Spatial Resolution Characterization for Aerial Digital Imagery

Slawomir Blonski, Kenton Ross, Mary Pagnutti
Science Systems and Applications, Inc.

Thomas Stanley
NASA Stennis Space Center, Mississippi

Acknowledgements
Robert Ryan, SSAI SSC
Vicki Zanoni, NASA GSFC

Participation in this work by Science Systems and Applications, Inc., was supported by NASA at the John C. Stennis Space Center, Mississippi, under Task Order NNS04AB54T.
Spatial Characterization Approach

• NASA and the U.S. Geological Survey (USGS) have jointly developed capability for characterization of aerial digital imagery:
  – USGS defines characterization requirements and interfaces with industry.
  – NASA performs characterizations of image products using the Stennis Space Center (SSC) test range.
• Analysis includes geopositional accuracy and spatial response:
  – Radiometric characterization is to be performed in the future.
• Spatial response is characterized based on measurements of Relative Edge Response (RER):
  – RER is one of the engineering parameters used in the General Image Quality Equation (GIQE) to provide predictions of imaging system performance expressed in terms of the National Imagery Interpretability Rating Scale (NIIRS).
• RER is estimated using the SSC edge targets and the tilted edge technique:
  – RER is a geometric mean of normalized edge response differences measured in two directions of image pixels (X and Y) at points distanced from the edge by -0.5 and 0.5 ground sample distance (GSD).
SSC Edge Targets

- Two pairs of edge targets painted on a concrete surface
- Orientation differs by 4 degrees to accommodate images with various pixel directions (Universal Transverse Mercator (UTM)-projected and others)

Image of the SSC edge targets acquired by the QuickBird satellite (60 cm GSD).
Tilted Edge Technique

\[ x = \delta \cos \theta \]

\( \theta \) – edge tilt angle
\( \delta \) – pixel index
\( x \) – pixel's distance from edge (in GSD)

**Problem:** Digital cameras undersample edge target

**Solution:** Image tilted edge to improve sampling

Superposition of 24 edge responses shifted to compensate for the tilt

3 examples of undersampled edge responses measured across the tilted edge
Relative Edge Response

\[ RER = \sqrt{[ER_X(0.5) - ER_X(-0.5)][ER_Y(0.5) - ER_Y(-0.5)]} \]

\textit{RER estimates effective slope of the imaging system’s edge response, since the distance between the points for which the differences are calculated is always equal to the GSD.}
Effects of RER on Civil NIIRS

NIIRS estimates based on GIQE (assuming no MTF compensation).

Identify large farm animals by type (e.g., horses, cows) (NIIRS 6.7).

Smaller RER can degrade interpretability, despite finer GSD.

Detect individual large domesticated animals (e.g., horses, cattle) in grazing pastures (NIIRS 5.3).
Meaning of RER in Remote Sensing

Radiance measured for each pixel is assumed to come from the Earth’s surface area represented by that pixel. However, because of many factors, actual measurements integrate radiance $L$ from the entire surface with a weighting function provided by a system’s point spread function (PSF):

$$L_T = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} PSF(x, y)L(x, y)dx\,dy$$

Part of radiance that originates in the pixel area is given by:

$$L_P = \int_{-0.5}^{0.5} \int_{-0.5}^{0.5} PSF(x, y)L(x, y)dx\,dy$$

One can show that the Relative Edge Response squared ($RER^2$) can be used to assess the percentage of the measured pixel radiance that actually originates from the Earth’s surface area represented by the pixel:

$$\frac{L_P}{L_T} \approx RER^2$$

**A simple example:**

Box PSF

**Width = 2 GSD**

$ER(0.5) - ER(-0.5) = 0.75 - 0.25 = 0.50$

$RER = 0.50$

$$RER^2 = 0.25$$ means that 25% of information collected with the pixel PSF (blue square) comes from the actual pixel area (shadowed square)
Example: 15 cm GSD Panchromatic Image

Image area selected for the spatial resolution measurement in the Northing direction.

Full edge response extracted from the selected area of the image.

Central part of the edge response used to measure the RER difference.
Example: 30 cm GSD Multispectral Image

Section of the characterized image showing the SSC edge targets.

Full edge response extracted from the selected area of the image.

Central part of the edge response used to measure the RER difference.
## Spatial Characterization Results

<table>
<thead>
<tr>
<th>Image Acquisition Date</th>
<th>Sensor</th>
<th>Company</th>
<th>GSD (cm)</th>
<th>RER</th>
</tr>
</thead>
<tbody>
<tr>
<td>22-Nov-2002</td>
<td>Leica ADS40</td>
<td>EarthData International®</td>
<td>25</td>
<td>0.5 (BW)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.6 (IR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.5 (RGB)</td>
</tr>
<tr>
<td>24-Nov-2003</td>
<td>DAIS</td>
<td>Space Imaging® (GeoEye™)</td>
<td>50</td>
<td>0.7 (VNIR)</td>
</tr>
<tr>
<td>5-Dec-2003</td>
<td>IKONOS*</td>
<td>Space Imaging (GeoEye)</td>
<td>100</td>
<td>0.7 (pan)</td>
</tr>
<tr>
<td>18-Feb-2004</td>
<td>Z/I Imaging DMC</td>
<td>AERO-METRIC, INC.®</td>
<td>15</td>
<td>0.4 (pan)</td>
</tr>
<tr>
<td>8-Nov-2004</td>
<td>Z/I Imaging DMC</td>
<td>3001, Inc.®</td>
<td>15</td>
<td>0.5 (RGB), 0.4 (CIR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>0.6 (RGB), 0.5 (CIR)</td>
</tr>
<tr>
<td>23-Feb-2005</td>
<td>Z/I Imaging DMC</td>
<td>Florida Department of Transportation</td>
<td>30</td>
<td>0.6 (RGB)</td>
</tr>
</tbody>
</table>

*satellite

Reports with the characterization results have been delivered by NASA to USGS.

GSD – Ground Sample Distance  
RER – Relative Edge Response  
BW – Black, White  
IR – Infrared  
RGB – Red, Green, Blue  
VNIR – Visible/Near Infrared  
CIR – Color Infrared