Characterization of Canopy Anisotropies Over a Forested Area using a Multispectral Imager Integrated into an Unmanned Aerial System: the Droniometer Experiment

Sergio Bernardes[1] and Marguerite Madden[2]

[1]Center for Geospatial Research - University of Georgia
[2]University of Georgia

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Abstract

Challenges in remote sensing, including remote sensing of vegetation, include the spectral characterization of objects over space and time. One key aspect for this characterization involves the geometry of data acquisition and positional relationships between light source, the target and the remote sensor. Several configurations of goniometers have been used to acquire spectral data as a function of this geometry and this strategy has been particularly efficient when applied to the study of short canopies (e.g., grasses). Tall canopies present logistical challenges when conducting these analyses, which can be resolved by replacing physical structures (rails) with flying systems capable to conform to different canopy geometries and data acquisition requirements. This work (the Droniometer Experiment) investigates anisotropies of a forest using radiometrically calibrated images from a multispectral camera (MicaSense RedEdge) mounted on a rotary-wing unmanned aerial system programmed to follow a planned flight that simulates data acquisition by a goniometer assembled over tall canopy. The experiment used multiple planned flights, conducted to represent changes in illumination, considering sun azimuth and elevation (multiple flights per day and over the course of months). Multi-angle data acquisition was addressed by controlling aircraft position and camera pitch at regular intervals. This work presents the integration of the droniometer system, including platform and camera requirements and control, data acquisition and processing, and analyses of results for target/vegetation characterization and to support information extraction and multi-angle remote sensing. A radiative transfer model, the Soil Canopy Observation, Photochemistry and Energy fluxes (SCOPE) was used for comparative analysis and to further describe anisotropies in spectral responses of tall canopies.

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Sergio Bernardes & Marguerite Madden

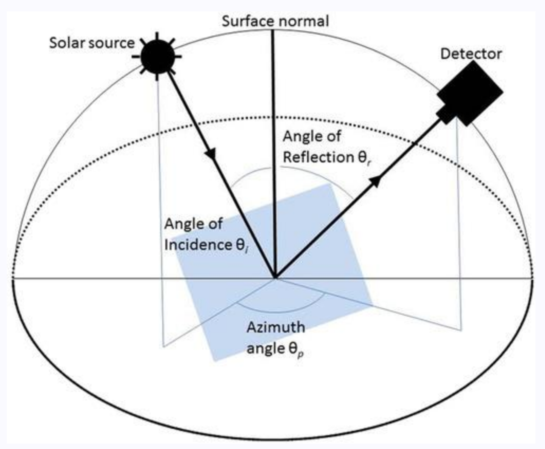
Center for Geospatial Research (CGR), Department of Geography, The University of Georgia

(sbernard@uga.edu, www.cgr.uga.edu)

BACKGROUND

Challenges in remote sensing, including remote sensing of vegetation, include the spectral characterization of objects over space and time. One key aspect for this characterization involves the geometry of data acquisition and positional relationships between light source, the target and the remote sensor. Several configurations of goniometers have been used to acquire spectral data as a function of this geometry and this strategy has been particularly successful when applied to the study of short canopies (e.g., grasses). Tall canopies present logistical challenges when conducting proximal multi-angle remote sensing analyses, which can be resolved by replacing physical structures (rails) with flying systems capable to conform to different canopy geometries and data acquisition requirements.

Proximal multi-angle remote sensing solutions



Data acquisition geometry

Spectra Vista Corporation

Proximal multi-angle remote sensing solution for short canopies

Matrice 600 Pro

- Ronin-MX gimbal
- Multisensor integration
- 25+ min. flight

Phantom 4 Pro

- camera: RGB, 20 MP 1 inch CMOS sensor
- ~30 min. flight/battery
- Augmented with multispectral system

Droniometer (aerial goniometer)

