Improvement in ABI/AHI Lunar Image Registration Algorithm for the Extraction of Lunar ROI Radiance

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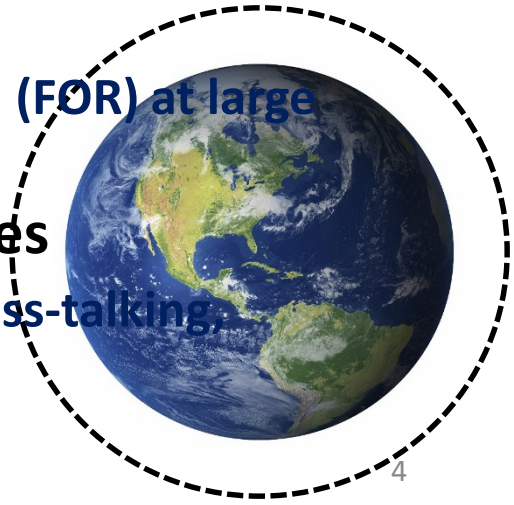
Outlines

- **Background**
  - **Lunar radiance calibration for high spatial resolution instruments, e.g. ABI/AHI**
  - **Previous studies/efforts**
  - **Challenges**
- **Combined method to select the matched points for image-to-image registration**
  - **geometric model - Ray-tracing**
  - **SIFT**
  - **Iterative method**
- **Early Results**
- **Summary**

Lunar Radiometric Calibration – Irradiance-based

- Lunar irradiance calibration is currently widely used
- Most popular physical model: USGS ROLO (GSICS GIRO) model
  - Works very well for the trending study when the phase angle range is small
    - e.g. MODIS/VIIRS/SeaWIFS
  - Relatively large absolute calibration accuracy
  - Relative accuracy may be phase angle dependent with possible residual of libration correction
- Challenges with the ROLO/GIRO model in the GEO instruments
  - The moon can be appear within the Field of Regard (FOR) at large range of phase angle range
- Uncertainty in the satellite irradiance estimates
  - Oversampling factors, out-of-field energy (MTF, cross-talking, straylight, etc) and detector noise



Lunar Radiometric Calibration – Radiance-based

- **Lunar radiance calibration can be an alternative method**

- **Relatively spectral/spatial uniform sites at the lunar surface**
  - **Minimize the phase and libration effects on the physical model**
  - **Minimize the effects of out-of-field radiance and oversampling factors on the satellite measurement**

- **Challenges:**
  - **Accurate image-to-image registration**
  - **Accurate BRDF model**
    - **Large phase angle range**
    - **Libration duration**

Requirements, Challengues and Procedures

- **Long-term accurate measurements of high spatial resolution of lunar surface**
  - **Himawari-8 AHI and GOES-16 ABI**
    - **High temporal resolution from the Earth orbit**
    - **Multiple times per month, depending on the available operation schedule**
  - **Others**
    - **LEO: CNES Plaiedes, Landsat TM/OLI, EOS Hyperion, etc**
    - **GEO weather instruments: GOES Imager, MTSAT, COMS, etc.**

- **Accurate image-to-image registration**
  - **Automated image registration algorithm**
  - **Region of Interest (ROI) radiance extraction**

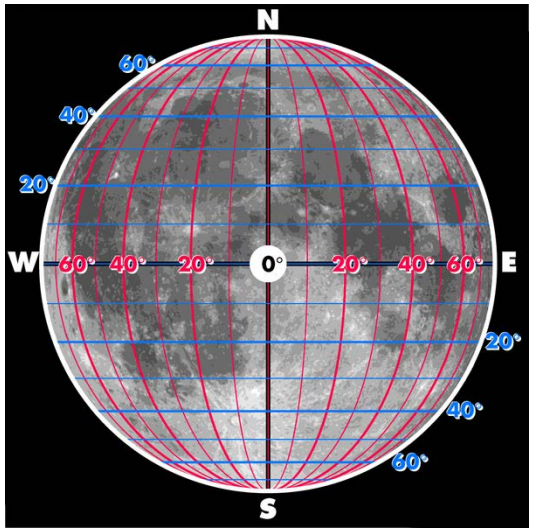
- **Accurate model development and validation**

Past Efforts

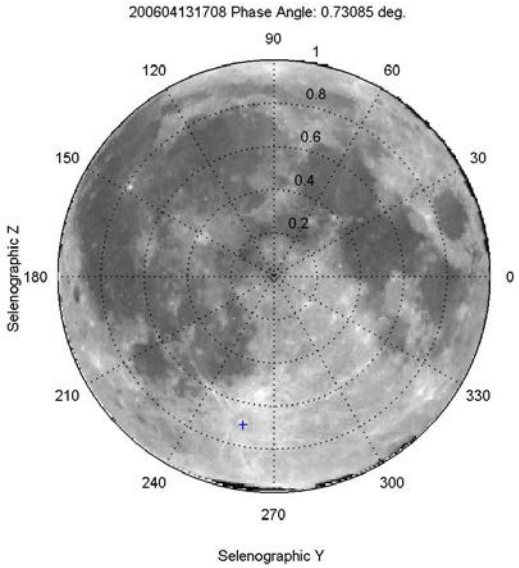
- **Relatively spectral and spatial uniform surface selections**
  - **Yu et al. 2015, "Photometric properties on selected lunar surface for GOES-R ABI solar reflective channels using SELENE/SP data", EUMETSAT, Oct. 2015.**
    - **Site selections**
- **Automated image to image registration algorithm**
  - **Shao et al. 2015, "Selenographic coordinate mapping of lunar observations by GOES Imager", SPIE 9639, Sensor, Systems, and Next-Generation Satelltes XIX, 963918 doi:10.1117/12.2193914, Oct. 2015.**
    - **Ray-tracing**
    - **Fast with relative large uncertainty**
  - **Yu, et al. 2016, "Effort toward characterization of selected lunar sites for the radiometric calibration of solar reflective bands", CALCON, Logan, UT, 2016.**
    - **SIFT (Scaled Invariant Feature Transform) method**
    - **Very accurate when phase angle is similar**
    - **Few matched keypoints with large phase angle difference**

