Handling Of High Resolution Space Images In ImageStation

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Presentation Outline

- Introduction
- Rigorous / Approximate Sensor Models
  - Rational Functions (RFs)
  - Advantages / Disadvantages of RFs
- Multi-sensor Triangulation Workflow
- Numerical Results
- Summary
Satellite Orbital Characteristics

- Circular earth orbit
  - Sun-Synchronous
  - Asynchronous
- Altitudes of 200-680 km
- Average orbit revolution time ~ 90 minutes
- Revolutions are numbered with an average of 16 passes per day
Satellite Image Acquisition Principles

“WHISKBROOM”
Cross-track Electromechanical Scanner
Multiple Detectors/Bands
Scan Mirror

“PUSHBROOM”
Linear Detector Array
Electronically Scans Across Track
Linear Detector Array (One Array/Band)

“STARING ARRAY”
Frame Imaging
Two-Dimensional Array For Each Band
Satellite Imagery - Advantages/Limitations

**Advantages:**
- Global Access
- Wide area
- Frequent access
- Non-intrusive
- Digital downlink
- Worldwide archive (back to 1973)

**Limitations:**
- Atmospheric Conditions (clouds, haze, etc.)
- Distribution networks
- Timeliness and Price
- Data/Image Quality and Standards
- Education and Training
- Government Regulations
- International Copy Right
- Security and Criminal Use
Satellite Sensor Models

- Interpolative Models – Collinearity Equations
- Projective Models – Polynomials (1\textsuperscript{st}, 2\textsuperscript{nd}, 3\textsuperscript{rd} order)
  - Depending upon the values of $i, j, k, p_2,$ and $p_4$)
Rigorous Sensor Models

**Advantages:**
- Time-dependant collinearity equations
- Rigorous orbital constraints (ephemeris data)
- “Exterior Orientation” on an orbital basis
- Platform and sensor distortion
- Earth, datum/map projection distortion

**Disadvantages:**
- Sensor physical parameters not often known
- Vendors may not publish sensor model
- Sensor model is complex requiring specialized software
- Real-time loop math must be changed for each sensor
RFs – Advantages / Disadvantages

**Advantages:**
- Sensor independent
- Sufficient speed for real-time loop
- Support any map projection system
- Easy inclusion of external sensors

**Disadvantages:**
- Cannot model local distortions
- Coefficients do not have physical meaning
- Accuracy decreases when image gets larger
- Over parameterization
- Zero crossing
Digital Photogrammetry Workflow

ImageStation Products

- Mission Planning
- Photogrammetric Manager
- Orient / Trig
- 3D Feature/DTM Collection
- Orthophoto Production

Scan Photos
Input Digital Images

GIS
Maps
Digital data
Engineering
Implemented Satellite Sensors

- IKONOS
- QuickBird
- SPOT
- Landsat
<table>
<thead>
<tr>
<th>Sensor</th>
<th>Image Support Data</th>
<th>Processing Level</th>
<th>Image Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat</td>
<td>FAST, FASTL7a, HDI</td>
<td>1G - Space Oblique Mercator</td>
<td>4 and 5 TM (30 m) 7 ETM (15 &amp; 30m)</td>
</tr>
<tr>
<td>IRS</td>
<td>SuperStructure (LGSOWG)</td>
<td>1A</td>
<td>Pan sub-scene 1-9 Pan strip L, M, R</td>
</tr>
<tr>
<td>SPOT</td>
<td>CAP, DIMAP</td>
<td>1A</td>
<td>SPOT 1-3 (10-20 m) SPOT 4 (10-20 m) SPOT 5 (10, 5, 2.5 m)</td>
</tr>
<tr>
<td>QuickBird</td>
<td>ISD</td>
<td>1B (30m DTM)</td>
<td>Pan Multi (0.61 m) (2.44 m)</td>
</tr>
</tbody>
</table>
Satellite Triangulation Workflow

- Create Satellite Project
- Import or Key in Control Point (WGS84)
- Read Ephemeris Data for Each Imagery
- Define Rational Function Bitmaps
- Measure Control/Check/Pass Points
- Perform Satellite Triangulation
- Generate Image/Object Grids
- Fit RFs to These Grids
- Use RFs for 3D Collection and Orthophoto Generation
Coordinate System & Map Registration

Generate “Drive Parameters”

Map Registration

Map Sheet Coordinate System
Map/Image Registration
Generate Image/Object Grids & RFs

After a Successful Bundle Adjustment:

