UNIVERSITY OF TWENTE.

OBLIQUE AERIAL IMAGES: POTENTIALITIES, APPLICATIONS AND BEST PRACTICES

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ITC FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

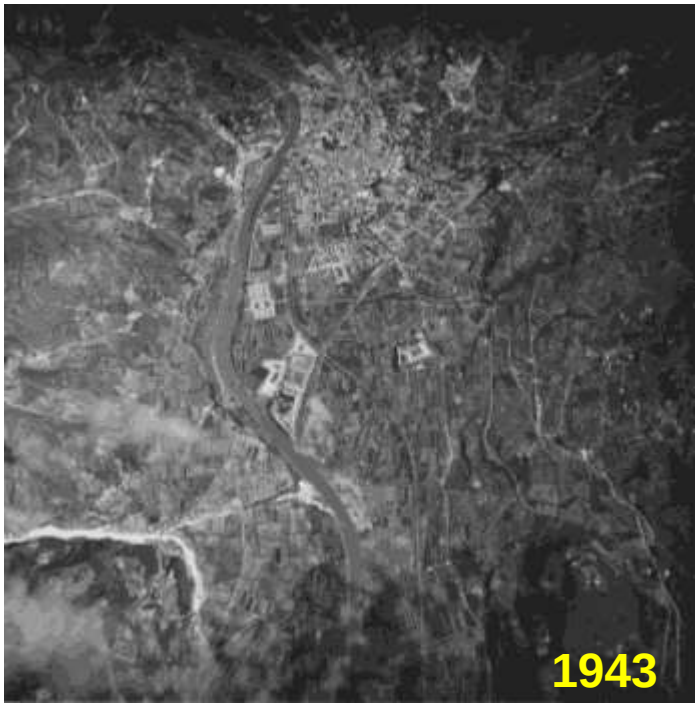
The history of oblique imagery

- **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.

The history of oblique imagery

- Oblique cameras on airplanes gained importance for military reconnaissance during World War I and World War 2.
- However, these systems were too expensive in the “analogue times”.
- Oblique systems were re-introduced on the market by Pictometry more than 10 years ago.



Zeiss twin RMK

USGC-9

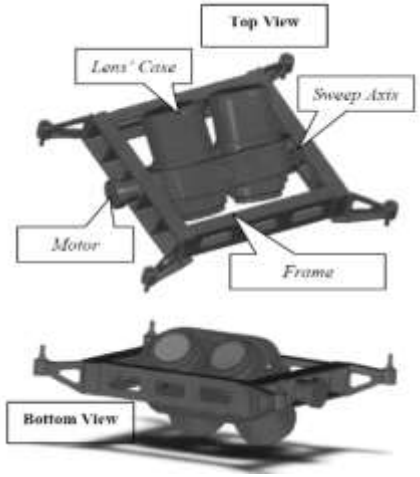
Fairchild T-3A

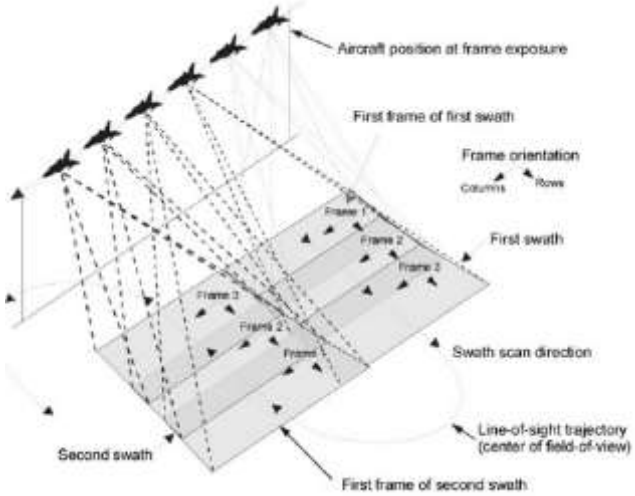
Current oblique camera systems – Swiping camera

- Different solutions are nowadays available on the market, adopting:
  - Different number of cameras
  - Different acquisition geometries