Ray-tracing Method

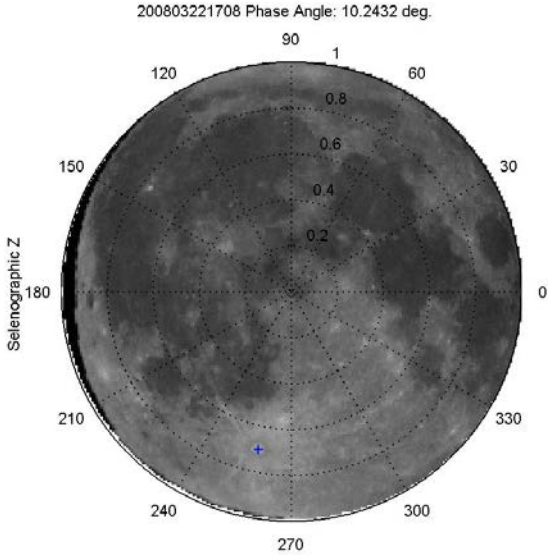
- **Project each pixel to a plane coordinate**
  - **Requirements: Time and satellite orbit configuration**
  - **Issues: Jitter, uncertain of scan positions, and possible optical distortion, etc**
  - **Shao et al. 2015, SPIE 9639, Sensor, Systems, and Next-Generation Satellites XIX, 963918 doi:10.1117/12.2193914, Oct. 2015**
- **Need feature control points to further improve the registration accuracy**



