Institut für Photogrammetrie

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Oblique Image Data Processing – Potential, Experiences and Recommendations

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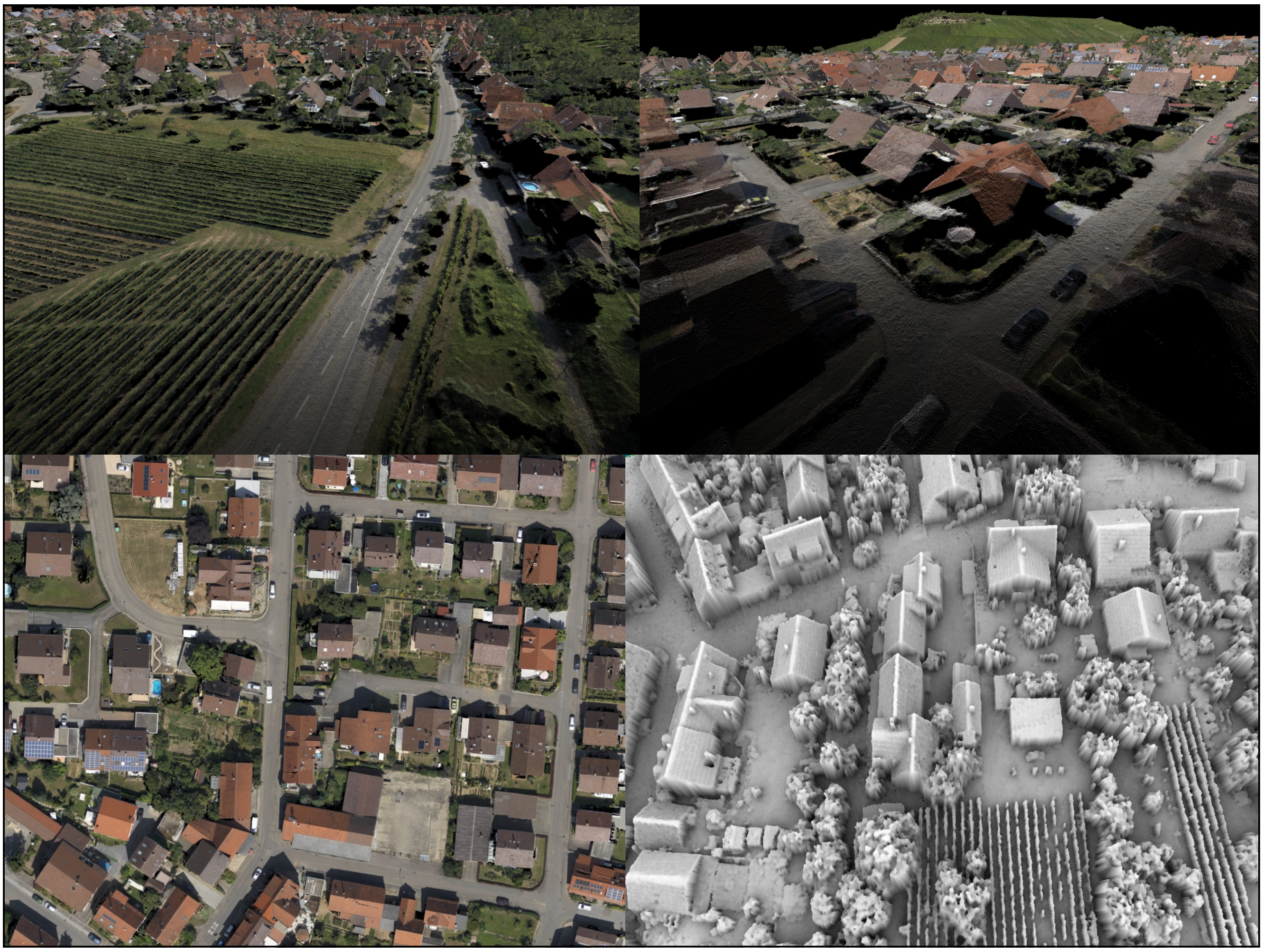
Contents



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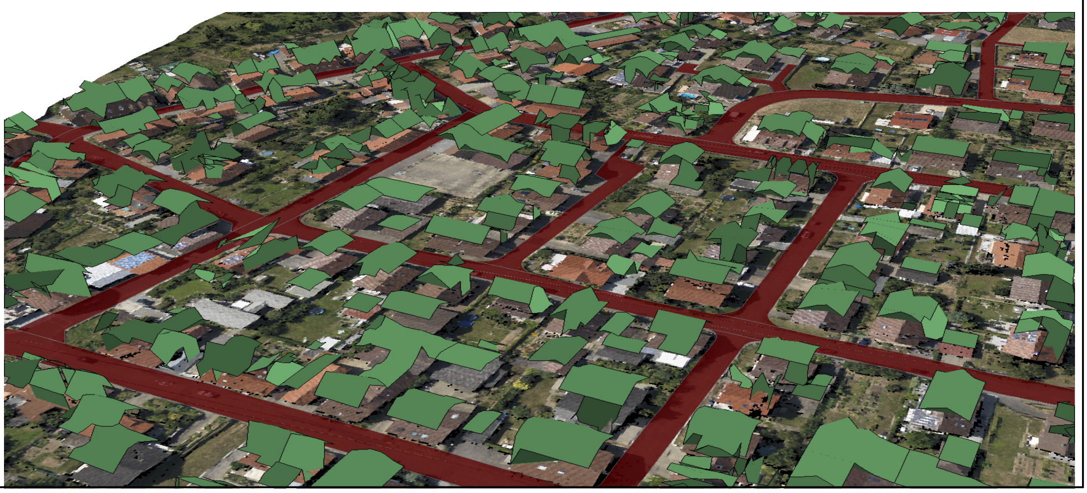
1. Motivation - Detect Unregistered Buildings

