Analysis of Oblique Image Datasets with OrientAL

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OrientAL

- Photogrammetric software package
- Python package: high level interface
- Multithreading, adjustment in C++ modules
- Using various 3rd party libraries (boost, OpenCV, GDAL, SQLite, Ceres, SuiteSparse, QT, ...)
- Scripts for SfM, Geo-Referencing, Orthophoto generation
- Image measurement viewer/editor
- Focus on orientation, calibration
ISPRS ICWG I/Vb Image Orientation Benchmark A/A

- Feature points:
  - Detection & description:
    - oblique aerials -> use Affine SIFT
    - Extract <= 40k features w strongest response
  - Matching:
    - Symmetrically nearest
    - Threshold on ratio of first & second nearest neighbors.
    - Extract 10k best matches.
  - Match filtering:
    - RANSAC E-matrix w threshold on distance from epipolar line
    - Break up feature chains at views with multiple projections (median 4%)

- 614k auto object points, 1.42M auto image points

<table>
<thead>
<tr>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>&gt;10</th>
</tr>
</thead>
<tbody>
<tr>
<td>486k</td>
<td>87k</td>
<td>28k</td>
<td>8k</td>
<td>3k</td>
<td>1.2k</td>
<td>517</td>
<td>293</td>
<td>156</td>
<td>146</td>
</tr>
<tr>
<td>79.2%</td>
<td>14.1%</td>
<td>4.6%</td>
<td>1.3%</td>
<td>0.5%</td>
<td>0.2%</td>
<td>0.08%</td>
<td>0.05%</td>
<td>0.03%</td>
<td>0.02%</td>
</tr>
</tbody>
</table>
ISPRS ICWG I/Vb Image Orientation Benchmark A/A

- Bundle block adjustment
  - Transform to local cartesian CS
  - Rigid fine-transformation to GCPs
  - Observations:
    - Manual GCP & CP image obs. (given)
    - Automatic feature point image obs.
  - Unknowns: EORs, IORs, polynomial radial distortion 3rd degree, object points
  - Robust loss function
  - Until max auto image residual < 3pix:
    - Discard object points with small maximum intersection angle
    - Discard image observations with large residuals
    - Reduce scale of robust loss function
  - Replace robust loss function with squared loss
  - 598k auto object points
  - 1.38M auto image points
Bundle block adjustment, cont.

- $\sigma_0 : 0.65\text{pix}$

Image residual norms:

<table>
<thead>
<tr>
<th></th>
<th>min</th>
<th>median</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>0.0</td>
<td>0.22</td>
<td>3.0</td>
</tr>
<tr>
<td>GCP</td>
<td>0.3</td>
<td>1.28</td>
<td>2.44</td>
</tr>
</tbody>
</table>

Omega/Phi:

<table>
<thead>
<tr>
<th></th>
<th>min</th>
<th>median</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega$</td>
<td>-1.00</td>
<td>-0.11</td>
<td>0.34</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>0.09</td>
<td>0.14</td>
<td>0.70</td>
</tr>
</tbody>
</table>

- IORs, ADPs within reasonable bounds
### ISPRS ICWG I/Vb Image Orientation Benchmark A/A

Maxima of absolute values of correlation coefficients $\rho$:

<table>
<thead>
<tr>
<th>Cam</th>
<th>$x_0$</th>
<th>$y_0$</th>
<th>$z_0$</th>
<th>$r^3$</th>
<th>$x_0@$</th>
<th>$y_0@$</th>
<th>$z_0@$</th>
<th>$r^3@$</th>
</tr>
</thead>
<tbody>
<tr>
<td>163 (nadir)</td>
<td>0.40</td>
<td>0.57</td>
<td>0.93</td>
<td>0.11</td>
<td>$z_{0,148}$</td>
<td>$z_{0,159}$</td>
<td>$Z_0$</td>
<td>$\varphi$</td>
</tr>
<tr>
<td>148 (front)</td>
<td>0.51</td>
<td>0.99</td>
<td>0.99</td>
<td>0.12</td>
<td>$\kappa$</td>
<td>$z_{0,148}$</td>
<td>$y_{0,148}$</td>
<td>$\omega$</td>
</tr>
<tr>
<td>145 (right)</td>
<td>0.32</td>
<td>1.00</td>
<td>1.00</td>
<td>0.16</td>
<td>$\varphi$</td>
<td>$z_{0,145}$</td>
<td>$y_{0,145}$</td>
<td>$\varphi$</td>
</tr>
<tr>
<td>147 (back)</td>
<td>0.55</td>
<td>0.99</td>
<td>0.99</td>
<td>0.09</td>
<td>$\kappa$</td>
<td>$z_{0,147}$</td>
<td>$y_{0,147}$</td>
<td>$\omega$</td>
</tr>
<tr>
<td>159 (left)</td>
<td>0.29</td>
<td>0.99</td>
<td>0.99</td>
<td>0.09</td>
<td>$\varphi$</td>
<td>$z_{0,159}$</td>
<td>$y_{0,159}$</td>
<td>$\varphi$</td>
</tr>
</tbody>
</table>
Object space is mostly flat

All nadir images share the same $\kappa$
  - $z_0$ and $Z_0$ highly correlated

Same rotation about optical axis for oblique images
  - $y_0$, $z_0$ of each camera fully correlated

