Contents:
- History, concepts, sensors, data processing & applications
- EuroSDR questionnaire
- ISPRS / EuroSDR benchmark
- Conclusions & Outlook

A look back........(1)

- **First** recorded aerial photo in the US (1860) by J.W. Black and S. King in Boston (USA) was an oblique shot from a balloon
- In 1906 G. R. Lawrence used between nine and seventeen large kites to lift a huge camera and take some oblique aerial images of San Francisco (USA) after the strong earthquake in the area
- Kites & balloon were then abandoned in favour of powered flight, which gained importance for military reconnaissance during World War I

Source: http://robroy.dyndns.info
- In the 1930’s USGS and militaries **systematically** captured oblique images
- During WWII oblique were used for **inspection and reconnaissance**
- In the “analogue times” too expensive technology
- Almost 10 years ago: **Pictometry** system
- Nowadays **different systems available**
- A “returned” technology / system
- January to May 2014 issues of the **GIM Int. magazine**

**General classification of oblique digital cameras**

- **single swiping camera**
General classification of oblique digital cameras

- single swiping camera
- 2 cameras
- 3 cameras
General classification of oblique digital cameras

- single swiping camera
- 2 cameras
- 3 cameras
- 4 cameras
- 5 cameras
General classification of oblique digital cameras

- single swiping camera
- 2 cameras
- 3 cameras
- 4 cameras
- 5 cameras
- Multiple cameras

Fan (static or sweeping) vs Maltese Cross configuration

- IGI Dual Cam
- A3 Visionmap

- Track’Air MIDAS
- IGI Penta DigiCam
- Hexagon/Leica RCD30
- Pictometry / BlomOblique
- Microsoft/Vexcel Osprey
Maltese Cross configuration

- One vertically pointing camera + 4 oblique cameras pointing to the four cardinal directions
- Modular (i.e. varying angles) vs fixed
- Small vs medium vs large format camera sensors
- RGB + NIR (in the nadir)
- Wide vs narrow angle lens

Oblique imagery – Pros & Cons

**VERTICAL**: good observation of roofs, constant scale, traditional approach

**OBLIQUE – Pros / Benefits**:  
  - Visibility of roofs as well as vertical structures (feature extraction, texturing, etc.)  
  - Multiple views, including nadir  
  - Better interpretation (building footprints, number of floors, etc.)  
  - Higher redundancy & reliability  
  - 3D vs 2.5D point clouds  
  - More detailed 3D city models  
  - Possibility to automatically produce true-ortho  
  - A lot of hidden potential

**OBLIQUE – Cons**:  
  - More occlusions (mitigated through multiple views and overlap)  
  - Varying scale / GSD
Applications

- Manual inspection
- Monoplotting / Building height measurements
- Detailed 3D city modeling
- Dense Matching
- Texturing
- Damage assessment
- Scene classification and interpretation (trees, facades, roofs, streets, etc.)
Applications

- Interactive city modeling (Imagemodeler + Blomoblique)

Source: Xiao, 2013

- Dense matching

Source: Fritsch et al., 2012
Source: Gerke, 2013
Source: FBK Trento, 2014
Applications

- Automatic generation of 3D textured models

Source: EADS Streetfactory / Astrium

Applications

- Damage assessment

Source: CGR / FBK
- Cadastral needs

- Number of floors
- Building footprints

- State-of-the-art is 5 images for every “acquisition position”

- Large image block size (thousands of images)

- New issues / problems / challenges for flight planning

- Problems for traditional photogrammetric approaches:
  - Convergent images
  - Varying image scale / resolution (GCPs measured with different accuracy)
  - Large perspective distortion (SIFT-like operator are less efficient)
  - Long processing time
Simulated flight plan
- Flight 80/60, Maltese-cross camera with 30deg and 45deg oblique cameras
- Urban area with 20m height buildings, narrow (5m) and large (10m) streets
- Façades parallel to the flight direction
- High tilt angles (e.g. 45 deg) lead to inhomogeneous redundancy of points
- Smaller tilt angles (e.g. 30 deg) lead to fewer but more uniform redundancies

➢ To fully exploit advantages of oblique cameras, the street’s width and the building’s height play a major role in planning a successful urban survey campaign
➢ The taller the city architecture the lower the camera incidence angle should be
➢ A right compromise should be found between the camera tilt setting, given focal length, sensor size, overlap and geometry of the surveyed area

Simulated AT
- Different camera configuration tested (small, medium, large; 60/40, 80/60, 80/80, 90/90)
- Run AT and estimated std of objected coordinates
- The larger the overlap, the better the quality of object coordinates (and larger the redundancy)
- The higher the oblique angles, the better the quality of objected coordinates

➢ High tilt angles and very large overlap lead to very good object coordinates and large redundancy
➢ Cost-Benefit analysis
Advanced workflow for AT
- Rely on GNSS/INS data
- Create a connectivity map/graph
- Use constraints like: Overlap, Look direction, Min numb of extracted tie points
- Exploit large observations’ redundancy

Dense Image Matching
- Use connectivity map
- Prefer images with same looking direction

[Rupnik, E., Nex, F., Remondino, F., 2013: Automatic orientation of large blocks of oblique images. ISPRS Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS Hannover 2013]

Dense image matching

- Use connectivity map
- Prefer images with same looking direction
- Point cloud filtering to remove blunders in oblique views

- Dortmund dataset (IGI PentaCam) – ISPRS/EuroSDR benchmark
- GSD 10cm
- > 1000 images
SURE true-orthophoto
Examples

Graz, Osprey camera, 10cm GSD

MicMac dense point cloud

EuroSDR Questionnaire

- Questionnaire on the current status of oblique airborne imagery
- Run throughout 2014
- 200+ participants

- About 10 questions, divided in users vs hw/sw producers
- Publication in the GIM International, Vol28(12), 2014
Best application with oblique imagery?