- Input; DSM from DIM, building footprints from cadastre (ALKIS)
- Compute DTM using the DSM by means of morphological „Opening“
- Orthophoto and ALKIS streets (contents of cadastre) overlayed with DTM, ALKIS building footprints with DSM



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1. Motivation – Detect Unregistered Buildings

- Input: DSM from DIM, footprints from cadastre (ALKIS)
- Compute DTM by means of morhological „Opening“
- Subtract DTM from DSM DOM
- Check for areas higher than 3m and not registered in ALKIS

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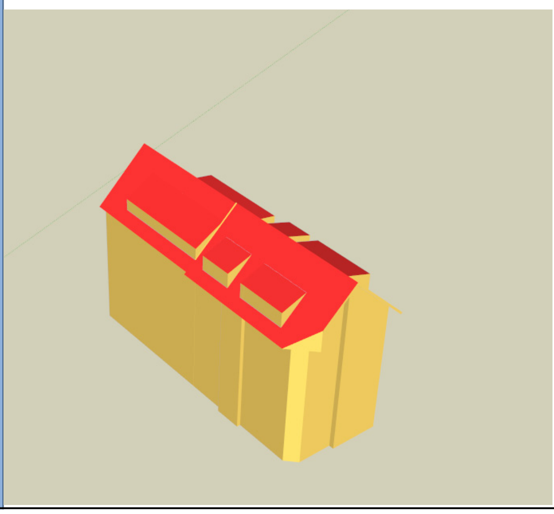
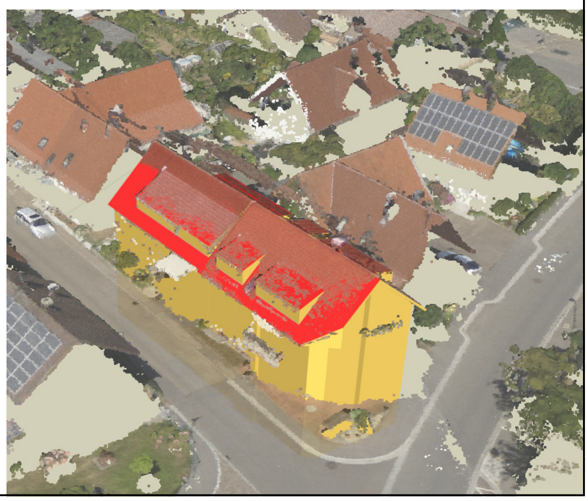
1. Motivation – Detect Unregistered Buildings

- Reconstruct automatically unregistered 3 buildings
- Methods at ifp exists which use the footprint
- The roof structures can be reconstructed completely automatic
- Facade information still missing
- NMCAs in Europe would like to have such methods!





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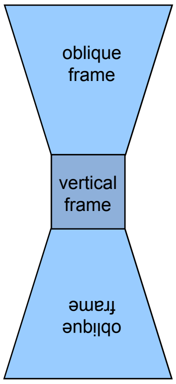
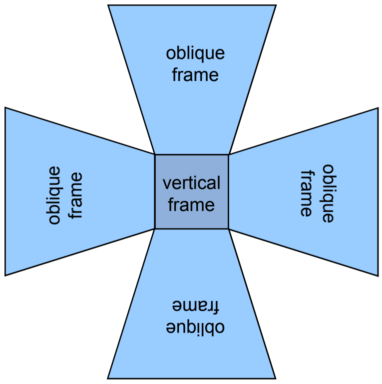
2. Oblique Aerial Photography

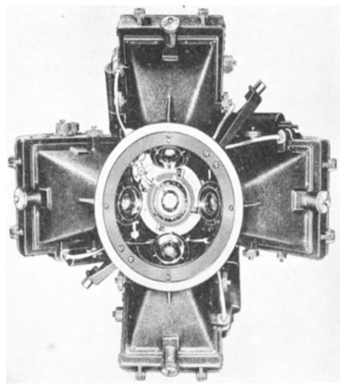
- oblique aerial photography increasingly used within the last 15 years
- based on multiple camera arrangements, featuring up to 5 different cameras with different viewing directions
- already used from the 1930, with multiple analogue camera set-up, today typically small format digital cameras (<16 MPix) used
- Pictometry International relaunched oblique aerial photogrammetry in 2000



3 camera coverage



5 camera coverage



Fairchild T-3A (1934)

