RER, FWHM, MTF from Landsat-8 OLI Lunar data (Level 1R) (Draft)

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Purpose

- Measuring the Spatial Characteristics from Landsat-8 OLI Lunar data (Level 1R)
  - RER, FWHM, MTF

- Major Initial Considerations
  1. Not Geometric Corrected
     a. CCD Geometry
  2. Not Circle (Level 1R)
  3. Not Uniform Brightness
  4. Shadow area

LO800U0006422013175LGN00
Level 1R, Band_8, PAN
Assumption & Uncertainty

1. Minor initial effects
   a. Almost circle of Lunar data after Geometric corrected (Level 1R)
   b. Symmetric LSF each direction of Landsat-8 OLI
   c. Outer line of Lunar data is almost circle line at the Landsat 8 resolution (30m)
   d. Brightness variation in one Step angle (Pie)
   e. Inflection point on LSF may be the starting point of Bright & Dark area
   f. Top inflection point on LSF may be the center of RER by CSAPS

2. Geometric Correction with CCD Geometry (Minor initial effect)
   a. Scanning rate on Pitch for imaging the Moon may be Constant.

3. Drop out the low reliable angle values
   a. Big Brightness variation in one Step angle (StdDev_B_Y) (> 0.07)
   b. Angle: 0, 90, 180, 270deg
   c. etc.
Step to Calculate (1/6)

1. Decide Initial value
   a. Step angle (Pie): ‘5 deg’
   b. Fitting method: Fermi-Direct (Symmetric LSF)
   c. Width of Bright/Dark area from Starting point: ‘1 pixel’

2. Read CPF & Get the CCD Geometric data
   a. Get ‘OLI_FOCAL_PLANE’ & ‘OLI_DETECTOR_OFFSETS’ in CPF
   b. Band: 9, SCA: 14
   c. Save them into ‘MAT’ file for Matlab

3. Read L8 Lunar data (Level 1R), HDF5 & temp Mapping XY
   a. Search the Number of SCA that has Lunar data
   b. Read Legendre & Offset with Band & SCA from (2.c)
   c. temp Mapping XY(Along & Across) from Legendre & Offset

4. Search, Subset & Display the only Lunar data
   a. Search & subset the area of the Lunar data on the whole image
   b. Make temporarily circle(?) Lunar data by applying with nearly offset ‘2’ & nearly ‘8’ (2 x 8 = 16)
   c. Display it
Step to Calculate (2/6)

5. Find the Shadow angle range with the subset Lunar data (4.b)
   a. ‘imgradient(4.b)’ in Matlab
   b. Remain the only Edge area from (5.a)
   c. Calculate the next value for every pixel in Edge area (5.b);
      1) Angle from temp center
      2) Distance from temp center
      3) DN
      4) Y, X (row, column)
   d. Calculate the next value for Step angle (1.a);
      1) StdDev(Distance * DN)
      2) Mean(DN)
      3) Max(DN)
   e. Calculate the next value for Step angle from (5.d)
      a. Ang = 0 : (Step angle, 5 deg) : 355
      b. Mean[(5.d)(Ang : Ang+180)]
   f. Shadow angle range is
      1) (Start) Min(5.e) ~ (End) Max(5.e)
   g. Edge angle range is
      1) (Start) Max(5.e) ~ (End) Min(5.e)
6. Get ‘Alpha, deltaY(along) / deltaX(across)’
   a. Apply imgradient in Matlab to the Lunar data of only Odd or Even detector
   b. Remove the Shadow angle range by (5.f)
   c. Ellipse fitting
   d. Get the next;
      1) Center (x0, y0)
      2) a (deltaY, along), b (deltaX, across)
      3) Alpha = a / b

7. Get the Final Map XY
   a. Multiply ‘Alpha’ to MapXY with the number of Row(Y) & Column(X) (integer) by the size of the subset Lunar data (4.a)
   b. Apply temp Mapping XY (3.c) to MapXY (7.a)
Step to Calculate (4/6)

