Calibration and Validation of Air-borne Multispectral Imaging Sensors: State of the art and Standardization Requirements

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PART

Background
Geographic information industry is developing rapidly and natural resource monitoring needs are increasing.
New demands

All-factor, all-coverage and all-weather natural resources monitoring

Application situation

- agricultural
- forestry
- rivers
- arable land
- town

High precision quantitative inversion and fine management of natural resources
Advantages of air-borne multispectral imaging sensors

Connect space and ground observation

- CBERS
- TM, SPOT, AMS, ATLAS,
- Multispectral

Cover space and attribute data

- Object parameters
- Spectral data
- Environmental data
- GIS data
- Terrain data
- Control data

High efficiency

High flexible

Rich elements

High precision
Application of air-borne multispectral imaging sensors

Water quality monitoring

Crop stress status analysis

Plant identification of vegetation

Historic building conservation

Support all-factor, all-coverage and all-weather natural resources monitoring
Demands of calibration and validation

Geometric distortion

Vignetting effect

Central wavelength shift

Complex field radiation environment

Detection system and evaluation indexes are inconformity

Calibration

Validation
State of the art
Status of multispectral imaging sensors

- **Foreign multispectral imaging sensors:**
  - MicaSense, Tetracam, SlantRange, MAPIR and PIXELTEQ (America)
  - Parrot (France)

- **Domestic multispectral imaging sensors:**
  - Tongji University
  - Chinese Academy of Sciences

Distribution of airborne multispectral imager research
Status of calibration

- Gas emission radiant lamp method (Curtiss, 2002);
- Diffuse reflector calibration method (Hedman, 2009);
- Monochromatic light collimation method.
- Based on standard irradiance lamp method (James, 1998);
- Integrating sphere calibration method (Zhou, 1988);
- Spectral radiometer - parallel light calibration method.
- Brown Model;
- BFGS Model;
- Zhang's calibration method.

Indexes are confused and methods are not suitable for low altitude, light and small remote sensing sensors

Construct the calibration and validation scheme of air-borne multispectral imaging sensors
Status of calibration and validation filed

- White Sand Calibration Field, USA;
- LaCrau calibration field, Marseille, France;
- Ellesite geometry and radiation inspection field, Australia.

- Baotou, Songshan, Heihe, Dunhuang Qinghai Lake and other calibration fields.

Dedicated to calibration and validation of space-borne sensors and not suitable for low-altitude remote sensing sensors.

Establish calibration and validation filed for air-borne multispectral imaging sensors.
PART 3

Standardization requirements
Status of standard

There is no multispectral imaging sensor included in the optics section. It only covers frame type and linear array push-broom cameras and lack of applicability in multiple remote sensing applications.
Requirements

Promotes the construction of international standard for air-borne multispectral imaging sensors and fill in the gaps in this field.
ISO/TC 211 Geographic information/Geomatics

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ISO/TC 211 Geographic information/Geomatics

Requirements

Class CA_Air-borneMultispectralSensor

CA_CalibrationValidation

+ calibrationType: CA_CalibrationType

CA_Air-borneMultispectralSensor

+ multispectralType: CA_MultispectralType
  + observationType: CA_ObservationType
  + centralWavelength: Real
  + bandwidth: Real
  + numberOfWavelengths: Real

<<CodeList>>
CA_CalibrationType

<<CodeList>>
CA_MultispectralType

<<CodeList>>
CA_ObservationType

Calibration methods

CA_MultispectralCalibrationSpectral

CA_MultispectralCalibrationRadiometry

CA_MultispectralCalibrationGeometry

CA_MultispectralLaboratoryFacility

CA_MultispectralFieldedFacility

CA_MultispectralValidation

Calibration facilities

Validation methods
Work foundations
Novel air-borne multispectral imaging sensor

Multispectral imaging sensor

1. Position and pose module
2. Light sensitive elements
3. Synchronization module
4. Shock absorption frame
5. Aerial camera lens
6. Narrow band filters

Air-borne multispectral remote sensing integrated system
Comprehensive calibration and validation field

Support the calibration of multi-spectral, laser radar, video, synthetic aperture radar and other novel sensors.
- **Monochromatic light collimation method**

- Spectral bandwidth is 10 nm;
- Center wavelength shift is less than 1 nm;
- Transmittance is better than 98%.