2. Oblique Aerial Photography

Benefits

- oblique imagery extends the benefits of traditional vertical photography, provides a unique perspective view of a locality
  - see each side of a building, structure, or feature, exposing blind spots, exits, and entrances previously impossible to locate on vertical photography
  - measure height, length, and area of features directly from photography (if data is correctly georeferenced) or used for facade mapping
  - improve identification of hard-to-see assets and facilities (e.g. lamp posts, telegraph poles, trees at avenues etc.), difficult to distinguish on traditional orthophotography
  - easier readability of geographical information for non-cartographic or vertical photography skilled people
  - respresentation of GIS data in 3D by draping it on oblique imagery, extending the traditional and more familiar 2D view afforded by most GIS applications, in some cases easier interpretation

[http://www.profsurv.com/archive.php?issue=126&article=1832]

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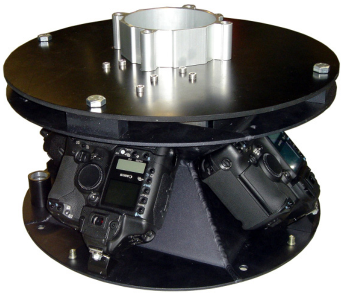
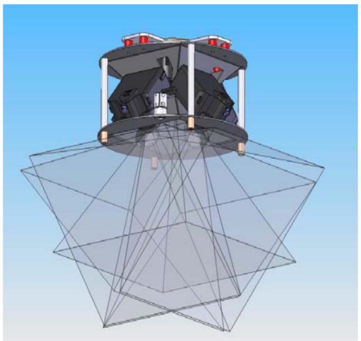
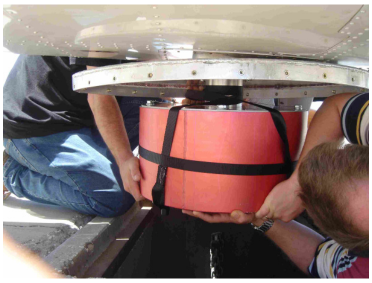
Image contents – satellite & aerial

2. Oblique Aerial Photography (2007)

MIDAS oblique 5-camera system built by Track'Air (Netherlands)







5 Canon small-format cameras featuring
5x16.7Mpix = 83.5Mpix per exposure
format 24x36mm²
tilt 30-60deg, 45deg standard

[images & information courtesy to G. Petrie & http://www.aerial-survey-base.com/Bilder2007/midas_brochure.pdf]

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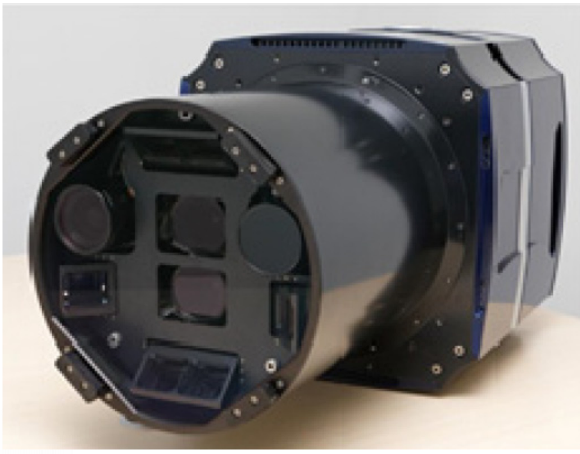
Image contents – satellite & aerial

2. Oblique Aerial Photography (2013)

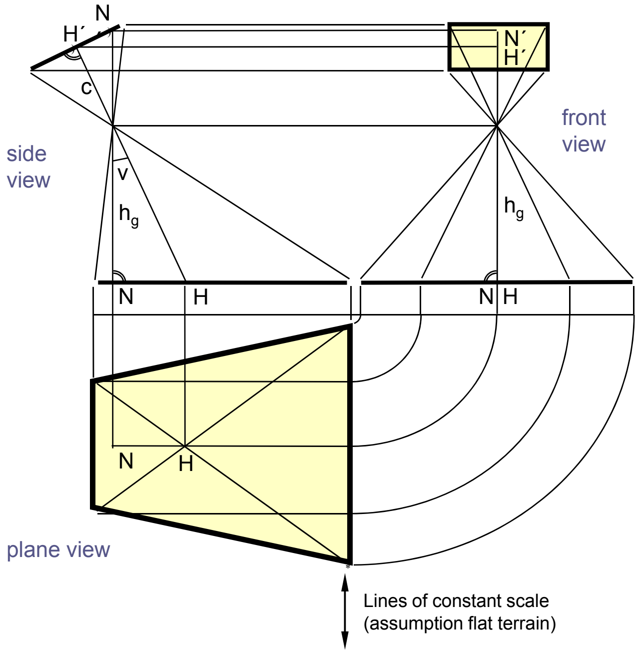


The 54th Photogrammetric Week: 4 systems

- RCD 30 Oblique
- MS UltraCam Osprey
- IGI Penta DigiCAM
- VisionMap A3 Edge

2. Oblique Aerial Photography

Image geometry



- oblique images have **strong variations** in image scale
- large off-nadir viewing angles result in large displacements, which exceed the effects of relief displacement
- scale variations depend on
  - image tilt
  - image size
  - camera focal length
  - flying height above ground
- is of influence of orientation / georeferencing process, i.e.
  - automatic tie point transfer
  - GCP visibility / measurement
- integration with GPS/inertial module straightforward