8. Get ESF (Edge Spread Function)
   a. Divide Images by Step angle (5 deg) on L1R Lunar data
   b. (X-axis) Every pixel’s distance from the center (6.d.1) of the L1R Lunar data to MapXY (7.b)
   c. (Y-axis) Every pixel’s DN
   d. Getting the Inflection points in LSF by CSAPS fitting (TBD)
   e. Trim the Bright & Dark area with 1 pixel (TBD) width from the inflection points
   f. Fitting ESF by Fermi-Dirac function (L8 OLI has a symmetric LSF)
   g. Calculating the Standard Deviation of X & Y at Bright & Dark area

(8.a)

(8.b)
X-axis: Distance from Center to a Pixel

Edge in each Angle (210 deg)
Step to Calculate (5/6)

   a. RER with the center of the LSF inflection point
   b. FWHM, FWHM80, FWHM25
   c. MTF value at Nyquist fr.
Step to Calculate (6/6)

10. Get the plot of RER, FWHM, MTF by each Step angle (pie)
   a. Plot by 0~360deg except the Shadow area by 5deg
   b. Drop out the low reliable results with the bad conditions

11. Get Mean, Along & Across
   a. (Mean) Average
   b. (Along) Value at angle 0, 180
   c. (Across) Value at angle 90, 270
Drop out the low reliable angle results (1/4)

1. StdDev
   a. StdDev_Y_min < 0.02
   b. StdDev_Y_max > 0.07 (Big Brightness variation in one Step angle)
   c. StdDev_X_min < 0.2
2. Biggest RER & Lowest RER
3. Angle
   a. 0, 90, 180, 270
4. Peculiar angle
   a. (Difference with adjacent angle > 0.15) & (StdDev_Bright_Y > 0.07)
   b. Difference with adjacent angle > 0.2
Drop out the low reliable angle results (2/4)

1. StdDev
   a. StdDev_Y_min < 0.02
   b. StdDev_Y_max > 0.07
   c. StdDev_X_min < 0.2
   d. StdDev_X_max < ?? (TBD)
Drop out the low reliable angle results (3/4)

1. StdDev
2. Biggest RER & Lowest RER
3. Angle
   a. 0, 90, 180, 270
Drop out the low reliable angle results (4/4)

1. StdDev
2. Biggest RER & Lowest RER
3. Angle
4. Peculiar angle
   a. (Difference with adjacent angle > 0.15) & (StdDev_Bright_Y > 0.07)
   b. Difference with adjacent angle > 0.2

```
1. StdDev
2. Biggest RER & Lowest RER
3. Angle
4. Peculiar angle
   a. (Difference with adjacent angle > 0.15) & (StdDev_Bright_Y > 0.07)
   b. Difference with adjacent angle > 0.2
```

![Graph 1](image1)
![Graph 2](image2)
Results of L1R_LO800U0006422013175LGN00
ESF, LSF, MTF (Band_1, Angle: 210deg)
ESF, LSF, MTF (Band_2, Angle: 210deg)
ESF, LSF, MTF (Band_3, Angle: 210deg)
ESF, LSF, MTF (Band_4, Angle: 210deg)
ESF, LSF, MTF (Band_5, Angle: 210deg)
ESF, LSF, MTF (Band_6, Angle: 210deg)
ESF, LSF, MTF (Band_8, PAN, Angle: 210deg)
ESF, LSF, MTF (Band_9, Angle: 210deg)
RER, FWHM, MTF (Band_1)

- **RER:**
  - Along = 0.927, Across = 1.062
  - Mean = 0.985

- **FWHM:**
  - Along = 0.755, Across = 0.590
  - Mean = 0.684

- **MTF:**
  - Along = 52.316, Across = 66.002
  - Mean = 58.207

- **StdDev of Bright Y area:**
  - Mean = 0.041
RER, FWHM, MTF (Band_2)

- **RER**
  - Along = 0.912, Across = 1.061
  - Mean = 0.977

- **FWHM**
  - Along = 0.774, Across = 0.591
  - Mean = 0.694

- **MTF**
  - Along = 50.765, Across = 65.866
  - Mean = 57.374

- **StdDev of Bright Y area**
  - Mean = 0.040
RER, FWHM, MTF (Band_3)
RER, FWHM, MTF (Band_4)

- RER:
  - Along = 0.950, Across = 0.981
  - Mean = 0.964

- FWHM:
  - Along = 0.726, Across = 0.687
  - Mean = 0.708

- MTF:
  - Along = 54.651, Across = 57.954
  - Mean = 56.186

- StdDev of Bright Y area:
  - Mean = 0.038
RER, FWHM, MTF (Band_5)

