UAV-based Remote Sensing Payload
Comprehensive Validation System

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Outline

1. Background
2. System Overview
3. Inflight Calibration & Performance Assessment
4. Future Plan
1. Background

Trend of Earth observation systems:

- Quantitative remote sensing application
- Pre-launch Cal & Val demand
- International standardization of data quality assessment and data sharing
- Monitoring of payload performance in system operation period
1. Background

**LOW COST**
Development cost: 10% of manned aircraft
Operation cost: 10% of manned aircraft

**Why UAV?**

- Provide realistic validation environments (telemetry, telecontrol, etc)
- Carry out flight experiment in specific scenarios

**UAV-based Remote Sensing Payload Comprehensive Validation System**
2. System Overview

System Components

- Two UAV Platforms
- Optical and SAR RS sensors
- Comprehensive Cal&Val sites
- Data processing/analyzing systems
- Auxiliary support systems
Two comprehensive Cal&Val test sites were preliminarily established, which have different climate characteristics, various land cover types and topographic features.

Now they are being further developed so as to support multi-grade validation of airborne and spaceborne sensors for stable and long-term operation.
2. System Overview - The Comprehensive C&V Site

- Standard artificial and natural targets

**Optical targets**
- Knife-edge target
- Fan-shaped target
- Gray-scale target
- Colored target
- Three-bar target
- Layout of targets

**SAR targets**
- Trihedral Corner Reflector
- Dihedral Corner Reflectors
- Ku-band Active Transponder

**Natural ground targets**
- Rice
- Maize
- Potato
- Sunflower
- Surface parameters measurement
- Spectral curves
2. System Overview - Data processing/analyzing system

Data processing/analyzing system

- Data processing
  - Radiometric correction
  - Geometric correction
  - Spectral correction
  - Reflectance retrieval
  - Vegetation index retrieval
  - SAR data processing

- Radiometric performance assessment
  - Absolute radiometric calibration
  - Signal to Noise Ratio, SNR
  - Dynamic range
  - Response linear degree
  - Radiometric resolution, NEΔρ

- Geometric Performance Assessment
  - Ground resolution
  - MTF
  - Band registration precision

- Spectral Performance Assessment
  - Hyperspectral camera: central bandwidth; FWHM
  - Multispectral camera: spectral response function
3. Inflight Calibration & Performance Assessment

- **Flight campaigns**
  - **Nov 2010 Campaign**
    Airborne optical sensors in North China test site
  - **Jul 2011 Campaign**
    Airborne optical and SAR sensors in South China test site
  - **Sep 2011 Campaign**
    Airborne optical and SAR sensors in North China test site
3. Inflight Calibration & Performance Assessment

- **Atmospheric and field measurements**

Spectral reflectance of targets were measured. The aerosol optical thickness data and meteorological profile above the test site were synchronously collected.

- **Moisture content**

- **BRF properties of targets**

- **Spectral reflectance of gray-scale targets**

- **550nm aerosol optical thickness**

- **Radiosounding balloon**

- **Automatic sun tracking photometer, CE318**

- **Automatic weather station**
3. Inflight Calibration & Performance Assessment

- Cal&Val of Optical sensors – Absolute radiometric calibration

Flow chart of optical sensor radiometric calibration

Radiometric calibration coefficients have very good linearity and the correlation coefficient reaches above 99%.
3. Inflight Calibration & Performance Assessment

• **Cal&Val of Optical sensors – Relative radiometric calibration**
  
  • Because of the variation in velocity height ratio, the images of hyperspectral imager between adjacent flight strips lack of comparability for different surfaces.
  • A relative radiometric calibration method based on line frequency difference is proposed to solve this problem.
3. Inflight Calibration & Performance Assessment

- Cal&Val of Optical sensors – Spectral calibration
  - Spectral calibration for hyperspectral sensor
    - Retrieval central wavelength based on flight data in 2011.
    - Band 75 is O₂ absorption band.
    - The shift of central wavelength is approximately 4~6nm compared to laboratory measurement.
3. Inflight Calibration & Performance Assessment

• Cal&Val of Optical sensors – Spectral calibration

  – Spectral calibration for multispectral sensor

  • **Difficulty**: Solving of spectral response function faces ill-condition matrix
  • **Solutions**: The spectral reflectance of 15 multispectral targets were measured to add the number of equations; Piecewise fitting SRF according to laboratory measurements
3. Inflight Calibration & Performance Assessment

• Cal&Val of Optical sensors– True-color calibration

A general true color calibration model is proposed based on the physical mechanism of color generation, which can fully employ all spectral information in VNIR reflection zones of hyperspectral images.

\[
M_{RGB \rightarrow R'G'B'} = \begin{bmatrix}
2.5635 & -0.3903 & -0.2178 \\
-0.1077 & 3.7997 & 0.5655 \\
0.0416 & 0.2628 & 12.4262
\end{bmatrix}
\]

True–color correction coefficient matrix
3. Inflight Calibration & Performance Assessment

- **Cal&Val of Optical sensors – Geometric performance**

**Ground resolution**
Defined as the least ground distance or the least size of object that can be distinguished.

- Red line denotes the location of ground resolution estimated by our method.
- Blue line denotes the location of GSD.
- Green line denotes the location of ground resolution estimated by visual method.

