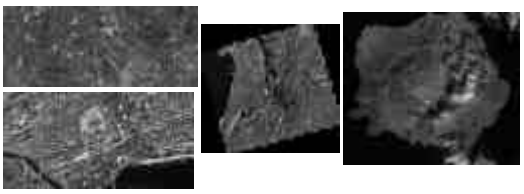
Radiometric and Geometric Evaluation of IKONOS GEO Images and their Use for 3D Building Modelling



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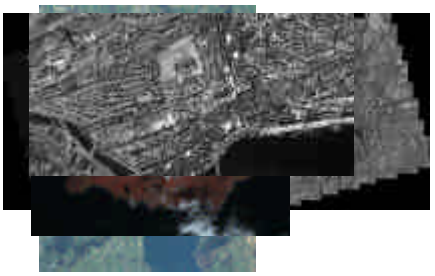
Outline

- Description of Image Data
- Radiometric Analysis
- Preprocessing
- Orthoimage Generation
- Building Extraction
- Conclusions

Image Data

Nadir PAN (Melbourne)



Radiometric Quality

Preprocessing by SI:

•Modulation Transfer Function Correction (MTFC)

Sharpen image especially in flight direction due to TDI imaging (typically 16 lines), which causes blurring

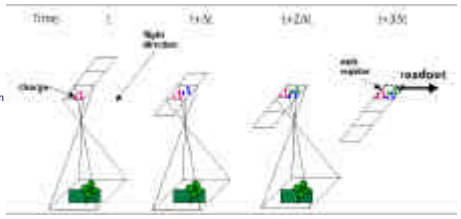
•Dynamic Range Adjustment (DRA)

Stretchgrey values to better occupy grey value range

Additional artifacts are due to compression from 11 to 2.6 bit (esp. in homogeneous areas)

Radiometric Quality

Time Delay and Intergration



Exposure Principle of TDI detector with 3 stages

Radiometric Quality

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Radiometric Quality

Important aspects for Feature Extraction

Pan-Sharpened 1m *Ikonos* (7⁰ tilt, summer end)

Stereo 1m *Ikonos* (29⁰ tilt, winter)

- ♣ View angle
- ♣ Sun angle & Shadowing
- ♣ Season
- ♣ Atmospheric conditions

- ♣ Stereo or mono
- • Colour or B&W
- ♣ Image preprocessing
- • Building characteristics & size

♣ *factors over which there is no or limited operational control*

Radiometric Quality

• Role of shadows and saturation

Radiometric Quality

• Image quality / interpretability can vary dramatically

Luzern

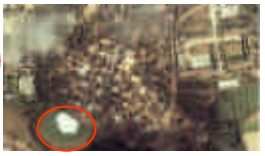
Greek village (Nisyros)

Image feature variation - *Ikonos* GEO 1m pan sharpened (RGB)
Similar sun elevation / azimuth, quite similar sensor elevation

4 / 4 / 2001

9 / 4 / 2001

10 / 4 / 2001



30 / 4 / 2001

Radiometric Quality

11bit histogram Nadir PAN (Melbourne) - without DRA

11bit histogram Nadir PAN (Luzern) - with DRA

D R A stretches the GVs to cover more uniformly the 11 bit range .

Result : Absolute radiometric accuracy is destroyed + leads to combination of GVs that are not frequently occupied

Radiometric Quality

Noise characteristics analyzed in areas:

• homogeneous (lake and sea surfaces)

Image type	Mean std. dev.
PAN-MSI	5.2
MSI	2.0
PAN	4.6
PAN-DRA	5.0

Noise generally high since 11bit data represent 8-9 effective bits

Radiometric Quality

Image Data
Rad. Quality
Noise
Artifacts
Preprocessing
Orthoimage
Building extraction
Conclusions

Noise characteristics analyzed in areas:

- **non-homogeneous (whole image excluding large homog. areas)**

Stereo	0-127	128-255	256-383	384-511	512-639	640-767
Raw	2.6	3.1	4.1	4.7	5.6	6.6
Noise Reduc.	0.8	1	1.3	1.5	1.8	2.5

- **Noise generally increases with intensity**
- **Adaptive filtering reduces noise by ca. factor 3**

Radiometric Quality

Image Artifacts

Image Data
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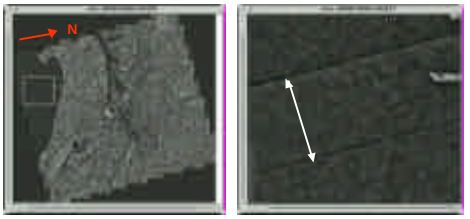