- **Single swiping camera**

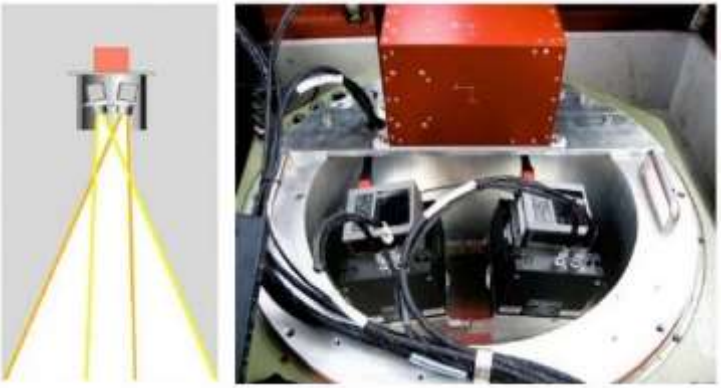
  FAN ACQUISITION





Current oblique camera systems – Multi-camera

2 cameras



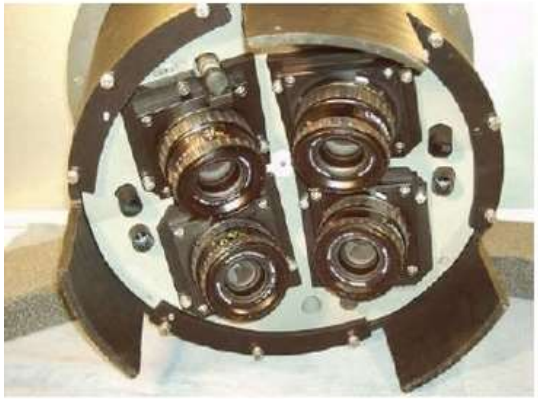
IGI Dual

3 cameras

DLR-3K

4 cameras

IGI Digicam 4



Rolleimetric AIC x4

n-cameras

MIDAS Optoblique

Current oblique camera systems – Multi-camera

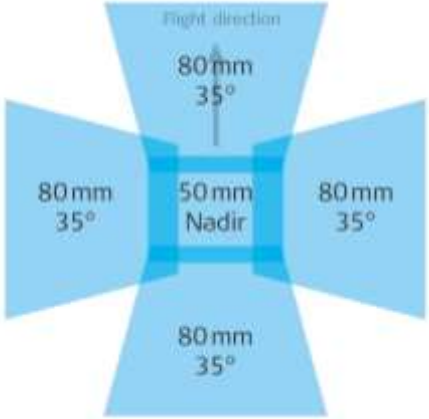
5 cameras

MALTESE CROSS CONFIGURATION

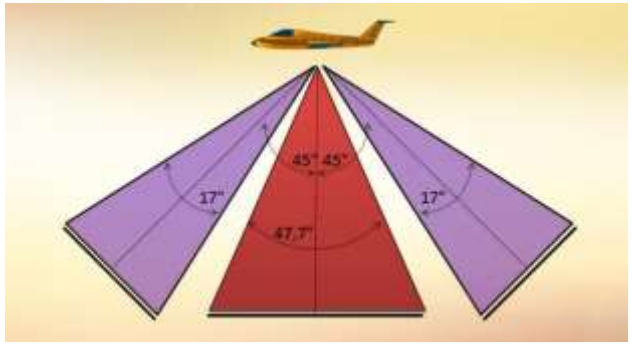
Vexcel Osprey

Leica RCD 30

IGI Penta DigiCAM

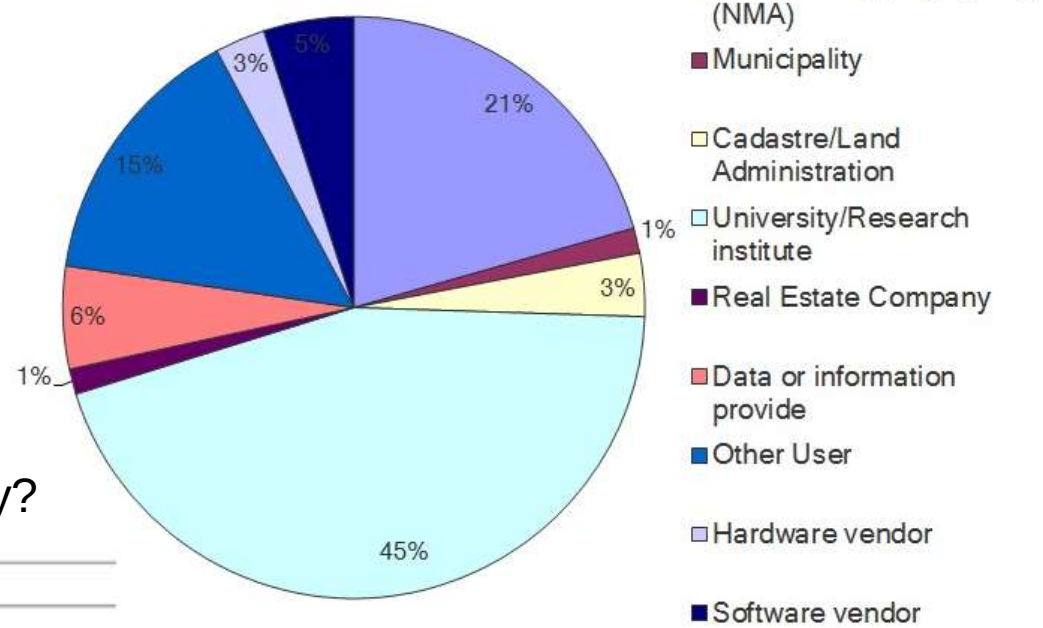


- One nadir + 4 oblique cameras
- Modular (i.e. varying angles) vs fixed
- Small, medium or large format sensors
- RGB + NIR (in the nadir)
- Wide vs narrow angle lens