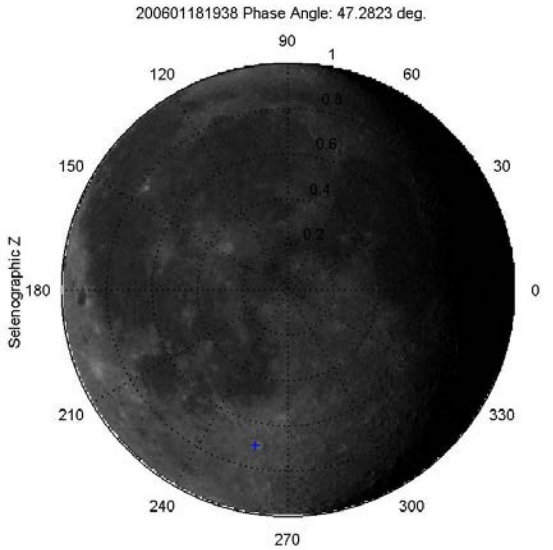
2006/04/13 ϕ = 0.73°



2008/03/22 ϕ = 10.24°



2006/01/18 ϕ = 47.28°

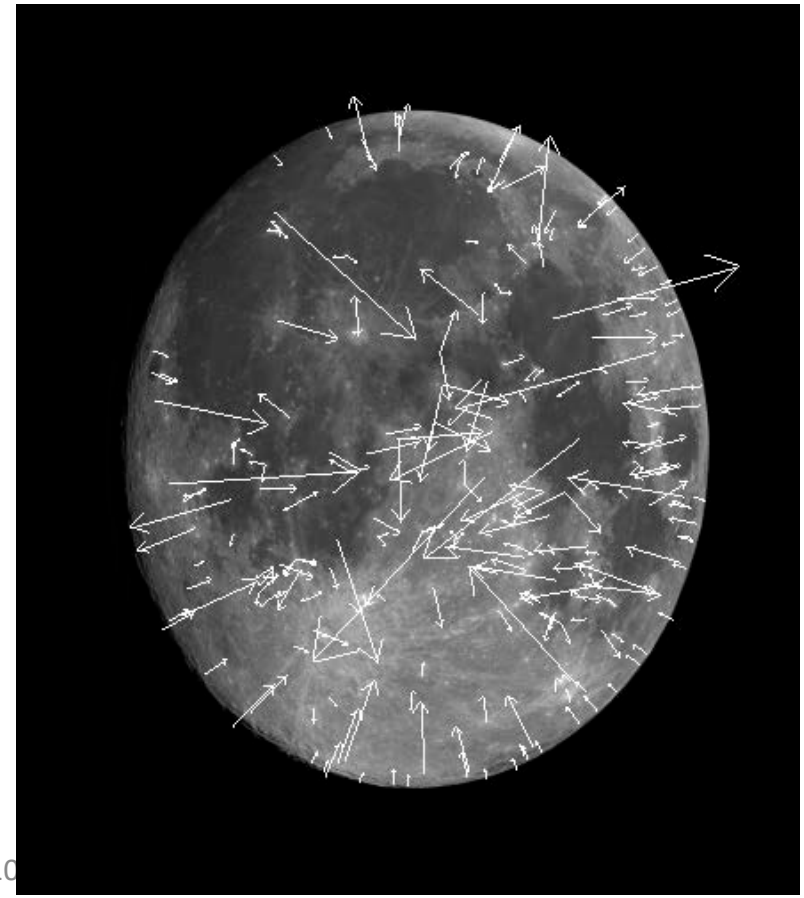


SIFT – Keypoint Indexing

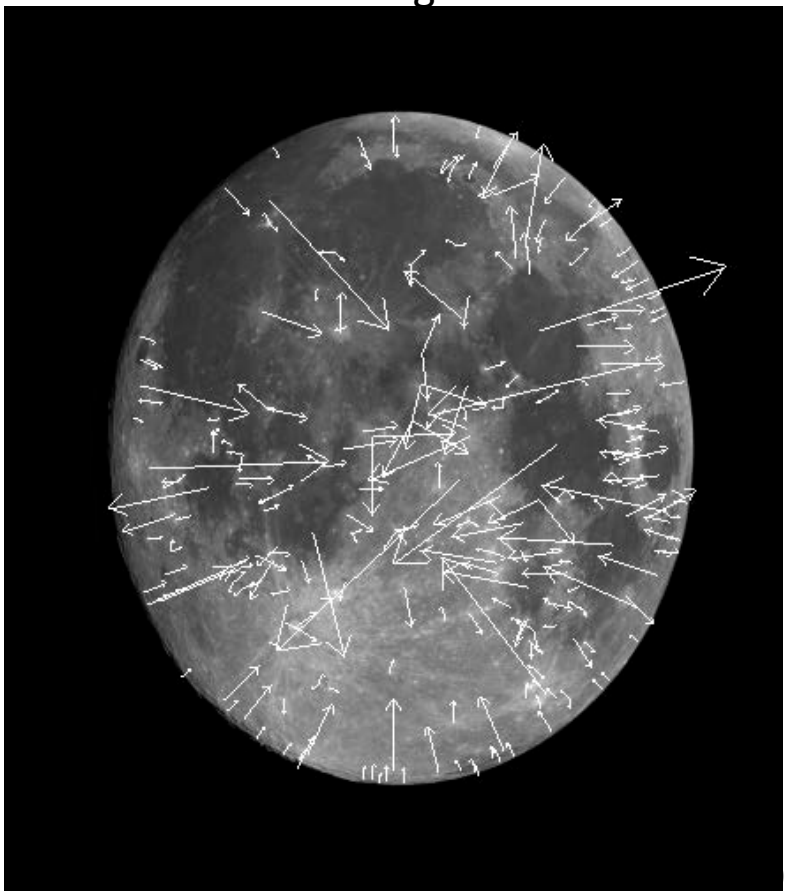
- **Scaled Invariant Feature Transform (SIFT) to detect features, which is invariant to image scaling, translation, and rotation, and partially invariant to illumination changes and affine or 3D projection.**

- Lowe, D., 2004, International Journal of Computer Vision

Reference image



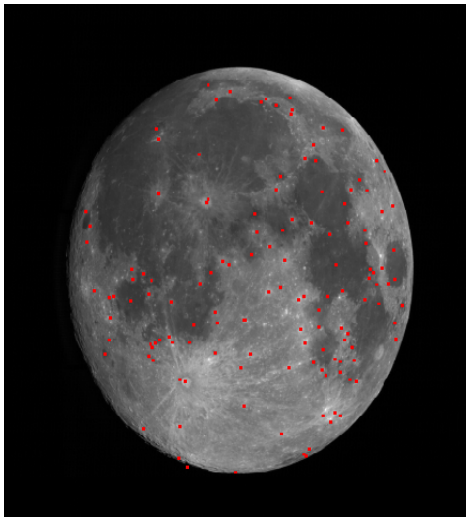
Source image



SIFT – an empirical method

- **Sufficient matchups can be identified with reference and source images have similar phase angle**