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3. Case Studies OAP & DIM

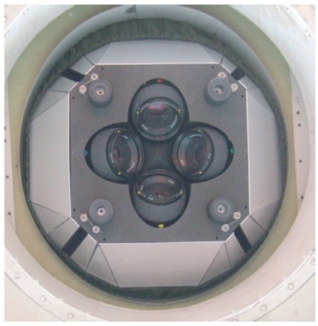
Motivation

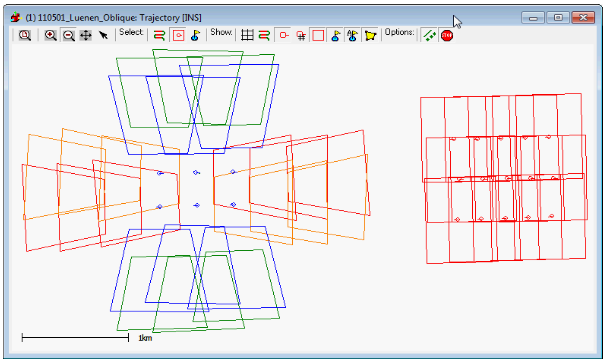
- Semi Global Matching (SGM) based approaches showed impressive results for (short baseline) nadir imagery
- For some applications additional facade information is desired
- How does SGM perform on oblique aerial imagery?

3. Case Studies OAP & IM

IGI DigiCAM Oblique Dataset Luenen

- IGI Quattro DigiCam Oblique
  - Angle: 45°
  - forward, backward, left, right
- 170 images
- 6.7cm – 13.6cm GSD
- AT Match-AT (Trimble)
- BA: BINGO (GIP)

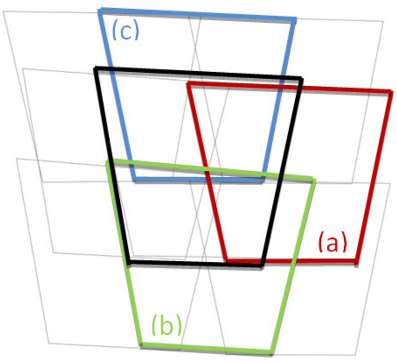




3. Case Studies OAP & DIM

IGI DigiCAM Oblique Dataset Luenen

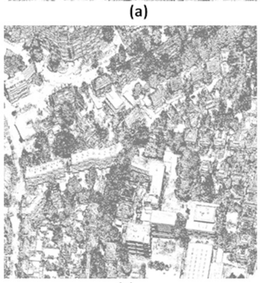
- Matching configuration
  - Centre image against 8 neighbours
  - Same viewing direction



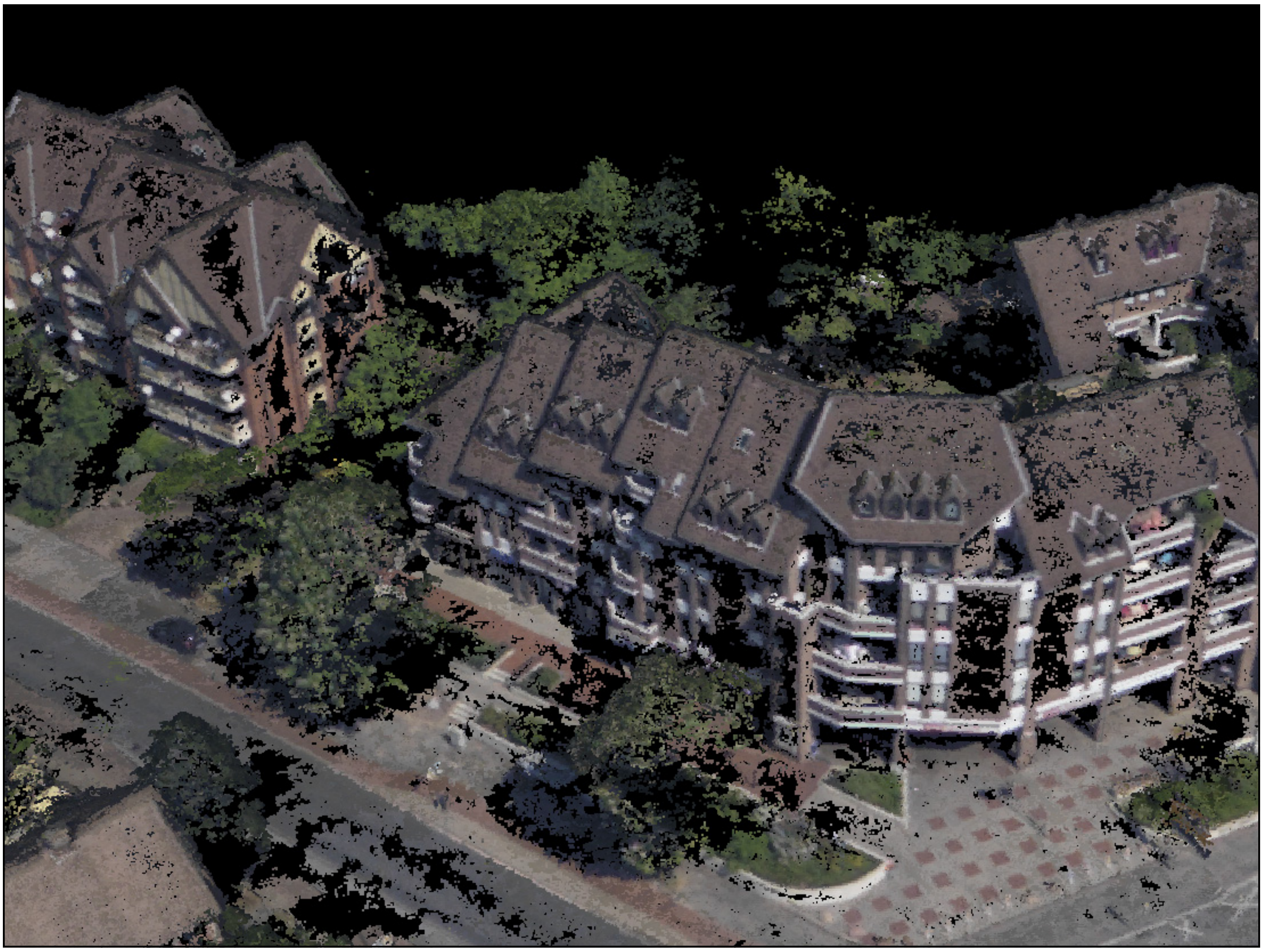
Match Image	Matched pixels [%]
In-strip (a)	64.5
Cross-Strip 1 (b)	59.9
Cross-Strip 2 (c)	53.4

