Development and Utilization of a Mirror Array Target for the Calibration and Harmonization of Satellite Imagery

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Introduction

• Building a larger time-series training dataset for different satellites brings following constraints:
  o The interpretation of EO images **needs expert knowledge**, so annotation is a time-consuming and resource-intensive procedure.
  o **Buying** enough scenes just for training data preparation for each satellite will be **very expensive** and **not very practical**.
  o Many **new micro-satellites** are getting launched and these **do not have enough images in their archived data** to prepare a large training dataset. Or we have to wait till the time they get enough images captured to use our models.
Satellite data harmonization

- Different satellites have different wavelength definitions for bands, along with the atmospheric influence, calibration errors, and even orbital overpass time influences the final results.

- Harmonization tries to minimize the differences among inter- and intra-satellites data.
How satellite harmonization performed

Overview of the calibration and harmonization* setup at Yamaguchi University

ミラーアレイによる校正
In accordance to the tasking and scheduling for satellite observation, the mirror reflectors have been set up by adjusting a precise azimuth and tilt angles to get maximum reflectance from the mirrors.
Observation of Mirror Array Target by GRUS-1A

Axelspace

Mirror array

Band 1 image

Pixel value

2021-02-22
Observation of Mirror Array Target by Cartosat2E
The spread of light spectrum around the satellite image pixel of the ground mirror reflector

The mirror reflector can precisely estimate a sub-pixel band registration accuracy and improve image quality of color composite images. The distribution and spread of light energy reflected from the mirrors show that YUCARS mirror array station has a potentiality to construct a point spread function of in-flight image.
Development of Point Spread Function – IPSF
Mirror reflectors and Point Spread Function for optical satellite data calibration

Satellite data collection and pre-processing

Analysis of light spectrum spread around the pixel of ground mirror reflector

Determine of distribution type of light spectrum

Estimate parameters (Kernel, sigma, angle, …) and construct IPSF

Satellite image transform to frequency domain

Reconstruct satellite image
Result of Calibration by Mirror Array Target

GRUS1-A 2021-02-22

<table>
<thead>
<tr>
<th>Red band</th>
<th>Green band</th>
<th>Blue band</th>
<th>RGB Image</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Original image" /></td>
<td><img src="image2.png" alt="Original image" /></td>
<td><img src="image3.png" alt="Original image" /></td>
<td><img src="image4.png" alt="Original image" /></td>
</tr>
</tbody>
</table>

Original image

Calibrated image

Improving band registration

Deblurring the image

Improved image
Transfer learning

Transferring knowledge from the networks trained on larger dataset (source dataset) to the target dataset containing similar but not same input data.

What if we don’t have very large dataset for satellite images with enough diversity? And how to make one?
Data used:

**Spectral bands**
- **Panchromatic**: 450-900 nm
- **Blue**: 450-505 nm
- **Green**: 515-585 nm
- **Red**: 620-685 nm
- **Red Edge**: 705-745 nm
- **Near Infrared**: 770-900 nm

**Ground resolution**
- **Panchromatic**: 2.5 m
- **Multispectral**: 5.0 m

**Satellite constellation**
- **GRUS satellites**
  - **GRUS1A**
- **PlanetScope satellites**
  - **PlanetScope PS2**
  - **PlanetScope PSB.SD**

**Satellite constellation details**
- **Instrument**
  - **PS2**
  - **PSB.SD**

**Spectral Bands**
- **Blue**: 455 - 515 nm
- **Green**: 500 - 590 nm
- **Red**: 590 - 670 nm
- **NIR**: 780 - 860 nm
- **Blue**: 465 - 515 nm
- **Green**: 513 - 549 nm
- **Red**: 650 - 680 nm
- **Red-Edge**: 697 - 713 nm
- **NIR**: 845 - 885 nm

**Resolution**
- **PlanetScope PS2**: 3.125 m
- **PlanetScope PSB.SD**
Study area and classes

• Area:
  o Ube area in Yamaguchi Prefecture, Japan.

• Classes:
  o Agriculture
  o Water
  o BareLand
  o BuildUp
  o Forest

Image chips were created using sliding window non-overlapping sampling method.
Network Used

• UNet*

Experiments by different datasets

• **Network trained on Original images**-
  - Trained on GRUS and transfer to PS2.
  - Trained on GRUS and transfer to PSB.SD.

• **Network trained on Calibrated images**-
  - Trained on GRUS and transfer to PS2.
  - Trained on GRUS and transfer to PSB.SD.
Example tiles used for the training

• The ‘Other’ class is where the class type was not certain or cloud or cloud-shadow was present.
• In our study we have worked with only five defined LULC classes (Agriculture, Water, Bareland, Build-Up, and Forest).
Part of GRUS-1 satellite image

Corresponding non-overlapping tiles
LULC classes for the previous image-part

Corresponding non-overlapping tiles
# Results

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Agriculture</th>
<th>Water</th>
<th>BareLand</th>
<th>BuildUp</th>
<th>Forest</th>
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<tbody>
<tr>
<td><strong>Original</strong></td>
<td></td>
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<tr>
<td>GRUS-&gt; PS2</td>
<td></td>
<td>0.71</td>
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<td><strong>Calibrated</strong></td>
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<td>0.69</td>
<td>0.73</td>
<td>0.88</td>
</tr>
</tbody>
</table>
Conclusion

• Even when the targeted dataset is very small transfer learning with harmonization give notable improvement.

• This is an important observation as creation of large dataset for each satellite separately can be avoided.

• Also, Image harmonization can help us to create a larger dataset by combining various micro-satellite images after harmonisation. This kind of training dataset may play an important role for future development in the remote sensing domain. Also, this will help us to build a high frequency time-series dataset.
Thank you for your kind attention