Reference image



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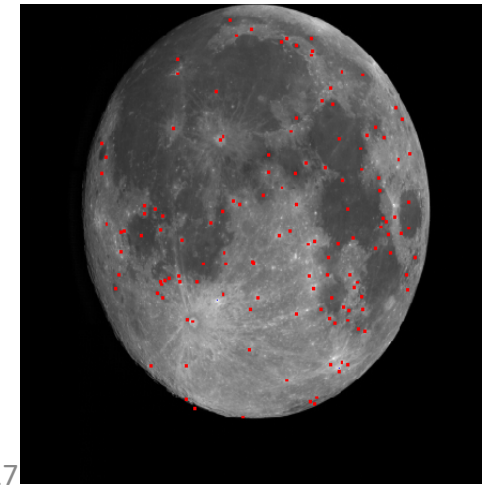
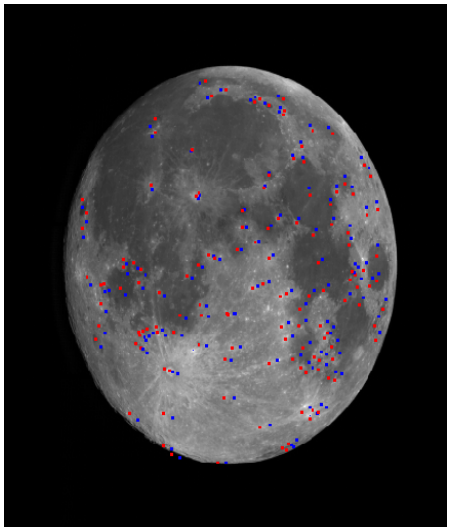
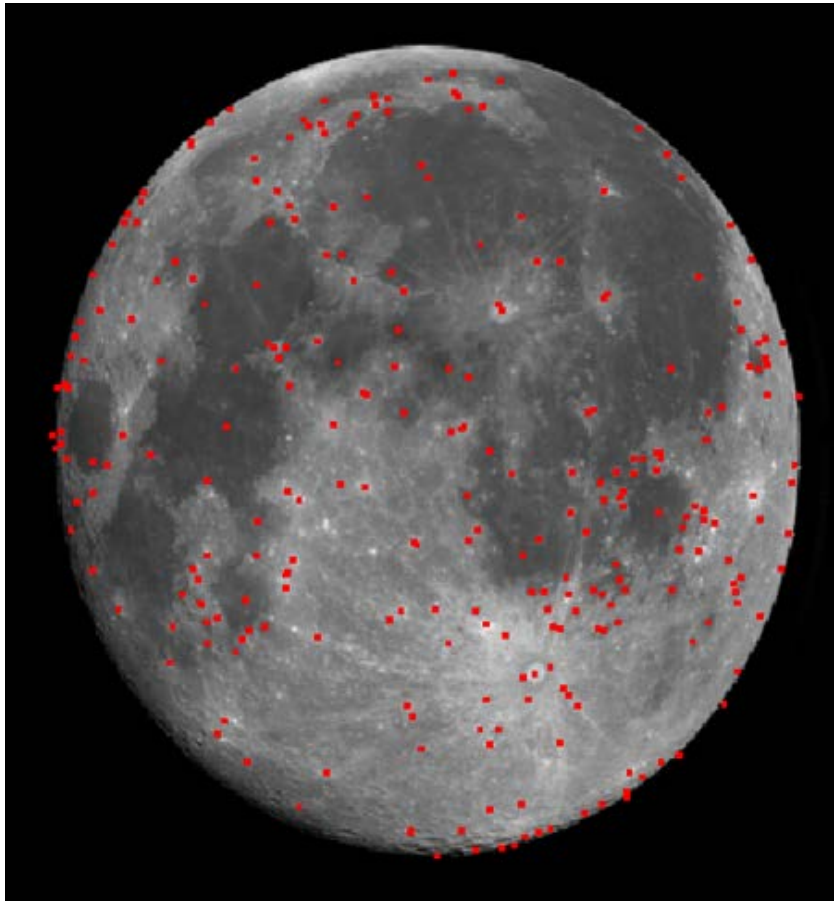