Users:
- identification / mapping tasks have priority

Vendors:
- Visualization
- Texturing of city modeling
- Interpretation

What can oblique do better?

- easier identification of objects
- increase degree of automation
- increase reliability
- do what is not possible today
GSD and Stereo Overlap

Q: What is the max allowed GSD at image centre (cm)?
A: Mean 19cm, but majority in the 10cm range

Q: What is the desired min overlap?
A: At least 60% (majority)

**Benchmark**

- “Multi-platform photogrammetry” (initiated by F. Nex & M. Gerke)
- ISPRS Scientific Initiative + EuroSDR co-founded activity
- http://www2.isprs.org/commissions/comm1/icwg15b/benchmark_main.html
- Aims:
  1) Fully automatic and reliable co-registration of multi platform/perspective imagery
  2) Dense image matching within/across platforms

City center (Dortmund, Germany)

**OBLIQUE SYSTEM**
- IGI PentaCam (80/80)
- GSD 10cm – 1260 images (yellow area)

**UAV** (3 selected buildings)
- oblique/nadir,
- GSD 1-2cm (red area)
- only rotary wing

**TERRESTRIAL** (3 selected buildings)
- GSD < 1cm (red area)

**REFERENCE DATA**
- GNSS, total station
- TLS, ALS

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Zeche Zollern (Dortmund, Germany)

**OBLIQUE SYSTEM**
- IGI PentaCam (80/80)
- GSD 10cm – 910 images (yellow area)

**UAV** (4 selected buildings)
- oblique/nadir,
- GSD 1-2cm (red area)
- rotary and fixed wing

**TERRESTRIAL** (4 selected buildings)
- GSD < 1cm (red area)

**REFERENCE DATA**
- GNSS, total station
- TLS, ALS
City center (Dortmund, Germany)

- Preliminary results (Pix4D & BLUH)
- Different configurations (overlap, GCP distribution, self calibration, etc.):
  - Nadir-to-oblique pairs have 6 times less tie points than nadir-to-nadir pairs
  - Only few matches across oblique viewing directions
  - Self-calibration mandatory to reduce RMSE to 1 GSD (or better)
  - In case of GCPs at the borders, always block deformation
  - 80/80, in general, delivers better results than 60/60

Oblique camera systems are definitely back and a promising solution for mapping purposes

- Different systems available but new systems might come out in the market soon
- Oblique airborne images will probably become a standard complementary to traditional large format nadir images
- Oblique will not replace traditional nadir acquisitions (maybe in urban areas?)
- Many possible applications: map update, 3D city modeling, inspection, interpretation, footprint identification, 3D cadastre, real estate, etc.
- NMCAs are slowly thinking to adjust their production pipeline to cope with obliques
- Oblique requires a new approach in the photogrammetric and production pipeline
  - Data acquisition (flight plan) + Data processing (convergent, huge point clouds, etc.) + 3D restitution / Automated interpretation
- **Additional costs** of oblique flights (especially additional flight lines) might be compensated by additional outcomes and benefits:
  - easier (or improved) object identification and readability of geographical information;
  - generation of denser 3D point clouds, also on vertical elements;
  - higher reliability with respect to traditional vertical acquisitions;
  - measurement of heights, lengths and areas of features directly from the single images (improved monoplotting with 3D point cloud in background);
  - quick generation of true-orthophotos;
  - extension of traditional 2D GIS data;
  - etc.

- **Conclusions and outlook**

  Very dense, accurate and detailed point clouds **but then**?
  - New solutions to derive structured information out of unstructured point clouds
  - Large polygonal models (e.g. GoogleEarth) are not useful if not only for visualization
- Some **open research issues**:
  - scale and radiometric changes;
  - correct and fast identification of homologues points, in particular across viewing directions;
  - processing time;
  - redundancy / overlap exploitation;
  - fusion of point clouds coming from different viewing directions (and with different accuracy & resolution);
  - automation in interpretation, especially for complex architectures
  - etc.

- **Concurrence / Competitor:** **UAV acquisitions?**
  - BlomOblique: Large area overview, details at 5-10 cm level on façades & buildings
  - UAV: Small area only, but details at cm level on façades & buildings and access unsafe areas
Ordnance Survey headquarter in Southampton (UK)

Registration fee: free

www.eurosdr.net/workshops/eurosdr-workshop-oblique-cameras-and-dense-image-matching

THANK YOU!

FABIO REMONDINO
3D Optical Metrology unit
Bruno Kessler Foundation (FKB)
Trento, Italy
Email: remondino@fbk.eu

MARKUS GERKE
EOS dept.
ITC / Univ. Twente,
Enschede, The Netherlands
Email: m.gerke@utwente.it

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