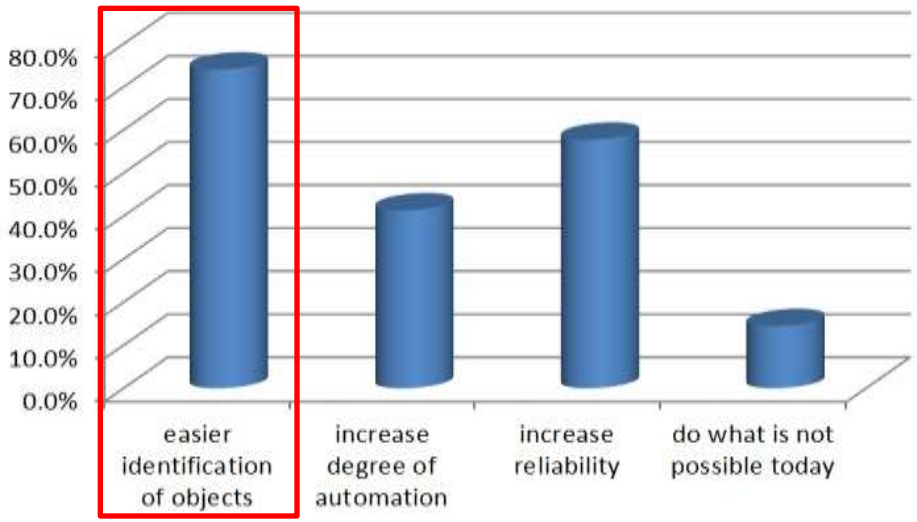


Who is interested in the oblique systems?

- Questionnaire submitted by EuroSDR on the current status of oblique airborne imagery
- Run throughout 2014 and 2016
- 300+ participants



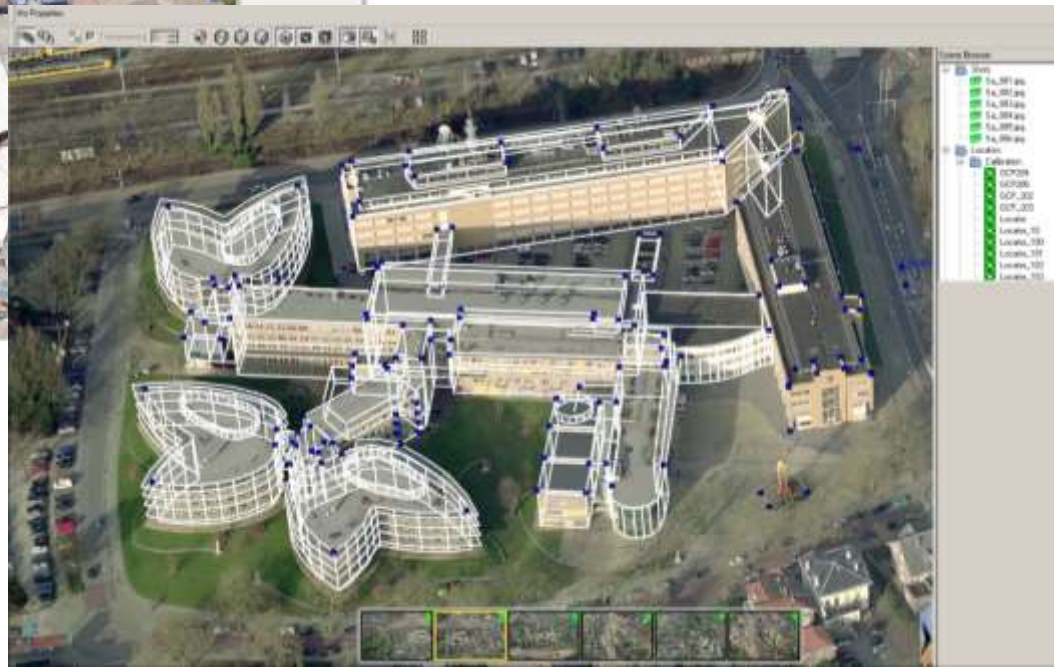
Advantages of oblique imagery?