Blue: source image
Red: reference image Keypoints

Key Points derived with SIFT Method

Phase angle = 10.6 degree
2015-08-01_03-00-29_B1



#keypoint = 251

Phase angle = 78.6 degree
2015-08-06_07-20-29_B1

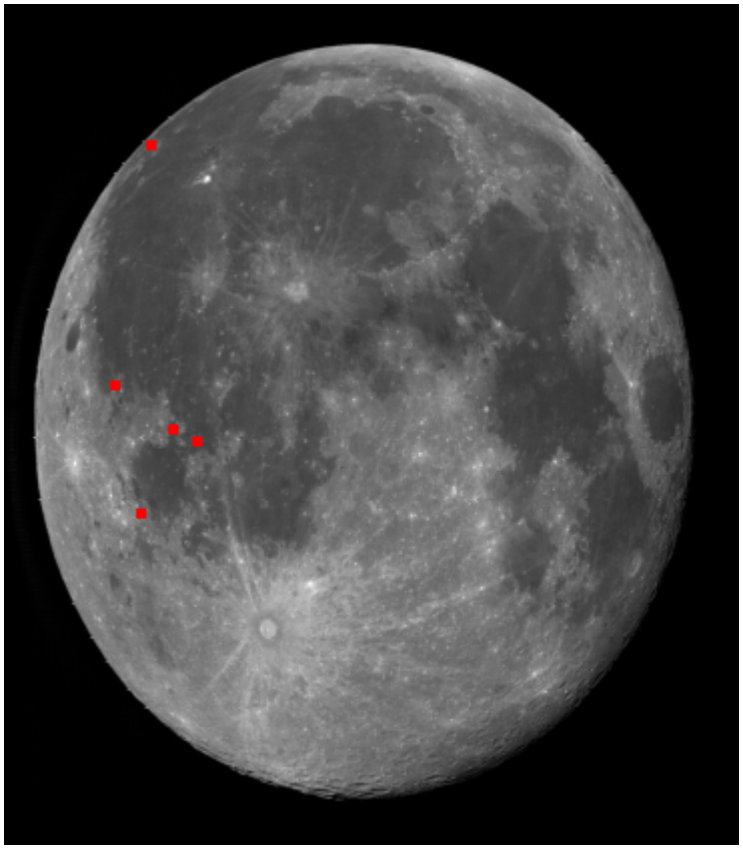
#keypoint = 106

Matched SIFT Keypoints with Euclidean Distance

Issue 1: Insufficient matched Keypoints

2015-08-01_03-00-29_B1

Phase angle = 10.6 degree



2015-08-06_07-20-29_B1

Phase angle = 78.6 degree

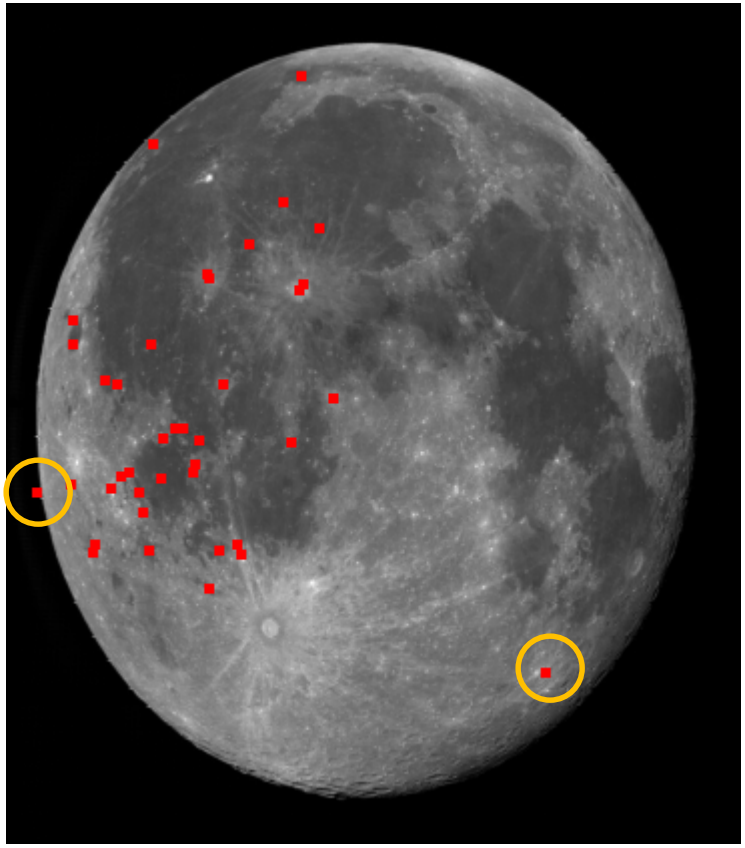
#matchup = 4

Matched SIFT Keypoints with Euclidean Distance

Issue 2: Mis-matched keypoints

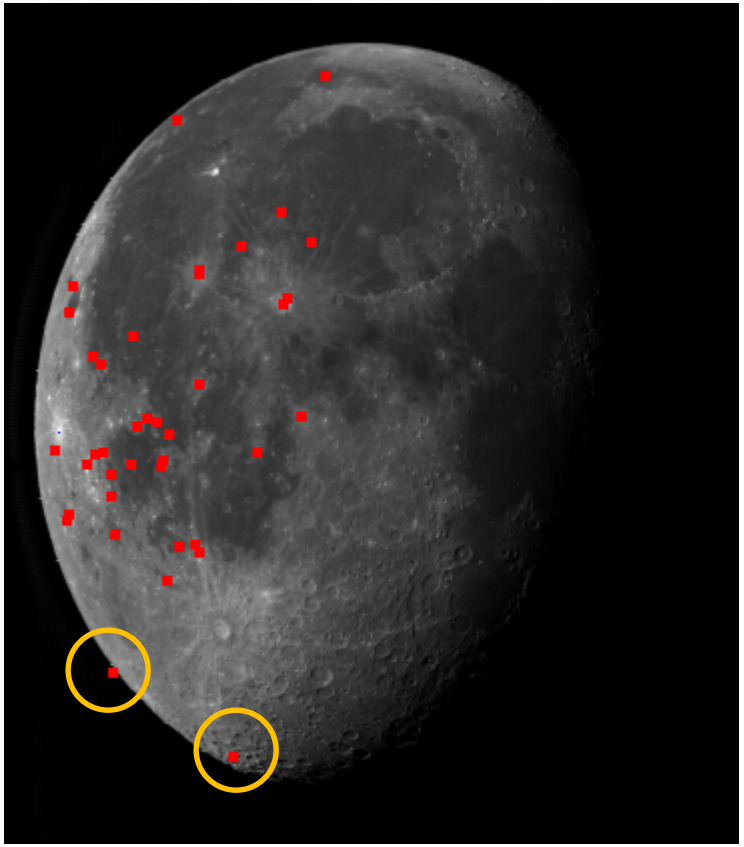
2015-08-01_03-00-29_B1

Phase angle = 10.6 degree



2015-08-04_05-10-29_B1

Phase angle = 54.0 degree



#matchup = 47

Combined Method

ABI/AHI Radiometric Calibrated Data

Edge adjustment with BDS maps

Ray-Tracing

Selenographic Lat/lon

SIFT Keypoint Identification

