Collection of Ultra High Spatial and Spectral Resolution Image Data over California Vineyards with a Small UAV

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Abstract – A small UAV was used to collect digital RGB (red-green-blue) and hyperspectral imagery above San Bernabe Vineyards (King City, Calif.) in August 2003. Data from the downsized payload were transmitted across a wireless local area network to a ground receiving station in near-real-time. High spatial resolution (~20 cm) RGB imagery was registered to the grower’s GIS database, and used to map vigor differences within fields. High spectral resolution data were collected in 580 channels, and used for more detailed examination of canopy reflectance differences as related to crop vigor. An *in-situ* wireless sensor web was used to collect a time-series of air temperature data at several locations, simultaneous with the flight.

Keywords: UAV, remote sensing, high resolution, sensor web, local area network, vineyard.

1. INTRODUCTION

Remote sensing is increasingly being used to support “precision” farm management (e.g., Pinter et al., 2003). In vineyards, remote sensing has been linked to fruit and wine quality, and can otherwise be used to support efficient canopy management (Johnson et al., 2001, 2003). In addition, agriculture is regarded as a Critical Infrastructure Sector under the U.S. National Strategy for Homeland Security, thus potentially increasing the demand for both remote and *in-situ* monitoring. The effort described here demonstrates the feasibility of using a small UAV to support localized agricultural monitoring needs. The study was complementary to an earlier effort by many of the same investigators, performed in 2002, which involved the use of a much larger NASA UAV for monitoring another high-value crop (coffee) in Hawaii (Herwitz et al., 2003a,b).

2. METHODS

A small UAV (RCATS/APV-3) was used to collect imagery over a large commercial vineyard in California (Figure 1). The aircraft, which is under development by RnR Products (Milpitas, Calif.), MLB (Palo Alto, Calif.), and Lockheed-Martin is capable of remaining aloft for up to 8 hours, with an altitude ceiling of 3000 m. The UAV can support payload of approximately 5 kg and drawing 40 watts of power. The imaging payload for this flight was built around two charge coupled device (CCD) camera components acquired from Basler Vision Technologies (Germany) to provide complementary spatial and spectral information. A Model A101fc 1280x1024 Bayer array RGB camera was used for high spatial resolution, geometrically coherent 2-d imaging. A Model A302fm monochromatic camera was fitted to a miniature imaging spectrograph and operated in push-broom (linear array) fashion to collect high spectral resolution (580 band) data of reduced spatial resolution and geometric quality. Both imaging systems were interfaced to a common data system through a multi-channel IEEE 1394 controller. Image meta-data from an on-board GPS engine and 3-axis integrating attitude sensor were encoded into the image file headers. Two wireless links were used to provide reliable control of the payload at low bandwidth (19.2 Kbaud at 900 MHz carrier frequency) and rapid download of image data at high bandwidth (11 Mbaud via IEEE 802.11b WLAN at 2.4 GHz carrier frequency). The payload included an air traffic control radar beacon system (ATCRBS) mode C transponder and altitude encoder. The transponder code and altitude were radiated in order to reduce the risk of interference with other aircraft operating in the vicinity. The entire package, including imagers, on-board flight computer and telemetry systems, was integrated into the UAV payload bay (Figures 2, 3).

A wireless network of ground-based air temperature sensors was deployed. The sensors were positioned at several locations throughout the vineyard, and collected air temperature data approximately every 10 sec during the flight period. Data were collected both from the top of canopy and from below canopy in the fruit zone.

A number of waypoints (x/y geolocations) were input to an autopilot system to enable aircraft navigation above the temperature sensor network as well as over vineyards with variable soils, pest problems, and differences in fruit maturity.

Figure 1. RCATS/APV-3 on vineyard imaging mission.

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Figure 2. Final payload preparations.

Figure 3. Integration of payload onto UAV.

3. RESULTS

Flights were performed on 19-20 August, 2003, and were conducted at altitudes of 450 m and 600 m. A field spectroradiometer and Spectralon™ calibration panel were used during the overflight to characterize the mean reflectance of several relatively large "flat field" targets, such as the runway, parking lot, and bare soil.

3.1 RGB Camera

A total of 165 RGB images were collected, at a spatial resolution of approximately 20 cm. Several RGB images were registered to the grower's GIS and to the ground-based sensor web (Figure 4). Post-processing was performed to segment the RGB scenes into vegetation and soil components, and subsequently calculate the percent vegetation cover (Figure 5).