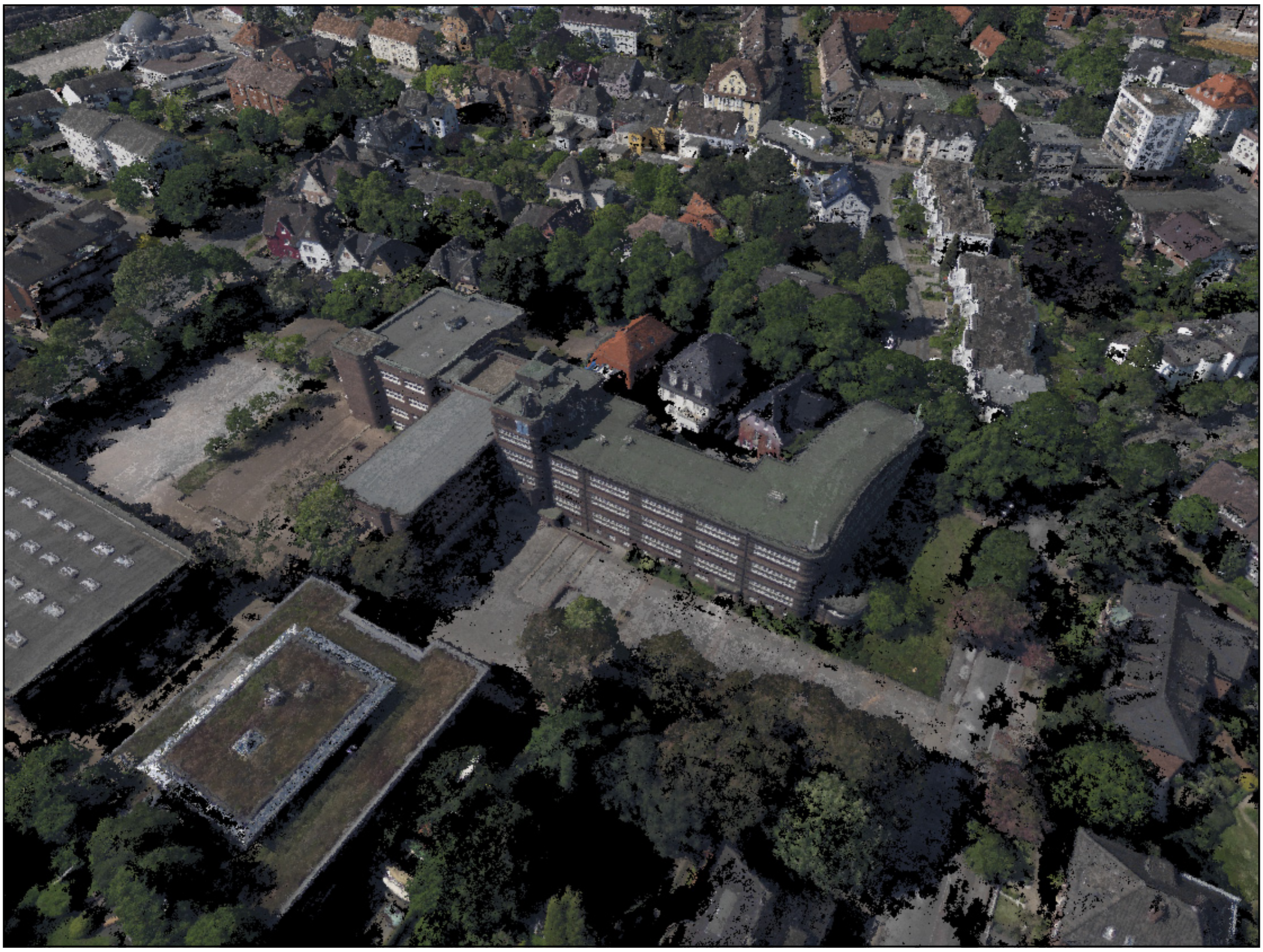
(a)