Visible bands in epipolar images

Radiometric Quality

Image Artifacts

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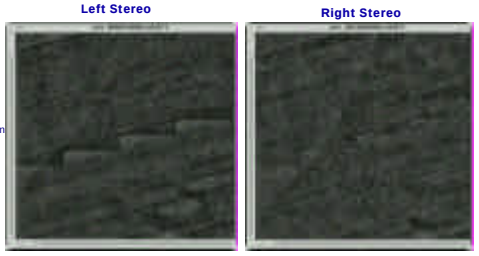
Left Stereo **Right Stereo**



- **Staircase effect in left image**
- **Nonexisting white dotted lines**

Radiometric Quality

Image Artifacts

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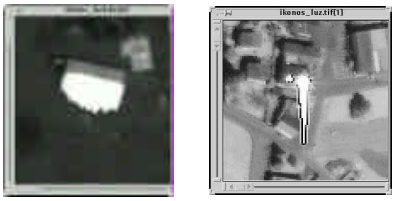

- **Strong reflection/saturation**
- **Blooming**
- **Edge sharpening artifacts**

Radiometric Quality

Image Artifacts

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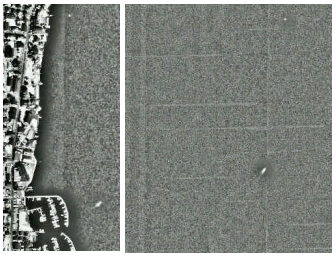

Left: GV jumps ; Right: bright horizontal stripes

Radiometric Quality

Image Artifacts
Stereo Pan-Sharpened pair

Image Data
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Ghosting of moving objects due to the 0.5 s time difference between acquisition of PAN and MSI

Preprocessing

Aim: Noise reduction, contrast & edge enhancement

- Image Data
- Rad. Quality
  - Noise
  - Artifacts
- ▶ Preprocessing
- Orthoimage
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- Conclusions

Methods:

1. - linear reduction from 11 to 8-bit
   - Gaussian anisotropic filtering
   - Wallis filter
2. Like 1 but after Gaussian filtering
   - unbiased anisotropic diffussion
3. - adaptive noise reduction (2 methods)
   - Wallis filtering
   - reduction to 8-bit
   (histogram equalisation or normalisation)

Preprocessing - Noise reduction , contrast & edge enhancement

Original

Original, contrast enhanced

Preprocessed 2

Preprocessed 3

Preprocessing

Adaptive Noise Reduction & Edge Enhancement

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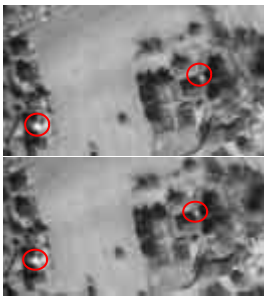

Orthoimage Generation

- Image Data
- Rad. Quality
  - Noise
  - Artifacts
- Preprocessing
- ▶ Orthoimage
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Methods:

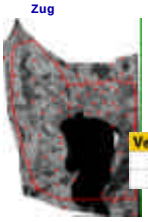
- **Kratky's Polynomial Mapping Functions (PMFs)**
- **Relief corrected affine transformation**

Reference plane -> reference plane of DTM

3 GCP's are needed but 4-6 are suggested

Orthoimage Generation

Zug



Test results

Sens elev. (deg)	85.7
DTM spacing/accur (m)	5 / 0.4
GCP accuracy (m)	1.5-2
GCP definition	Medium to good
Elevation range (m)	400-990

Version	GCPs / CPs	RMS/X	RMS/Y	Max. abs X	Max. abs Y
1	27 / 41	1.5	1.6	3.8	3.2
2	27 / 69	2.5	2	11.3	6.5

Method: Kratky's PFMs

Extrapolation occurs when check points are defined outside the perimeter of the GCP's (version 2)

Orthoimage Generation

Zug

Test results

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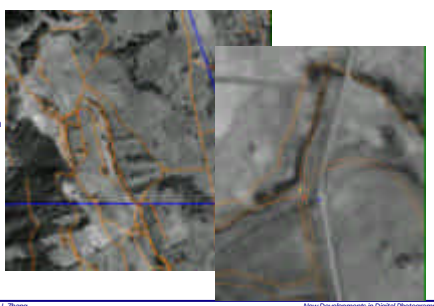


Orthoimage Generation

Luzern

Test results

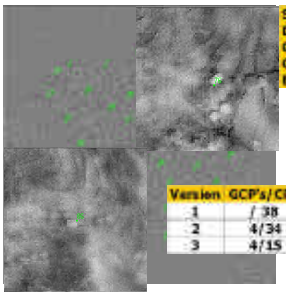
Sens elev. (deg)	67.7
DTM spacing/accur (m)	25 / 2.5 lowland, 10 Alps
GCP accuracy (m)	0.5 – 3
GCP definition	Very poor to good
Elevation range (m)	400-2100