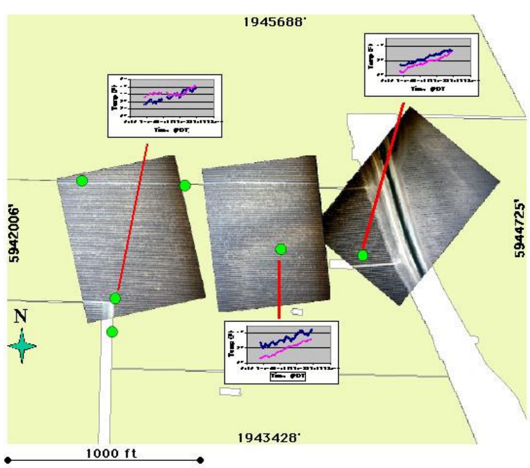

Figure 4. Vineyard canopy images aligned with ground-based temperature time-series, and superimposed on grower's GIS. Data from top-of-canopy (blue traces) and in fruit zone (purple traces). Map projection is California State Plane, zone 4, 1983.

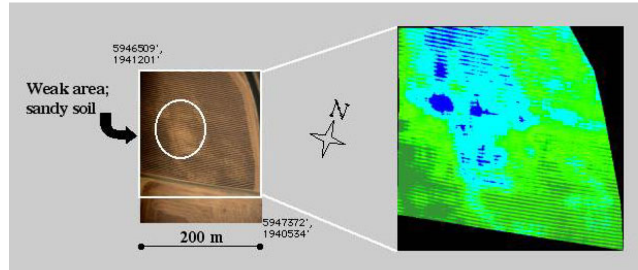

Figure 5. Left) RGB image of 4 ha vineyard. Right) Corresponding vigor map. Dark blue = 35-40% cover; light blue = 40-45%; light green = 45-50%, dark green > 50%.

3.2 Imaging Spectrometer

A laboratory radiance calibration was performed on the imaging spectrometer prior to flight. The resulting calibration equations were used to convert raw digital counts to radiance units. Figure 6 shows a portion of an image collected during flight, and the corresponding spectrum.

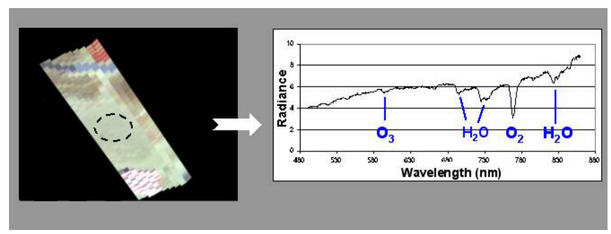

Figure 6. Imaging spectrometer data. Left) 3-band false-color composite, with bare soil area circled. Right) Corresponding at-sensor radiance spectrum (μW/cm^2/sr/nm), 580 spectral channels. Atmospheric absorption features as noted.

An empirical line correction was applied to the spectrometer data, using ground-based flat field measurements, to derive surface reflectance (e.g., Figure 7). Both sites are fairly bright in the visible region, as this vineyard was recently grafted. As a result, the vines are young and there is considerable exposure of bare soil, which is relatively bright in the visible region. As expected, the stronger (more closed) canopy absorbs more visible light and reflects more NIR light.

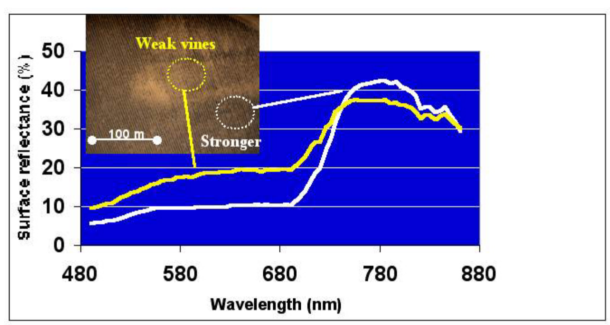

Figure 7. Canopy reflectance derived from the spectrometer, showing weak and moderate vineyard canopy. Aerial image from RGB camera superimposed for reference.

4. CONCLUSION

The RCATS UAV was successfully used to collect imagery and associated spectral information over agricultural targets, in conjunction with environmental monitoring performed by a ground-based wireless sensor web. Further UAV development, combined with continued refinement and miniaturization of imaging payloads, potentially offers an affordable alternative to more conventional remote sensing platforms for user communities requiring near-real-time delivery of (ultra) high-spatial and high-spectral resolution image data.

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