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**Discrete spectral curves**

**Gauss fitting**

**Spectral response curve**
Radiometric calibration

➢ Integral sphere-target sensor model

- Standard light source
- Standard light source radiation response curve
- Absolute calibration
- Test image
- Dark current coefficients
- Uniformity coefficient

- Uncertainty is less than 4%
- Dynamic response range of standard light source is 18bit
- Correctable band is 350nm~2500nm.
Geometric calibration

- **Chessboard calibration method**

  - Reprojection error is less than 0.10 pixels;
  - Pixel-by-pixel nonlinear radiometric correction.
Multi-band spectral registration

➢ Multi-channel geometric registration method based on feature points

- 675 nm waveband
- 705 nm waveband
- 850 nm waveband
- Three-waveband false color image

- Registration success rate reaches 100%;
- Registration accuracy is less than 0.3 pixel.
Relative radiometric calibration

- Effectively eliminate the impact of radiation in the field;
- Realize rapid and wide range field relative radiometric correction.

Standard white board

Ground objects image acquisition

Principle of relative radiometric correction

Result

Grayscale image of surface reflectance

\[
\rho_{\lambda} = \frac{M_{\lambda}Q_{\text{cal}} + A_{\lambda}}{\cos(\theta_{\text{E}})}
\]

- \(\rho_{\lambda}\) = TOA reflectance
- \(\theta_{\text{E}}\) = Local sun elevation angle provided in the metadata
- \(\theta_{\text{Z}}\) = Local solar zenith angle; \(\theta_{\text{Z}} = 90^\circ - \theta_{\text{E}}\)
- \(M_{\lambda}\) = Band-specific multiplicative rescaling factor from the metadata
- \(A_{\lambda}\) = Band-specific additive rescaling factor from the metadata
- \(Q_{\text{cal}}\) = Quantized and calibrated standard product pixel values (DN)
Validation of geometric calibration results

Geometric checkpoints distribution  Geometric targets

- Reprojection error is less than 1 pixels;
- The coordinates of ground points can be accurately obtained.

<table>
<thead>
<tr>
<th>GCP Name</th>
<th>Accuracy X/Y/Z [m]</th>
<th>Error X [m]</th>
<th>Error Y [m]</th>
<th>Error Z [m]</th>
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<tbody>
<tr>
<td>b3107 (3D)</td>
<td>0.020/0.020</td>
<td>0.080</td>
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<td>b3109 (3D)</td>
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<td>0.002</td>
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<td>b3111 (3D)</td>
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<td>0.009</td>
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<td>0.002</td>
<td>-0.048</td>
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<td>0.031</td>
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<tr>
<td>004 (3D)</td>
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<td>0.002</td>
<td>-0.003</td>
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<tr>
<td>007 (3D)</td>
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<td>0.012</td>
<td>0.016</td>
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<tr>
<td>008 (3D)</td>
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<td>0.004</td>
<td>-0.003</td>
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<tr>
<td>011 (3D)</td>
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<td>017 (3D)</td>
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<td>0.008</td>
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<td>0.020/0.020</td>
<td>-0.008</td>
<td>0.010</td>
<td>0.006</td>
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</tbody>
</table>

Mean [m] 0.014276  -0.019889  0.010950
Validation of radiometric calibration results

Based on typical ground objects

- Cement
- Wheat
- Broad bean
- Rape flower

Based on standard reflectors

- Standard reflecting plate

Reflectivity deviation is less than 1.5%
Outlook
Research the generic calibration technologies of "optics, video, synthetic aperture radar and lidar".
Promotes the construction of field and laboratory standardized calibration environment for novel remote sensing sensors.
Outlook

- Research on the novel air-borne multispectral imaging sensors calibration and validation methods.
- Establish the core performance evaluation system of novel remote sensing observation.
- Realize the standard transformation of standardized verification method and process.
- Fill the technical and standard gaps in the field.
Thanks !