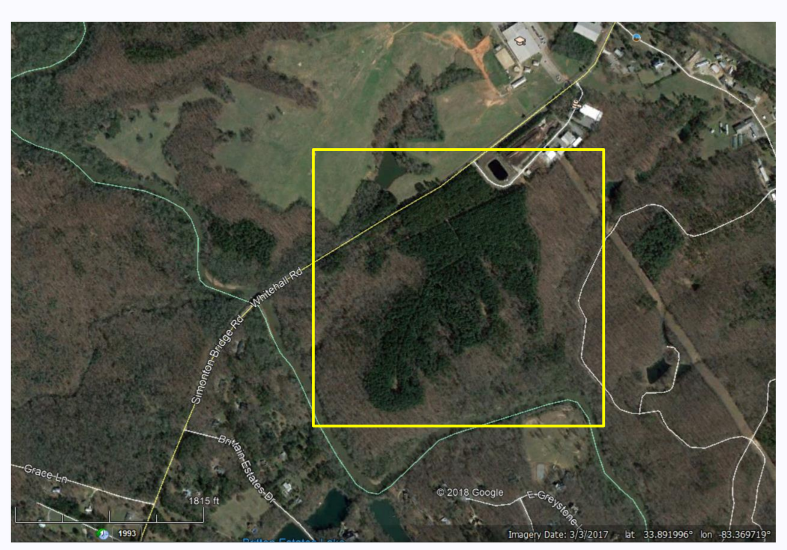
This work (the Droniometer Experiment) investigates anisotropies of a forested area using radiometrically calibrated images from a multispectral camera (MicaSense RedEdge) mounted on a rotary-wing unmanned aerial system programmed to follow a planned flight that simulates data acquisition by a goniometer assembled over a tall canopy.

The experiment uses multiple planned flights, conducted to represent changes in illumination, considering sun azimuth and elevation (multiple flights per day and over the course of months).

Multi-angle data acquisition is addressed by controlling aircraft position and camera pitch at regular intervals.

Field site and target characteristics

Athens, Georgia



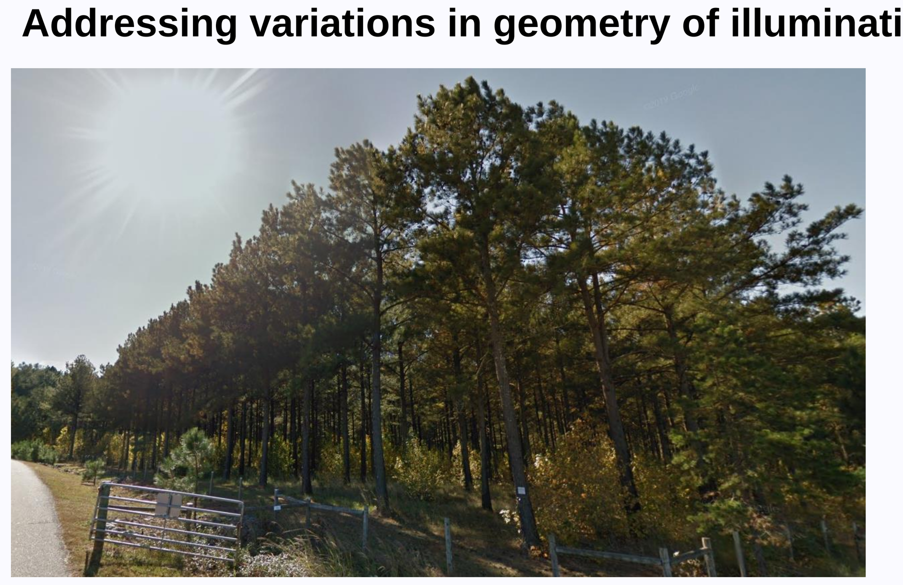
Stand of loblolly pine (*Pinus taeda*)