RER

- Along = 0.930, Across = 0.993
- Mean = 0.957

FWHM

- Along = 0.752, Across = 0.671
- Mean = 0.718

MTF

- Along = 52.608, Across = 59.145
- Mean = 55.425

StdDev of Bright Y area

- Mean = 0.036
RER, FWHM, MTF (Band_6)

- **RER**
  - Along = 0.942, Across = 0.937
  - Mean = 0.940

- **FWHM**
  - Along = 0.735, Across = 0.742
  - Mean = 0.738

- **MTF**
  - Along = 54.000, Across = 53.345
  - Mean = 53.696

- **StdDev of Bright Y area**
  - Mean = 0.031
RER, FWHM, MTF (Band_7)
RER, FWHM, MTF (Band_8, PAN)
RER, FWHM, MTF (Band_9)
### Dataset of Level 1R Lunar data

<table>
<thead>
<tr>
<th>No.</th>
<th>Filename</th>
<th>SCA</th>
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<tbody>
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<td>1</td>
<td>LO800U0006422013175LGN00</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>LO800U1043222014076LGN00</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>LO800U2007202013351LGN00</td>
<td>8</td>
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</tbody>
</table>
## Result of RER, FHWM, MTF

| Band | Dataset | SCA | RER | | FHWM | | MTF |
|------|---------|-----|-----|-----|-----|-----|-----|-----|
|      |         |     | mean| Along| Across| mean| Along| Across|
| B1   | LO800U0006422013175LGN00 | 8   | 0.985 | 0.927 | 1.062 | 0.684 | 0.755 | 0.590 |
|      | LO800U1043222014076LGN00 | 7   | 0.938 | 0.904 | 0.981 | 0.742 | 0.787 | 0.686 |
|      | LO800U2007202013351LGN00 | 8   | 0.980 | 0.948 | 1.009 | 0.688 | 0.728 | 0.651 |
|      | Average |     | 0.968 | 0.926 | 1.017 | 0.705 | 0.757 | 0.642 |
| B2   | LO800U0006422013175LGN00 | 8   | 0.977 | 0.912 | 1.061 | 0.694 | 0.775 | 0.591 |
|      | LO800U1043222014076LGN00 | 7   | 0.933 | 0.882 | 0.985 | 0.750 | 0.818 | 0.681 |
|      | LO800U2007202013351LGN00 | 8   | 0.962 | 0.924 | 1.002 | 0.711 | 0.759 | 0.660 |
|      | Average |     | 0.957 | 0.906 | 1.016 | 0.718 | 0.784 | 0.644 |
| B3   | LO800U0006422013175LGN00 | 8   | 0.970 | 0.947 | 0.996 | 0.703 | 0.730 | 0.670 |
|      | LO800U1043222014076LGN00 | 7   | 0.923 | 0.907 | 0.940 | 0.762 | 0.781 | 0.743 |
|      | LO800U2007202013351LGN00 | 8   | 0.963 | 0.953 | 0.972 | 0.709 | 0.722 | 0.696 |
|      | Average |     | 0.952 | 0.936 | 0.969 | 0.725 | 0.744 | 0.703 |
| B4   | LO800U0006422013175LGN00 | 8   | 0.965 | 0.950 | 0.981 | 0.708 | 0.726 | 0.687 |
|      | LO800U1043222014076LGN00 | 7   | 0.925 | 0.897 | 0.958 | 0.759 | 0.797 | 0.715 |
|      | LO800U2007202013351LGN00 | 8   | 0.973 | 0.930 | 1.011 | 0.697 | 0.748 | 0.653 |
|      | Average |     | 0.954 | 0.926 | 0.983 | 0.721 | 0.757 | 0.685 |
| B5   | LO800U0006422013175LGN00 | 8   | 0.957 | 0.930 | 0.994 | 0.718 | 0.752 | 0.672 |
|      | LO800U1043222014076LGN00 | 7   | 0.916 | 0.893 | 0.942 | 0.770 | 0.802 | 0.735 |
|      | LO800U2007202013351LGN00 | 8   | 0.939 | 0.941 | 0.938 | 0.739 | 0.737 | 0.741 |
|      | Average |     | 0.937 | 0.921 | 0.958 | 0.742 | 0.764 | 0.716 |
| B6   | LO800U0006422013175LGN00 | 8   | 0.940 | 0.942 | 0.937 | 0.738 | 0.735 | 0.742 |
|      | LO800U1043222014076LGN00 | 7   | 0.915 | 0.916 | 0.915 | 0.770 | 0.769 | 0.772 |
|      | LO800U2007202013351LGN00 | 8   | 0.922 | 0.916 | 0.928 | 0.764 | 0.779 | 0.751 |
|      | Average |     | 0.926 | 0.925 | 0.927 | 0.757 | 0.761 | 0.755 |
| B7   | LO800U0006422013175LGN00 | 8   | 0.929 | 0.932 | 0.925 | 0.753 | 0.750 | 0.757 |
|      | LO800U1043222014076LGN00 | 7   | 0.894 | 0.891 | 0.878 | 0.815 | 0.805 | 0.823 |
|      | LO800U2007202013351LGN00 | 8   | 0.925 | 0.943 | 0.908 | 0.758 | 0.735 | 0.780 |
|      | Average |     | 0.913 | 0.922 | 0.904 | 0.775 | 0.763 | 0.787 |
| B8   | LO800U0006422013175LGN00 | 8   | 0.846 | 0.819 | 0.885 | 0.871 | 0.910 | 0.813 |
|      | LO800U1043222014076LGN00 | 7   | 0.790 | 0.765 | 0.816 | 0.961 | 1.001 | 0.918 |
|      | LO800U2007202013351LGN00 | 8   | 0.834 | 0.806 | 0.864 | 0.890 | 0.934 | 0.843 |
|      | Average |     | 0.823 | 0.797 | 0.855 | 0.907 | 0.948 | 0.858 |
| B9   | LO800U0006422013175LGN00 | 8   | 0.957 | 0.960 | 0.952 | 0.718 | 0.714 | 0.724 |
|      | LO800U1043222014076LGN00 | 7   | 0.933 | 0.928 | 0.938 | 0.748 | 0.753 | 0.743 |
|      | LO800U2007202013351LGN00 | 8   | 0.938 | 0.956 | 0.922 | 0.742 | 0.719 | 0.763 |
|      | Average |     | 0.943 | 0.948 | 0.937 | 0.736 | 0.729 | 0.743 |
## Compare and Result of RER, FHWM, MTF