- Create Image Grid for Each Imagery
- Project Image Coords. onto Several Elevation Planes
- Fit RFs to These Grids by Least Squares
- Analyze Results/Coefficients
- Use RF Coeffs. as Real-Time Math Model
Data and Numeric Results

- **IKONOS (San Diego, US)**
  - Two Stereo Pair (Geo Product)
  - 6 Control points
- **SPOT5 (Avignon, France)**
  - 4 Level 1A Images (5m, 2.5m)
  - 22 Control Points
- **QuickBird (Denver, US)**
  - 11 Basic Images
  - 70 Control points
  - USGS 10m DEM
IKONOS Adjustment
IKONOS – RFC Adjustment

[Image of software interface showing options for IKONOS images]
IKONOS Triangulation

**Satellite Triangulation Results**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>R</th>
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</thead>
<tbody>
<tr>
<td>RMS Control</td>
<td>0.04</td>
<td>0.02</td>
<td>0.00</td>
<td>0.02</td>
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<tr>
<td>RMS Check</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>RMS Limits</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Mean Std Dev</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Max Residual</td>
<td>0.06</td>
<td>0.08</td>
<td>0.06</td>
<td>0.08</td>
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<tr>
<td>Residual Limits</td>
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<td>3.00</td>
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<td>RMS Image</td>
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<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
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</tbody>
</table>

**Key Statistics**

- Number of Iterations: 2
- Degrees of Freedom: 24
- Solution Successful

**Number of Control Points Used**

<table>
<thead>
<tr>
<th># of Control Points Used</th>
<th>Latitude DX(m)</th>
<th>Longitude DY(m)</th>
<th>Height DZ(m)</th>
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<tbody>
<tr>
<td>0</td>
<td>1.3</td>
<td>1.6</td>
<td>2.2</td>
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<tr>
<td>1</td>
<td>0.1</td>
<td>0.7</td>
<td>-0.1</td>
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<tr>
<td>2</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
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<tr>
<td>4</td>
<td>0.0</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**IKONOS Options**

- **Mapping Coordinate System**
- **Adjustment Settings**
  - Bias Parameters: Line (4.0 pixels), Sample (4.0 pixels)
  - Scale Parameters: Std Dev

**Notes:**

- Update Model Grids and Rational Functions on Accept

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ISPRS Hannover Workshop 2005
SPOT Triangulation
QuickBird Project
QuickBird - Measurements
QuickBird Triangulation

Satellite Triangulation Parameter Weights

- In Track Position Std Dev: 3
- Cross Track Position Std Dev: 3
- Radial Position Std Dev: 3
- In Track Velocity Std Dev: 0.1
- Cross Track Velocity Std Dev: 0.1
- Radial Velocity Std Dev: 0.1
- Omega Bias Std Dev: 1
- Phi Bias Std Dev: 1
- Kappa Bias Std Dev: 1
- Omega Bias Rate Std Dev: 10
- Phi Bias Rate Std Dev: 10
- Kappa Bias Rate Std Dev: 10

Satellite Triangulation Results

Summary Statistics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>XY</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS Control</td>
<td>0.396</td>
<td>0.205</td>
<td>0.174</td>
<td>0.206</td>
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<tr>
<td>RMS Check</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>RMS Limits</td>
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<td>0.700</td>
<td>0.000</td>
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<tr>
<td>Mean Std Dev</td>
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<td>0.205</td>
<td>0.931</td>
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<tr>
<td>Max Residual</td>
<td>0.972</td>
<td>0.899</td>
<td>0.893</td>
<td>0.000</td>
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<tr>
<td>Residual Limits</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
</tr>
<tr>
<td>RMS Image</td>
<td>0.3</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Current Count:

- Control Points: 72
- Check Points: 0
- Photos Used: 11
- Observations: 137

Key Statistics

- Sigma: 1.0
- Number of Iterations: 2
- Degrees of Freedom: 274
- Solution Successful

Project Settings

- Linear Units: Meters
- Angular Units: Degrees
QuickBird Project Footprint
QuickBird – Source Data
QuickBird Orthos
ImageStation Satellite Triangulation is very flexible
- Math model is implemented in a Microsoft Common Object Model (COM)-based code module
- Allows support for new satellite remote sensor with relative ease
- Accommodates variations in the number and scope of adjustable parameters
- Unified, weighted, simultaneous least squares adjustment
- IKONOS math model is based on rational polynomial functions modified by an affine transformation

Mapping with high resolution space images is becoming a reality

For several applications there is a direct competition between aerial and space images, and the choice of which product to use is purely economical
Thank you for your attention.