Local Keypoint matchups

Recursively remove mis-matched keypoints

Matched keypoints

Result of Combined Method

2015-08-01_03-00-29_B1

Phase angle = 10.6 degree

2015-08-06_07-20-29_B1

Phase angle = 78.6 degree

#matchup = 32

Combined Method

2015-08-01_03-00-29_B1

Phase angle = 10.6 degree

2015-08-04_05-10-29_B1

Phase angle = 54.0 degree

#matchup = 68

SIFT only

2015-08-01_03-00-29_B1

Phase angle = 10.6 degree

2015-08-05_06-10-29_B1

Phase angle = 67.5 degree

#matchup = 15

Combined Method

2015-08-01_03-00-29_B1

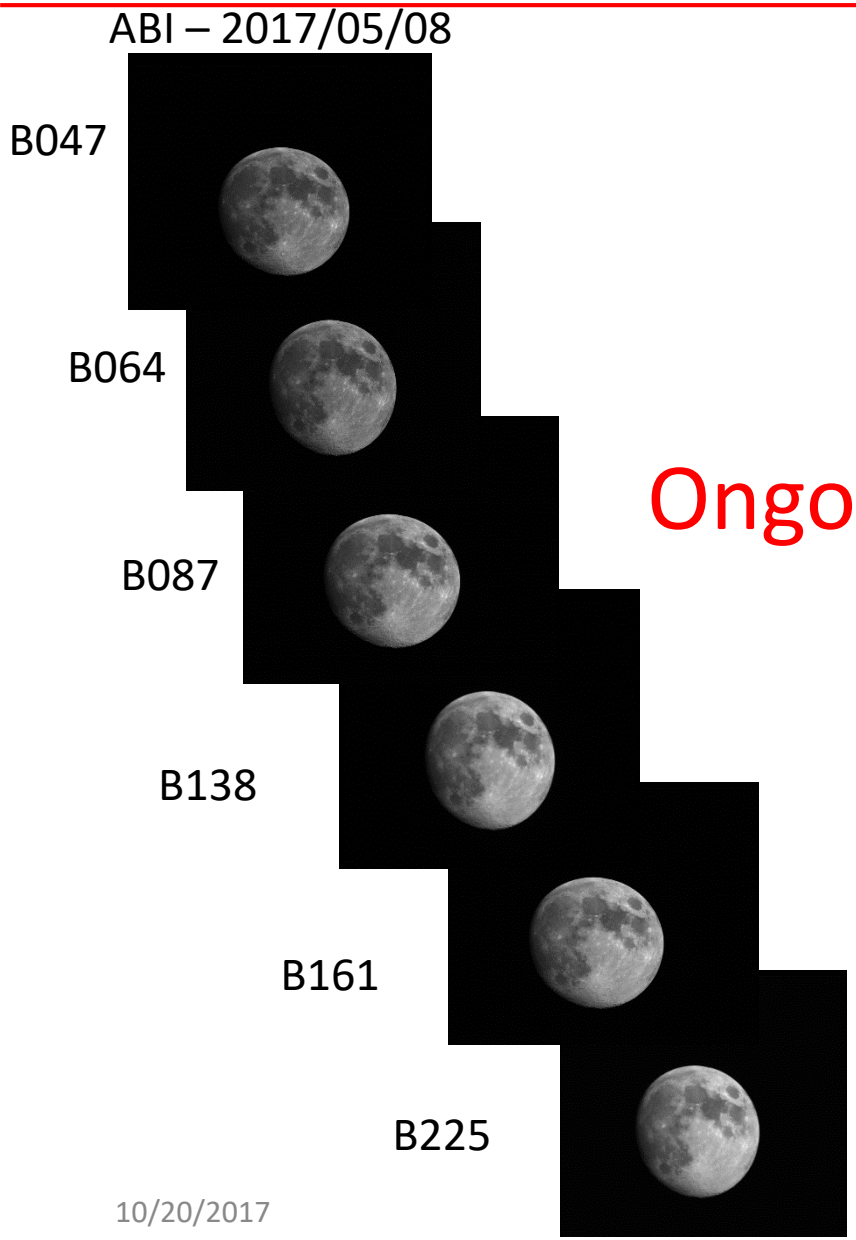
Phase angle = 10.6 degree

2015-08-06_07-20-29_B1

Phase angle = 67.5 degree

#matchup = 44

ABI and AHI Lunar Images Registration



Ongoing Effort....

ABI and AHI Image Registration

Some Early Preliminary results …..

- **Ray-tracing method not applied yet**
- **Combined from SIFT and recursive methods**

