Optimizing sensitivity of Unmanned Aerial System optical sensors for low zenith angles and cloudy conditions

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Optimizing sensitivity of Unmanned Aerial System optical sensors for low zenith angles and cloudy conditions

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Introduction

Satellite-based optical imagery cannot provide information on the land surface during cloudy periods. This issue is especially relevant for high latitudes where overcast days and low solar zenith angles are common. Current remote sensing-based models of evapotranspiration or carbon assimilation are biased towards clear sky conditions, lacking important information on biophysical processes under cloudy conditions. Unmanned Aerial System (UAS) imagery has great potential to monitor and understand surface fluxes under cloudy conditions.

Objective

UAS imagery acquired in overcast and cloudy conditions tend to present low brightness and dynamic ranges, and high signal to noise levels. Another problem is the influence of land cover types on the signal. For instance, over vegetated areas, even with low irradiance, saturation is reached in the near infrared, while visible channels have low brightness. An individual camera setting for each channel and light conditions can improve sensor sensitivity while preventing saturation. This study aims to optimize the camera exposure settings and radiometric corrections of a multispectral camera to produce high-quality UAV imagery under low but homogenous irradiance conditions.

Methods and data

Laboratory calibration:

- Instrument:
  - Sphere: a 2m diameter integrating sphere (ISP2000, Instrument Systems)
  - Light source: combined multicolor LEDs (various levels in VIS) and 3 tungsten halogen lamps (various levels in NIR) (flexible light intensities with 11 irradiance levels)
  - Radiance detector: ASD spectroradiometer (Analytical Spectral Devices, Inc.)
- Methods:
  - Radiometric correction: retrieve inherent camera geometric parameters
  - To improve the accuracy of image mosaicking
  - Vignetting correction: homogenous illumination from the sphere
  - To reduce the radiometric distortion
  - Converting digital numbers to radiance (L):
    - Extended calibration for low irradiance conditions

Gain: ON with radiance for specific exposure times
Calibration function: gains and integration times

\[ L = c_1 \times DN + c_0 \]

\[ c_1 = a \times t^b \]

Where \( c_1 \) is the gain, \( c_0 \) is a coefficient related to the dark current, \( t \) is the integration time, and \( a \) and \( b \) are coefficients.

Outdoor experiments:

- Homogeneous targets (Fig. 8): Validate radiance and test optimal exposure settings
  - Camera exposure settings (1, 4, 8, 12ms, Jan 6th, 2017)
- Forest flux sites: Risoe willow bioenergy plantation (31 ha)
  - UAS flight campaign: acquire images, validate surface radiance

Results

Laboratory calibration results

- Geometric correction
  - With pre-calibrated geometric parameters, the quality of the orthophoto could be improved.

Table 2. The calibration geometric parameter values for Tetra mini-MCA6 (unit:mm)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>9.850±00</td>
</tr>
<tr>
<td>Cx</td>
<td>5.395±00</td>
</tr>
<tr>
<td>Cy</td>
<td>6.183±00</td>
</tr>
<tr>
<td>kx</td>
<td>6.183±00</td>
</tr>
<tr>
<td>ky</td>
<td>5.395±00</td>
</tr>
<tr>
<td>( p_1 )</td>
<td>8.54±00</td>
</tr>
<tr>
<td>( p_2 )</td>
<td>3.71±00</td>
</tr>
</tbody>
</table>

C₁ and C₂ are principal point offset; \( k_x \) and \( k_y \) are radial distortion coefficients; \( p_1 \) and \( p_2 \) are tangential distortion coefficients.

Conclusion and future work

This study provides a methodology to thoroughly radiometrically calibrate a multispectral sensor for low irradiance conditions. Outdoor experiments were used to assess the performance for calibration with irradiance errors within ±8%. Future work will focus on using the obtained images in cloudy and overcast conditions to improve remote sensing based models of evapotranspiration or carbon assimilation.

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