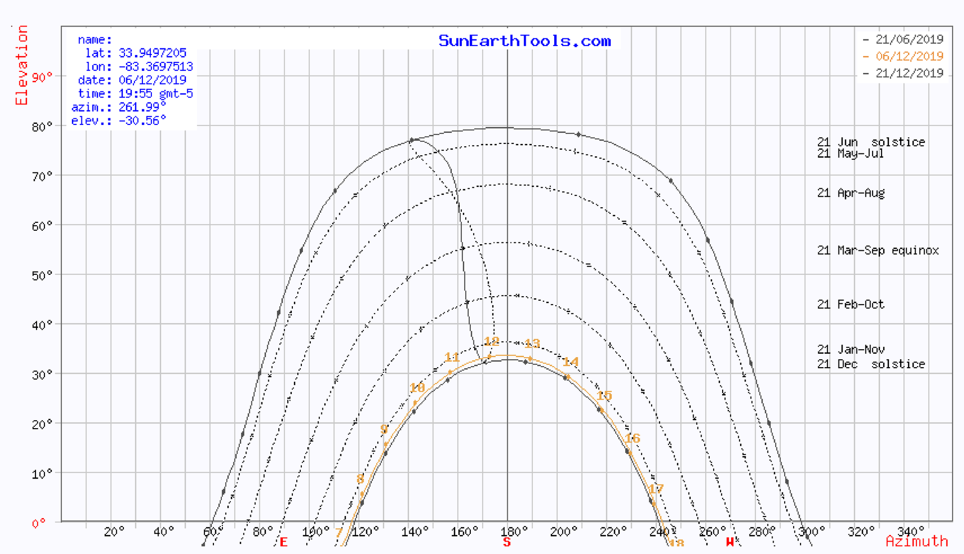
Area: ~57 acres

Challenges for proximal multi-angle remote sensing

- can reach 30–35 m (98–115 ft). Exceptional specimens may reach 50 m (160 ft).
- variations in the geometry of illumination.

Addressing variations in geometry of illumination over time





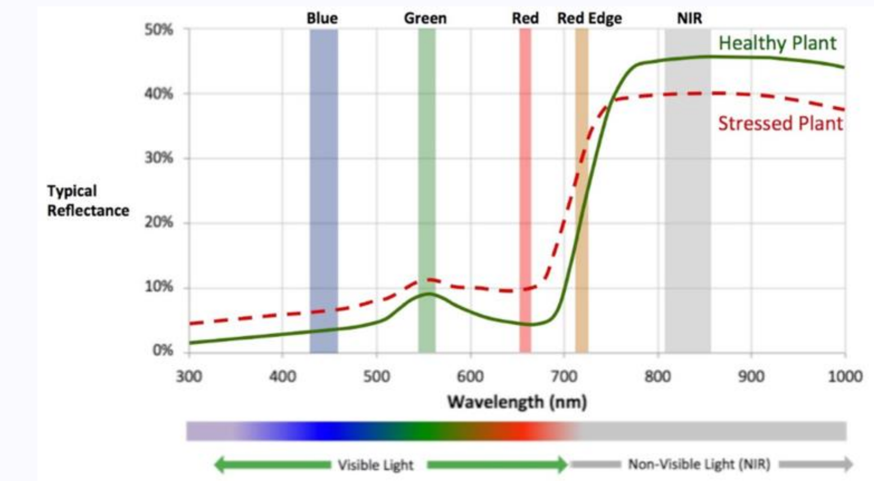
Changes in solar elevation and azimuth for a year over the field site.

Droniometer (aerial goniometer)

