite reflectance when atmospheric correction is not feasible. DN is a function not only of land-cover, but also of the sensor calibration, solar zenith angle, sensor viewing angle, seasonally variable Earth/Sun distance, and diurnally variable atmospheric conditions (Slater, 1980). Exposure settings on the digital camera are chosen based on overall light intensity, which varies over time with changes in solar elevation, atmospheric transmittance, and clouds (Gates, 2003). Consequently, it is desirable to convert DN to reflectance values that correct for these changes (Hunt *et al.*, 2005). Surface reflectance value has become the vital measurement required for most remote sensing models (Moran *et al.*, 2001). Laliberte *et al.* (2011) state that a UAS-based image acquisition system produces hundreds of very high resolution small footprint images that require geometric and radiometric corrections and subsequent mosaicking for use in a Geographic Information System (GIS) and extraction of meaningful data. Similarly Jensen *et al.* (2010) discuss the necessity of calibration of UAV imagery and navigation sensors.

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