ABI Band047um, 2017/08/11T20:28:56

AHI Band047um, 2016/02/27T05:23:24

Similar phase angle, but different in libration and detector size

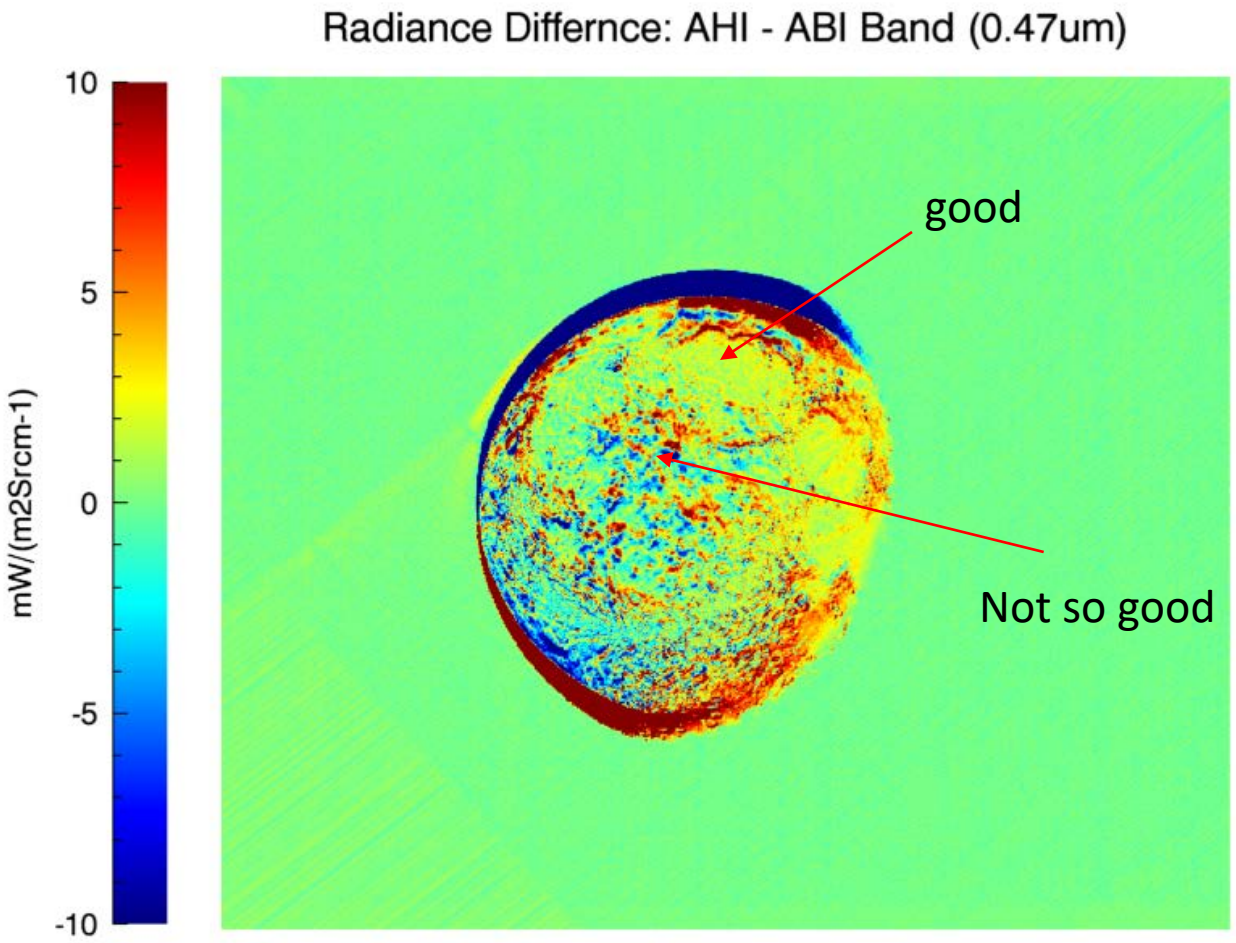
Image Transformation

Linear affine transformation

ABI Band047um, 2017/08/11T20:28:56

AHI Band047um, 2016/02/27T05:23:24

Radiance Difference for Band047



Linear affine transformation is not Sufficient for global image pixels

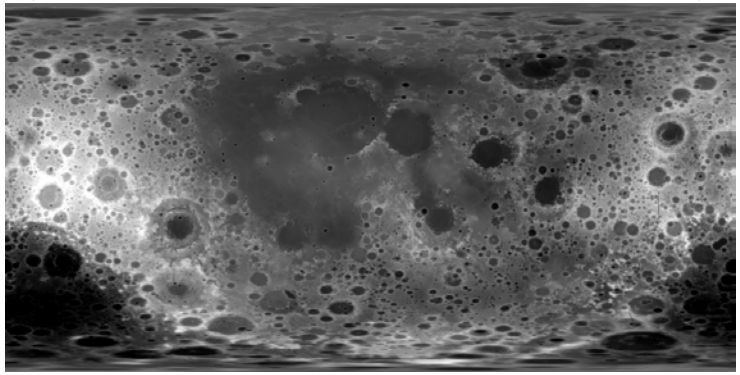
Summary

- **Combined method significantly increases the number of match-up of the keypoints**
  - **SIFT method to derive the keypoints**
  - **Selenographic lat/lon derived from the Ray-matching method provides the regional researching target**
  - **Iterated method removed the mis-matched keypoints outliers until the transformation algorithm is settled and converged.**
- **More matched keypoints will improve the image-to-image registration accuracy**
  - **Linear affine transformation is not sufficient to reach the registration accuracy at subpixel level for global image pixels**
  - **Consider to select the matched keypointes near the ROI regions only in the future.**

SELENE (Kaguya) Data to Select the Target Areas

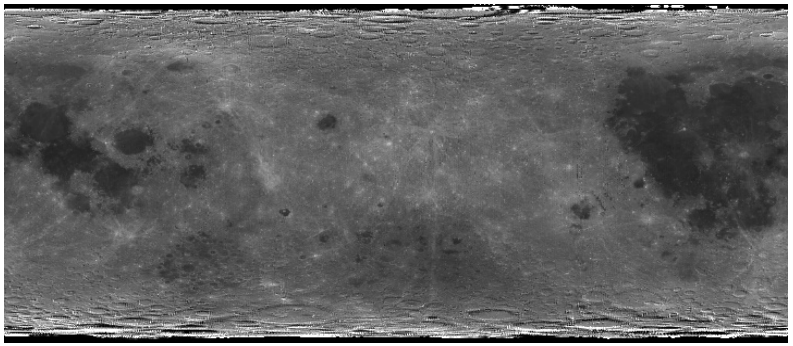
SELENE/LALT

(-180, 90) (180, 90)



