Spectral imaging from UAVs under varying illumination conditions

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Introduction

• Objective: to investigate methods for quantitative radiometric processing of images taken under varying illumination conditions

• Why: to expand the range of weather conditions during which successful imaging flights can be made.

• Empirical study in a precision agriculture application using realistic data collected in difficult illumination conditions.
UAV remote sensing using FPI spectral camera technology
Fabry-Perot interferometer based tuneable spectral imager, 2012 prototype

- Hyperspectral imagery in frame format
  - Developed by VTT Technical Research Finland (Heikki Saari et al.)
- Spectral data cube by changing the width of Fabry-Perot air gap
  - A burst of images, each with different filter setting
  - Image size: 1024 x 648 pixels (2xbinned), Pixel 11 µm
  - C=10.9 mm, F-number < 3.0
  - Spectral resolution 10-40 nm
  - Spectral range 500-900 (typical settings)
UAV operation

UAV
- Autopilot
- IMU
- GPS

Payload
- Spectral imager
- High spatial resolution imager
- GPS
- Irradiance sensors

Ground control station
- Mission design and control
- Insitu reference measurements: irradiance, reflectance targets,

- In typical flight 100-500 data cubes with 20-40 spectral layers
- Georeferencing data
- Irradiance data
- Insitu data
Processing of FPI image data
Output products: hyperspectral image mosaics, DSMs, point clouds

Empirical study
Vihti campaigns

- MTT agricultural test area in Vihti
- July 2, 2012 10:39 and 10:50 local time (UTC +3).
- Poor illumination conditions with fluctuating levels of cloudiness
- Flying altitude 140 m -> GSD of 14 cm
- Flying speed: 3.5 m/s.
- Block: five image strips and a total of 80 images; the forward and side overlaps were 78% and 67%, respectively
- Ground control points, reflectance targets

![Image of Vihti agricultural test area with drone and ground control points]
Correction method based on insitu irradiance measurement

- **Simplified equation**
  \[ L_{jc}(\lambda)_{at_sens} = L_j(\lambda)_{at_sens} C_j(\lambda) \]

- **Correction factor**: \( C_j(\lambda) = \frac{E_{ref}(\lambda)}{E_j(\lambda)} \)
  - \( E_j(\lambda) \) irradiance measured during image \( j \)
  - \( E_{ref}(\lambda) \) irradiance measured during reference image

- **Two different reference instruments**
  - **ASD FieldSpec Pro with irradiance optics**
    - Spectral measurement 3 nm FWHM @ 350-1000 nm
  - **Onboard irradiance sensors on the UAV**
    - Broadband 400-1000 nm
A block adjustment based method for reflectance image generation of frame images

- **Data**
  - Overlapping spectral rectangle format data cubes

- **Tasks**
  - Eliminate radiometric disturbances caused by sensor instability and illumination/atmosphere
  - BRDF compensation
  - Reflectance calibration

- **Approach**
  - Radiometric model parameters using radiometric block adjustment with a network of radiometric tie points
  - Optional insitu irradiance measurements
  - Reflectance images using reflectance targets
Results
Image data

• A total of 42 spectral layers in the original raw data
• 30 smile-corrected spectral layers.
Irradiance measurements

Wide-band irradiance from UAV

Spectral irradiance on ground
Correction factors

- The UAV based correction factor had a dependence on the flying direction.
- The factor based on radiometric block adjustment showed slight drift behavior.
- Average factor was dependent on object.
Image mosaics and sample spectra

No corr

Ground

UAV

Image based

BA: relA
Coefficient of variation

- Average coefficient of variation in tie points
  - Without correction: 0.14-0.18
  - UAV: 0.1-0.12
  - Ground: 0.06-0.09
  - Block adjustment: 0.04-0.07
Biomass estimation by knn-estimator

No correction
$R^2$: 0.64
NRMSE: 24.9%

Ground irradiance
$R^2$: 0.74
NRMSE: 17.8%

Block adjustment
$R^2$: 0.74
NRMSE: 16.8%
Conclusions

• Fabry Perot Interferometer camera is very promising technology
  • High spatial resolution, stereoscopic, spectrometric image data
  • FPI camera is operational from UAV platforms, suitable also for MAV platform
  • Well suited for time-critical and monitoring applications, such as water quality, agriculture, mining environments, disasters

• Radiometric processing technology for images collected in diverse weather conditions is needed, radiometric aspects need to be carefully considered

• A new method based on insitu measurement of irradiance either from UAV platform or from ground was developed.

• Method was tested in a precision agriculture application using realistic data collected in difficult illumination conditions.

• Results were very promising, indicating that quantitative UAV based remote sensing could be operational in diverse conditions, which is prerequisite for many environmental remote sensing applications.
Thank you!