Method: Affine transformation

Version	GCPs/CPs	RMS/X	RMS/Y	Max. abs X	Max. abs Y
1	/66	134.2	30.6	501.5	118.1
2	6 / 65	2.6	2.2	8.9	5.9
5	6/14	0.6	0.6	1	1.1

Orthoimage Generation

Nisyros



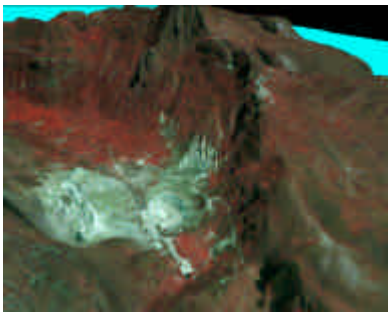
Test results

Sens elev. (deg)	73.5
DTM spacing/accur (m)	2 / 3.3
GCP accuracy (m)	ca. 0.5
GCP definition	Poor to good
Elevation range (m)	0-700

Method: Affine transformation

Version	GCP's/CPs	RMS/X	RMS/Y	Max. abs X	Max. abs Y
1	/ 38	106.1	75.5	153.1	122.8
2	4/34	1.7	1	4.4	2.3
3	4/15	0.9	0.6	1.5	1.4

Orthoimage Generation - Nisyros



Building Extraction

- Image Data
- Rad. Quality
  - Noise
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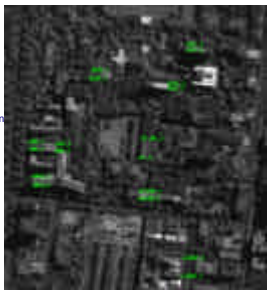
- Orthoimage
- ▶ Building extraction
- Conclusions

Roof corners



- 19 roof corners measured by GPS
- Measured in mono and stereo in all three images of Melbourne

Results from stereo images and 6 GCPs (RMSE):

Affine: XY = 0.6m
Z = 0.8m
DLT: XY = 0.7m
Z = 1.0m
RPCs: XY = 0.7m
(- bias) Z = 0.9m

Building Extraction

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Aerial Photography (1:15K) *Ikonos* 1m Pan Stereo

- Omission of 15% of buildings (small & large)

Building Extraction

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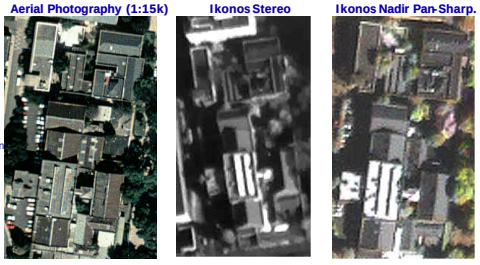
Aerial Photography (1:15k) Ikonos Stereo Ikonos Nadir Pan-Sharp.



Conducive to building feature measurement

Building Extraction

Aerial Photography (1:15k) | Ikonos Stereo | Ikonos Nadir Pan-Sharp.

Ikonos stereo of questionable value to building feature measurement in this case

Building Extraction

3D Model of University of Melbourne Campus from *Ikonos* 1m PAN Stereo

Produced with CyberCity Modeler

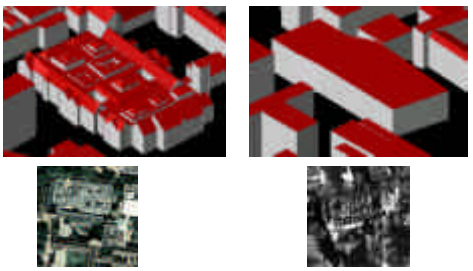
Building Extraction

3D Model of University of Melbourne Campus from *Ikonos* 1m PAN Stereo

Produced with CyberCity Modeler

Building Extraction

Aerial Photography (1:15K) | Ikonos 1m Stereo Imagery



Conclusions

- **Influence of factors, beyond the control of user, and lack of consistency/homogeneity will generate difficulties in exploiting full potential of imagery**
- **Noise and artifacts significant; SI preprocessing problematic; improvement through intelligent postprocessing possible.**
- ***Orthoimage generation:***

  - 1-2 m accuracy possible from Geo with simple methods and down to 3 GCPs; sub-metre possible with good GCPs and DTM (or high elevation)

  - Higher-cost Reference, Pro & Precision products or products with RPCs (OrthoKit) not necessary
- **Building feature determination to 1m accuracy is feasible in optimal cicumstances, but highly dependent on both building characteristics and, especially, imaging & operational factors.**
- **Problematic if emphasis is on completeness of scene description, both in terms of buildings detected & structural detail.**