(b)



(c)





3 Case Studies OAP & DIM

IGI Luenen Dataset - DigiCAM Oblique 2011

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- Large perspective differences between images
  - Dense matching method must be insensitive
  - Increased overlap is beneficial
- Changing ground sampling distance in oblique imagery
  - Point cloud generation using correspondences from dense matching must take ground sampling and intersection angles into account
- Outliers and Noise
  - Elimination and reduction using high redundancy
  - Overlap > 75 % ensures each point to be observed 3 times

3. Case Studies OAP & DIM

The VisionMap Dataset 2012

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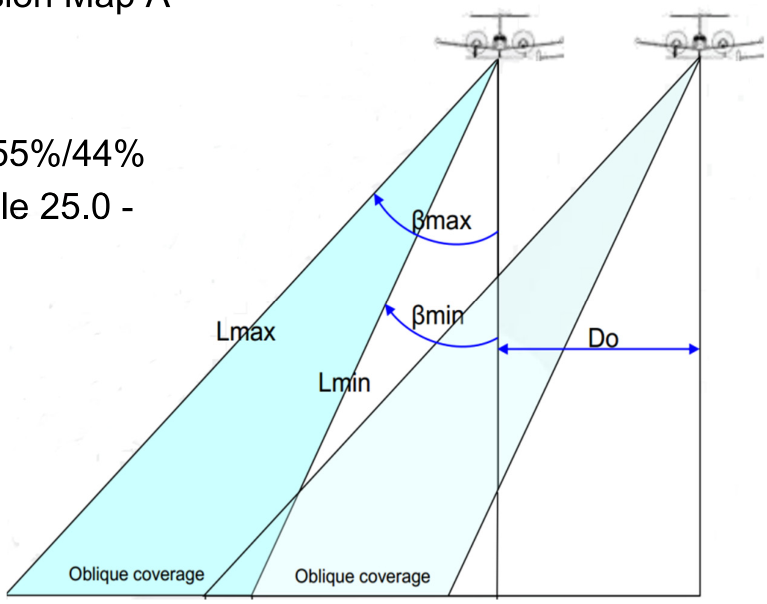
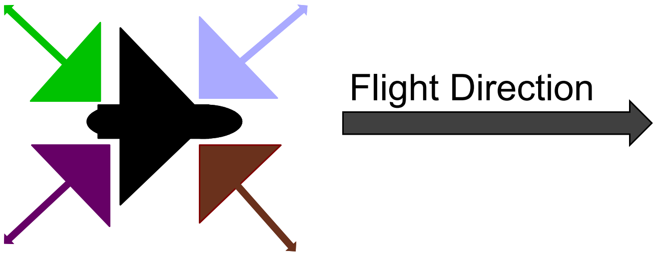
- Camera System: Vision Map A³
- GSD Nadir 6cm
- Flight height 2000m
- Forward/Side Laps 55%/44%
- Oblique viewing angle 25.0 - 44.98 deg

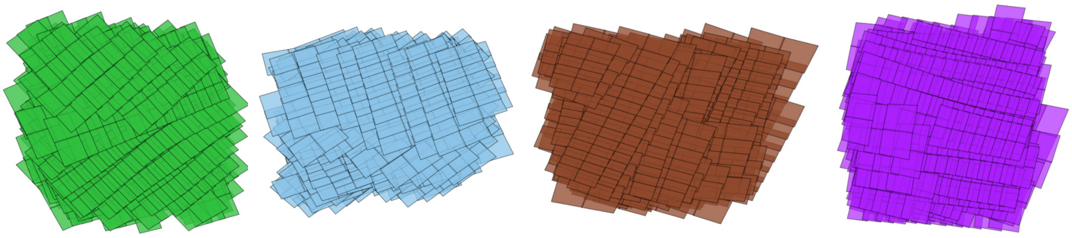


3. Case Studies OAP & DIM
The VisonMap Dataset 2012

- Flight with four mounted cameras was simulated first



- Resulting footprints:



3. Case studies OAP & DIM
VisionMap Tests and Results 2012

- All tests were conducted on one base image and the 41 proximate match images
- 41 overlapping match images were determined by evaluations of footprints on a plane


Base Image


Set of match images

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3. CASE Studies OAP & DIM

VisionMap Dataset & Stereo Matching

- Question:
  - How does the implemented algorithm perform on oblique imagery?
  - What accuracies can be expected (mainly dependent of the flight planning) ?