### Panchromatic image in 2011
![Image of radiometric target](image)

### Hyperspectral image in 2011

<table>
<thead>
<tr>
<th>Camera</th>
<th>Calculated Resolution (m)</th>
<th>Visual resolution (m)</th>
<th>GSD (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panchromatic</td>
<td>0.7941</td>
<td>0.8153</td>
<td>0.35</td>
</tr>
<tr>
<td>Multispectral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>0.8889</td>
<td>0.8178</td>
<td>0.70</td>
</tr>
<tr>
<td>B2</td>
<td>0.7800</td>
<td>0.8083</td>
<td>0.70</td>
</tr>
<tr>
<td>B3</td>
<td>0.8875</td>
<td>0.8428</td>
<td>0.70</td>
</tr>
<tr>
<td>B4</td>
<td>0.7500</td>
<td>0.7750</td>
<td>0.70</td>
</tr>
</tbody>
</table>

- Extract the grey value from the circumference of radius equal to \( r \)
- Calculate the contrast of this radius
- Distinguish?
  - No, \( r = r + 1 \)
  - Yes, Sensor GSD
3. Inflight Calibration & Performance Assessment

- **Cal&Val of Optical sensors – Geometric performance**

**Geometric distortion**

Geometric distortion evaluation result of panchromatic image in Sep. 2011 in Baotou city, China.

<table>
<thead>
<tr>
<th>Data Type</th>
<th>External distortion Positioning error</th>
<th>Internal distortion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X-direction (m)</td>
<td>Y-direction (m)</td>
</tr>
<tr>
<td>Geometric coarse correction</td>
<td>22.106</td>
<td>155.295</td>
</tr>
<tr>
<td>Geometric precision correction</td>
<td>0.568</td>
<td>1.012</td>
</tr>
</tbody>
</table>

After geometric precision correction, the positioning accuracy can reach a meter-scale and the image distortion has also been corrected well.
3. Inflight Calibration & Performance Assessment

- Cal&Val of SAR sensors – SAR data processing system

- Radiometric and geometric processing
- Polarimetric SAR data Processing and correction
- High resolution imaging processing
- Interferometric Processing and DEM generation
- Motion Compensation
3. Inflight Calibration & Performance Assessment

- **Cal&Val of SAR sensors – Relative radiometric calibration**

Before relative radiometric calibration

After relative radiometric calibration
3. Inflight Calibration & Performance Assessment

- Cal&Val of SAR sensors – data analyzing system
  - Point target analysis
  - DEM analysis
    - Resolution
    - PSLR (Peak Side Lobe Ratio)
    - ISLR (Integrated Side Lobe Ratio)
    - Dynamic range
    - .....
3. Inflight Calibration & Performance Assessment

• Application performance – reflectance retrieval and validation
  – A Look Up Table (LUT) atmospheric correction model with adjacency effect correction was proposed to retrieve land surface reflectance.

Colored targets in red frame

ref1: at-sensor reflectance without atmospheric correction
ref2: surface reflectance after atmospheric correction
ref3: field measured reflectance

It can be seen that the proposed method can eliminate the atmospheric effect well.
3. Inflight Calibration & Performance Assessment

- Application performance – LAI retrieval and validation
  - Leaf Area Index (LAI) was retrieved from hyperspectral data according to the image classification.

(1) Accuracy of LAI retrieval model is less than 7%.

(2) Validation results show that the retrieval error of LAI is approximately 21.7% with field measurement data.

(3) It might due to the retrieval error of reflectance, the saturation of NIR band with the increasing of LAI, the error of instruments.

Accuracy assessment using field measurements on Sep 3, 2011.
4. Future Plan

- Satellite
- Airborne platform
- Command vehicle
- Data process vehicle
- Baotou Comprehensive Cal&Val Site
- Aircraft Hangar
- Equipment store house
- Tower
- T&C vehicle
- Real-time monitoring of flight status
- Artificial target
- Natural scene
- Inflight and preflight geometric calibration
Thank you!