Do not estimate IOR, but use lab calibration!
Constant IOR:

- $\sigma_0 : 0.65\text{pix (same)}$
- Image residual norms (smaller for GCPs!):

<table>
<thead>
<tr>
<th>[pix]</th>
<th>min</th>
<th>median</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>0.0</td>
<td>0.22</td>
<td>3.0</td>
</tr>
<tr>
<td>GCP</td>
<td>0.26</td>
<td>0.91</td>
<td>1.74</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th></th>
<th>163 (nadir)</th>
<th>148 (front)</th>
<th>145 (right)</th>
<th>147 (back)</th>
<th>159 (left)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r^3$</td>
<td>0.853</td>
<td>-0.004</td>
<td>0.365</td>
<td>0.196</td>
<td>0.317</td>
</tr>
<tr>
<td>$\sigma_{r^3}$</td>
<td>0.07</td>
<td>0.09</td>
<td>0.09</td>
<td>0.08</td>
<td>0.09</td>
</tr>
<tr>
<td>$</td>
<td>r^3</td>
<td>/\sigma_{r^3}$</td>
<td>12.7</td>
<td>0.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>
ISPRS ICWG I/Vb Image Orientation Benchmark A/A

- **Constant IOR:**
  - EOR std.devs.: \(\approx 5\text{cm}, \approx 3\text{ mgon}\)
  - Median relative offsets of oblique cameras & \(\sigma_{\text{MAD}}\)
  - Inconsistent
  - Mostly insignificant

<table>
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<tr>
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<th>145 (right)</th>
<th>147 (back)</th>
<th>159 (left)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{med}_X)</td>
<td>0.082</td>
<td>-0.191</td>
<td>-0.120</td>
<td>-0.090</td>
</tr>
<tr>
<td>(\text{med}_Y)</td>
<td>-0.124</td>
<td>0.006</td>
<td>-0.009</td>
<td>-0.175</td>
</tr>
<tr>
<td>(\text{med}_Z)</td>
<td>-0.399</td>
<td>-0.296</td>
<td>-0.154</td>
<td>-0.265</td>
</tr>
<tr>
<td>(\sigma_{\text{MAD},X})</td>
<td>-0.21</td>
<td>0.11</td>
<td>0.13</td>
<td>0.14</td>
</tr>
<tr>
<td>(\sigma_{\text{MAD},Y})</td>
<td>-0.12</td>
<td>0.08</td>
<td>0.14</td>
<td>0.10</td>
</tr>
<tr>
<td>(\sigma_{\text{MAD},Z})</td>
<td>-0.09</td>
<td>0.64</td>
<td>0.11</td>
<td>0.07</td>
</tr>
</tbody>
</table>
Fast & Efficient Decimation of Tie Points

- For large blocks, too many tie points may prohibit/hinder the adjustment due to limited RAM
- Most (e.g. 80% for benchmark) tie points observed in only 2 views
- 2-folds should not simply be discarded, because:
  - Images at block outline need them
  - Weakly textured areas
- Project:
  - 5-camera rig
  - 42k images, 4.9 μm per pixel, 25 / 50 mm focal length
  - GSD 12cm, 70%/60% overlap, 600m flying height, nadir footprint ca. 600 x 900 m²
  - GPS/INS inaccurate, cams not synchronized
- Features detected/matched in sub-blocks using Pix4D
- 1.03M tie points - too many to estimate all EORs, IORs, ADPs at once.
- How many are really necessary, and which ones?

EurosSDR/ISPRS workshop on Oblique Cameras & Dense Image Matching
20. 10. 2015, Southampton, UK

Analysis of Oblique Image Datasets w OrientAL
Fast & Efficient Decimation of Tie Points

- Decimate tie points in object space
  - Grid overlay in X,Y-plane, cell size 100m
  - For each cell, select the tie point detected in most images (multiplicity)
  - Discard all other tie points
  - 85k tie points (8%), 613 images non-orientable, all oblique.

- Decimate in object space for each camera separately
  - 427k (42%) tie points, 50 images non-orientable, all oblique.

- Decimate in image space
  - Grid overlay in x,y-plane of each camera, 5x3 grid
  - For each camera
    - For each cell
      - If cell is empty, select tie point with highest multiplicity
      - Insert tie point into resp. cells of other cameras, if visible
Fast & Efficient Decimation of Tie Points

- Decimate in image space, cont.
  - 144k (14%) tie points, all images orientable

<table>
<thead>
<tr>
<th></th>
<th>1 (nadir)</th>
<th>2 (oblique)</th>
<th>3 (oblique)</th>
<th>4 (oblique)</th>
<th>5 (oblique)</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>14</td>
<td>15</td>
<td>14</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>median</td>
<td>101</td>
<td>34</td>
<td>37</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>max</td>
<td>296</td>
<td>138</td>
<td>158</td>
<td>138</td>
<td>148</td>
</tr>
</tbody>
</table>

- Tie points with high multiplicity mostly in nadir images!
- Decimation in object space is steered by nadir images.
Outlook

- **Benchmark dataset:**
  - Investigate relative orientation of cameras on the rig

- **Tie point decimation:**
  - Investigate effect of decimation on precision of estimated parameters
  - How much decimation can be done without affecting them?
Thanks for your attention!