- Test Design:
  - Computed 41 stereo models
  - Evaluation of successfully matched points
  - Evaluation of the theoretical accuracy in object space
  - All results are evaluated with respect to α_{mean} which denotes the average of all ray intersection angles defined by the reconstructed points and the two camera centres
  - α_{mean} is an estimation for the similarity of the image pairs

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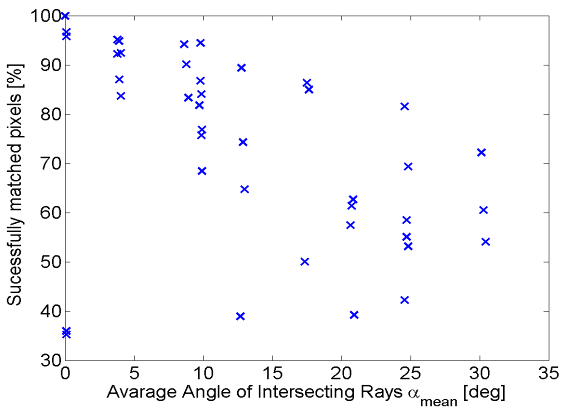
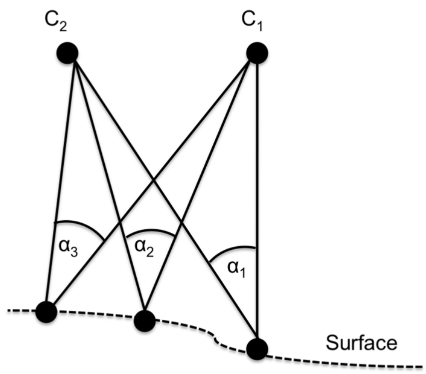
3. Case Study OAP & DIM

VisonMap Stereo Matching - Density





$\alpha_{mean} = 1/n^* \text{ sum}(\alpha_i)$

- Decreasing density for increasing α_{mean} due to changing image content
- Values below 40% correspond to pairs which sparsely overlap or do not overlap at all
- Overall pretty good density

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3. Case Studies OAP & DIM

Vison Map data set - Disparity Map Fusion / Multi-View Triangulation

- Questions:
  - What densities/accuracies can be expected for the final results?
  - What models contribute to the final result? Can models be excluded from the processing to reduce computation time?
- Test Design:
  - 6 Subsets were selected from 41 stereo models and fused using the multi-view triangulation approach (min. consistent measurements: 2)
  - Subsets are defined by all models possessing an α_{mean} <=5^0, <=10^0, <=15^0, <=20^0, <=25^0 and <=35^0.
  - Models of subsets were fused and characteristics were computed
    - Average standard deviations in depth σ_D^{mean} derived by covariance matrices in Levenberg Marquardt optimization
    - Number of successfully triangulated points
    - Average number of models used for triangulation of a single 3D point
    - Number of models to be processed

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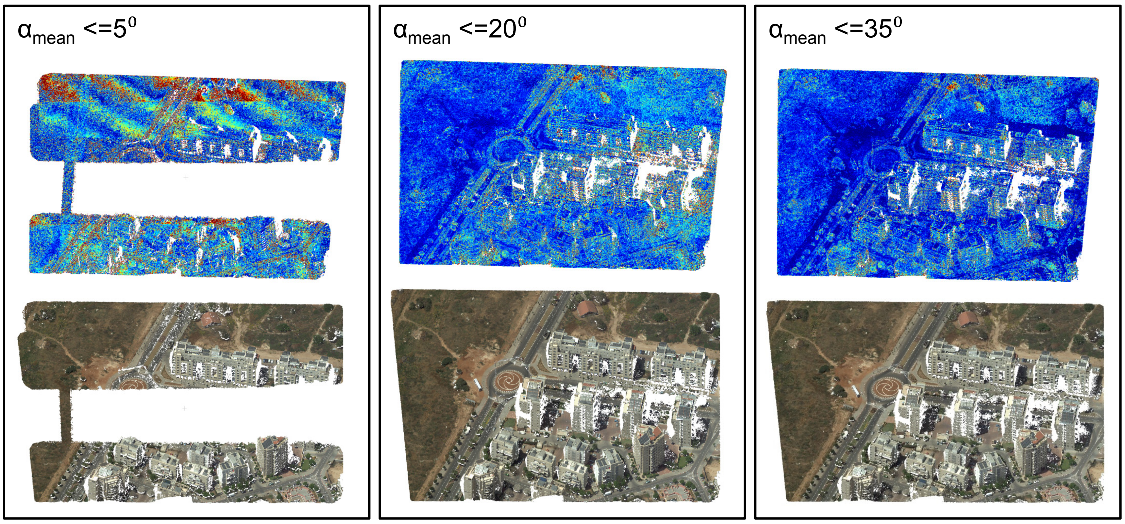
3. Case Studies OAP & DIM

Disparity Map Fusion / Multi-View Triangulation

- Visualization of standard deviations in depth σ^i_D
  - Red: σ^i_D >= 20cm Blue: σ^i_D <= 1cm