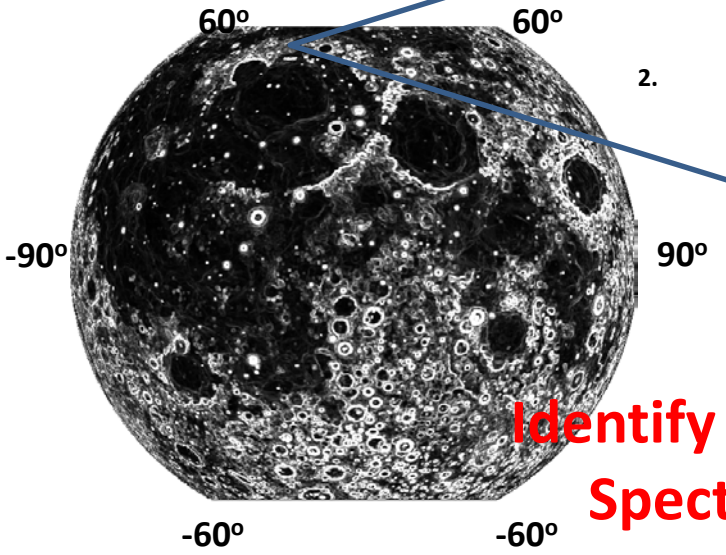
(-180,-90) (180, -90)

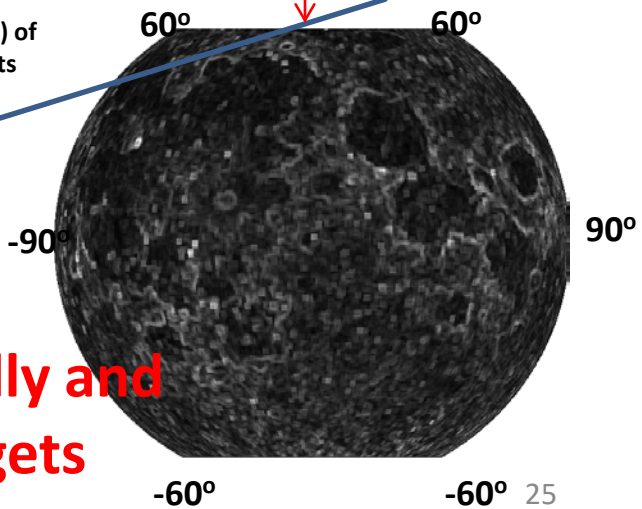
SELENE/SP



Spectral convolution with ABI B2 SRF

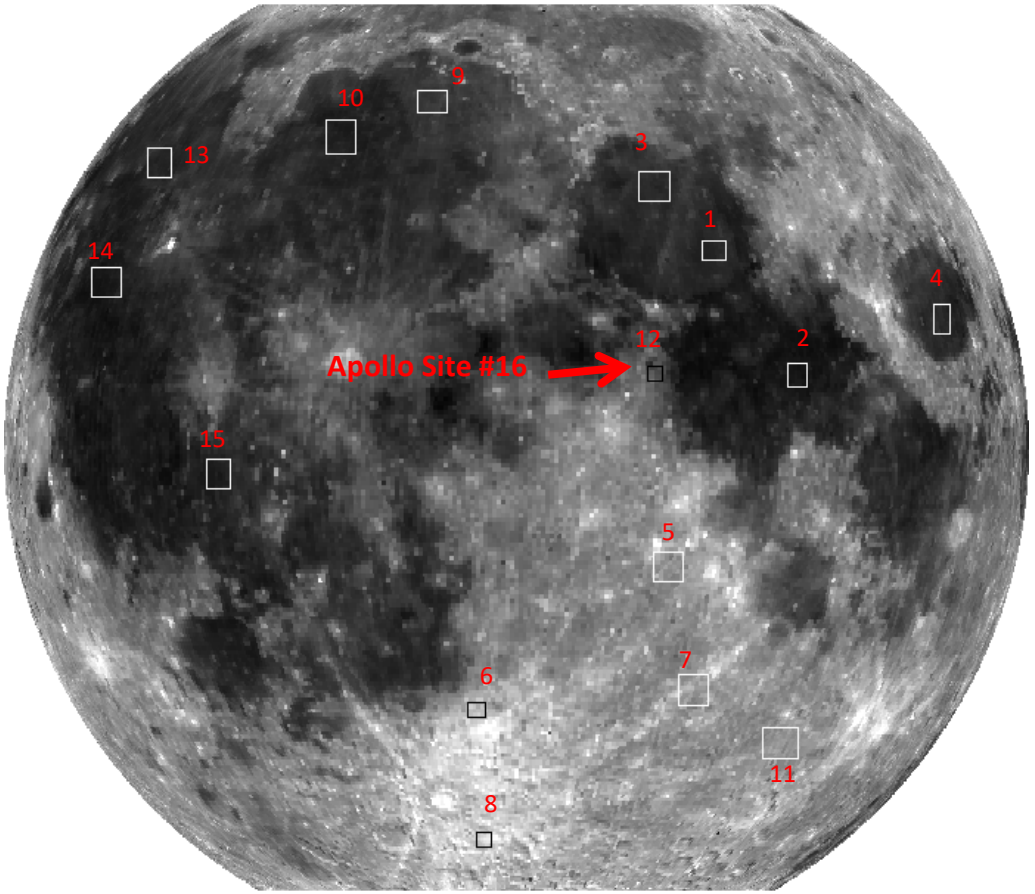
1. Re-project the near side of lunar surface products from cylindrical onto plane projection with selenographic coordinate at 5km/grid spatial resolution at Equator
2. Generate the Coefficient of Variation (CoV) of the topographic and radiometric products
3. Combine the CoV maps





Identify the Topographically and Spectrally Uniform Targets

Lunar Surface Targets



Selected Lunar Target Sites

ABI and AHI Lunar Images Registration

ABI – 2017/02/12T18:57:28

AHI – 2017/02/12T03:11:32

Ongoing Effort....