<table>
<thead>
<tr>
<th>OLI</th>
<th>Edge Slope</th>
<th>GSD</th>
<th>RER</th>
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<tbody>
<tr>
<td>Specification</td>
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<td>15</td>
<td>0.81</td>
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<tr>
<td>Measured (Jim Storey at TIM, 2013.12)</td>
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<td>Measured (Jim Storey at TIM, 2014.04)</td>
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<td>29.934</td>
<td>14.932</td>
<td>0.887842</td>
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<table>
<thead>
<tr>
<th>Band</th>
<th>RER</th>
<th>FWHM</th>
<th>MTF</th>
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<tr>
<td>1</td>
<td>0.968</td>
<td>0.705</td>
<td>56.47</td>
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<td>3</td>
<td>0.952</td>
<td>0.725</td>
<td>54.87</td>
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<td>4</td>
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<td>0.721</td>
<td>55.09</td>
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<tr>
<td>5</td>
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<td>6</td>
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<td>8 (PAN)</td>
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<td>41.37</td>
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<tr>
<td>9</td>
<td>0.943</td>
<td>0.736</td>
<td>53.92</td>
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</table>
Issues & Concerns

1. Along & Across
   a. \((X\text{-axis}) \ast \cos(\text{Edge line angle})\)
   b. (Along) Value at angle 0, 180 / (Across) Value at angle 90, 270 by ‘Sine Fitting’
   c. In B6, B7 and B9, Along & Across are almost same (Is it OK?)
      a. Cause by Sine Fitting (?)
      b. Signal difference between Bands (?)

2. SCA_7 & SCA_8
   a. SCA_7 is smaller than SCA_8
   b. Cause by the short number of Dataset (?)
   c. Cause by scanning difference between them
Future Work

1. Debugging

2. Process, Get and Compare the result of more Level 1R Lunar data

3. Need More Criterions to remove the low reliable angle value