- Critical: Vegetation, weak texture (streets), depth steps

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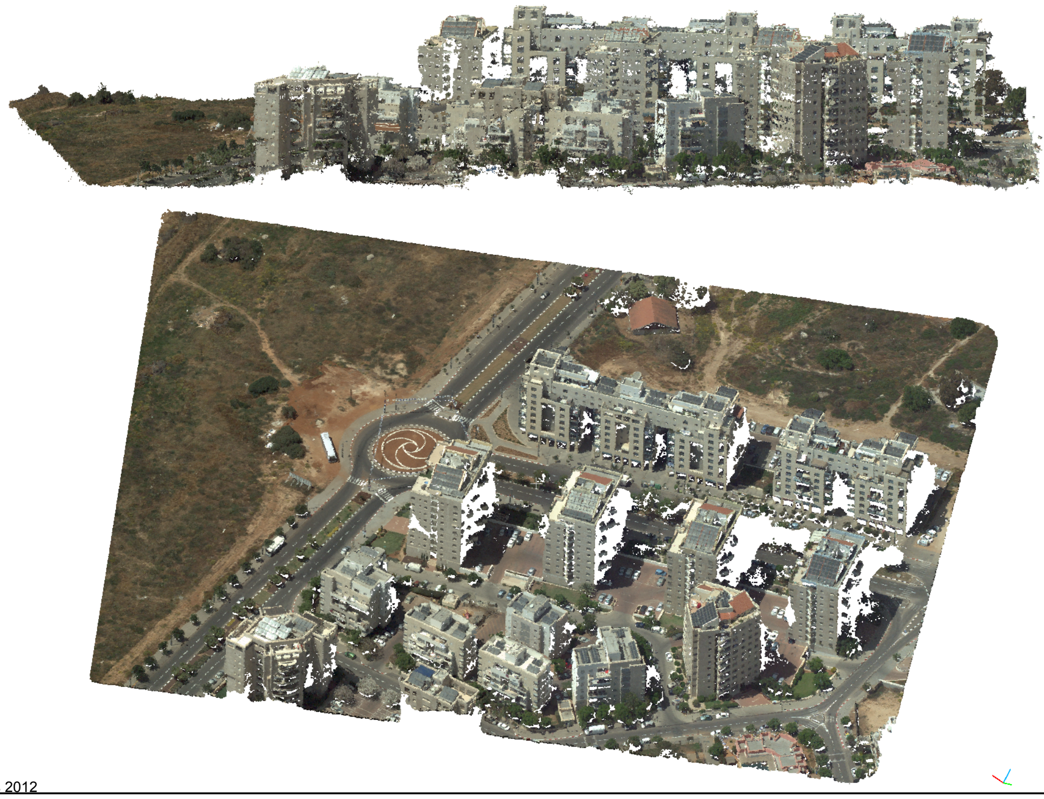
3. Case Studies OAP & DIM

VisionMap 3D Point Cloud of Test Scenario



3. Case Studies OAP & DIM

VisionMap 3 Stereo Pairs

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3. Case Studies OAP & DIM

The VisionMap Dataset

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4. Lessons Learned

- Provide a sufficient image overlap, 75-80%. Particularly in flight direction (no additional costs). Matching is known to work well for base to depth ratios of **0.12.**
- This should also guarantee sufficient redundancy. A surface point should be seen in at least 3 images from the same viewing direction. More detections are preferable.
- Within the bundle adjustment the degree of overlap of single images can be derived. This information should be passed along the image data. This way time consuming preprocessing steps for stereo-pair selection can be simplified.
- Indicative naming of imagery

4. Lessons Learned

- For all processed datasets BA is in a sufficient range for dense image matching
- 3D structure as balconies, tree treetops can be reconstructed and add value to the final point clouds especially for non-Manhattan-like buildings and undercut structures
- Facades are reconstructed with notably higher density and accuracy than wide angle nadir configurations
- Complex configurations make selection of suitable stereo pairs challenging
- Heavily varying image scales in a single image imply different accuracies of the extracted surface points. This demands for a smart fusion approach of final point clouds
- Varying radiometry in image block cause point clouds to look stained. This demands for block-wise color adjustment or adequate post-processing steps

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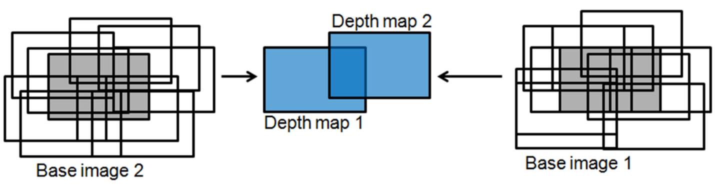
5. Conclusions

- SGM-based matching techniques are capable to match oblique aerial imagery
- For examined image configuration
  - Completeness of over 90% could be obtained
  - Average accuracies in depth of up to 4.09cm were obtained (based on evaluation of covariance matrices)

- Further work:
  - Merge generated (fused) depth maps to



    - Reduce number of points
    - Exploit redundancy (accuracy outlier elimination)

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5. Conclusions

- As much as possible multiview stereo combinations are obtained for an inflight overlap of 75%
- Best results for precise and complete 3D point clouds for cross overlaps of up to 60%
- ISO may play a crucial role for penta-view imagery
- In-situ camera calibration of penta-systems should directly make use the Legendre or Fourier additional parameters (R. Tang, 2013)
- Forget the Ebner and Gruen additional parameter models for in-situ camera calibration as they stem from the film-based era