Platforms and sensor

MicaSense RedEdge

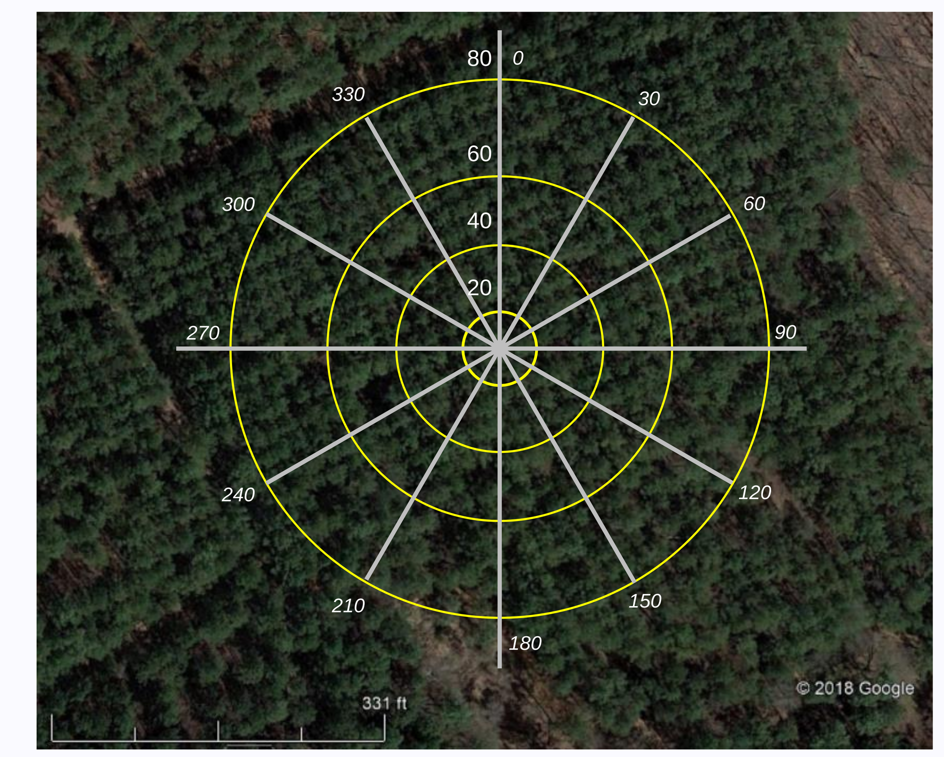
- multispectral (RGB, NIR, red edge)
- 3.6 MP, Global Shutter
- downwelling radiation sensor
- GPS
- calibration Panel



Software and hardware received different degrees of augmentation and in-house customizations.

Modes of data acquisition:

- Multi-angle view controlled by gimbal (changes in sensor pitch)
  Flight mode: multiple orbit with common center of orbit lock
  Decreasing orbit radius with increase in flight height
  UAV looks inwards
- Multi-angle view controlled by gimbal (changes in sensor pitch)
  Flight mode: UAV rotates around its vertical axis (pivot mode)
  UAV looks outwards
- Multi-angle view with reduced gimbal control
  Pixel selection from frame
  Decreasing orbit radius with increase in flight height



Data acquisition design options, showing concentric paths for orbit flights (including changes in camera pitch) and configuration for data collection including multiple azimuth angles.

Design for data acquisition:

- one acquisition per month over 12 months
- times of acquisition: 9:00 am, 12:00 pm and 3:00 pm
- angles of acquisition (20-degree step): 0º, 20º, 40º, 60º, 80º
- flight height: 80 m (262.5 feet) above canopy (5.45 cm GSD)
- image collection from calibration panel before and after flight
- use of downwelling radiation sensor

Processing:

- account for dark pixel offset (unbias images)
- compensate for imager-level effects
- compensate for optical chain effects (vignette)
- normalize images by exposure and gain settings
- convert to radiance
- convert to reflectance

Challenges

- mission planning and system setup for consistent data acquisition over time
- stability of footprint dimension
- stability of sampling location
- limitations in maximum flight height and largest possible sampling area

Complementary efforts

Multi-component system integrated for data acquisition and target characterization, including a high-resolution RGB camera, a LiDAR sensor and a thermal camera.

Radiative transfer modelling of canopy anisotropies, including multispectral band simulation, and comparative analyses.

OUTLOOK

This work presents the integration of an aerial goniometer (the droniometer) system, including platform and sensor requirements and control, data acquisition and processing for target/vegetation characterization and to support multi-angle remote sensing and information extraction. Further system interactions include radiative transfer models used for comparative analysis and to further describe anisotropies in spectral responses of tall canopies.

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