First applications / use of oblique images

- Monoplotting / Building height measurements
- Interactive city modeling (Imagemodeler + Blomoblique)

Source: BlomUrbex



Source: Xiao, 2013

Nadir vs Oblique images and Photogrammetry

VERTICAL:

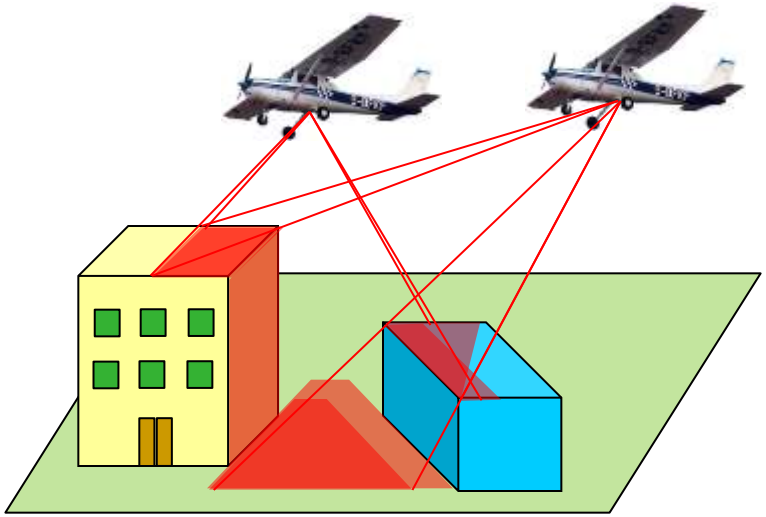
- Good observation of roofs, constant scale, traditional approach

OBLIQUE – Pros / Benefits:

- Visibility of roofs and vertical structures (feat. extraction, texturing)
- 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
- Improvement of the true-orthophoto automated generation

OBLIQUE – CONS:

- More occlusions (mitigated by multiple views and overlaps)
- Varying scale / GSD
- Big illumination changes
- Need for dedicated processing



Photogrammetric use of oblique imag

- The photogrammetric use of oblique images is challenging → researchers / companies interest
- Many papers and initiatives dealing with oblique imagery are already available

Terrestrial image blocks

UAV (nadir/oblique)

Airborne (nadir/oblique)

Foster research concerning:

1) Fully automatic and reliable orientation of multi platform imagery

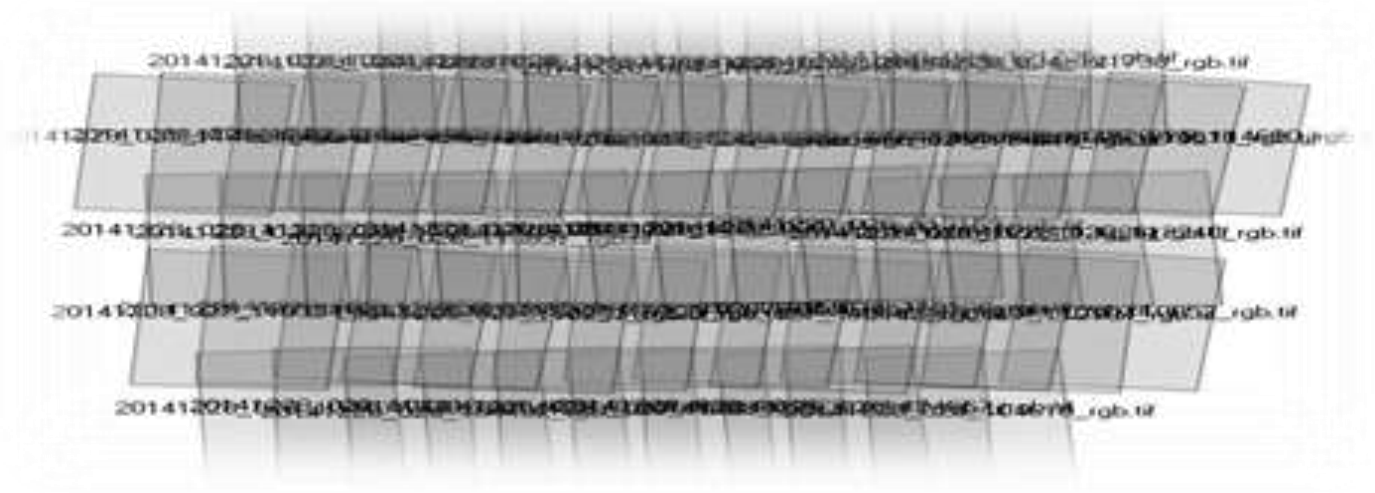
2) Dense image matching within/across platforms

[F. Nex, F., Gerke, M., Remondino, F., Przybilla, H.-J., Bäumker, M., Zurhorst, A., 2015: **ISPRS benchmark for multi-platform photogrammetry**. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. II-3/W4, pp. 135-142. PIA15+HRIGI15 – Joint ISPRS conference]

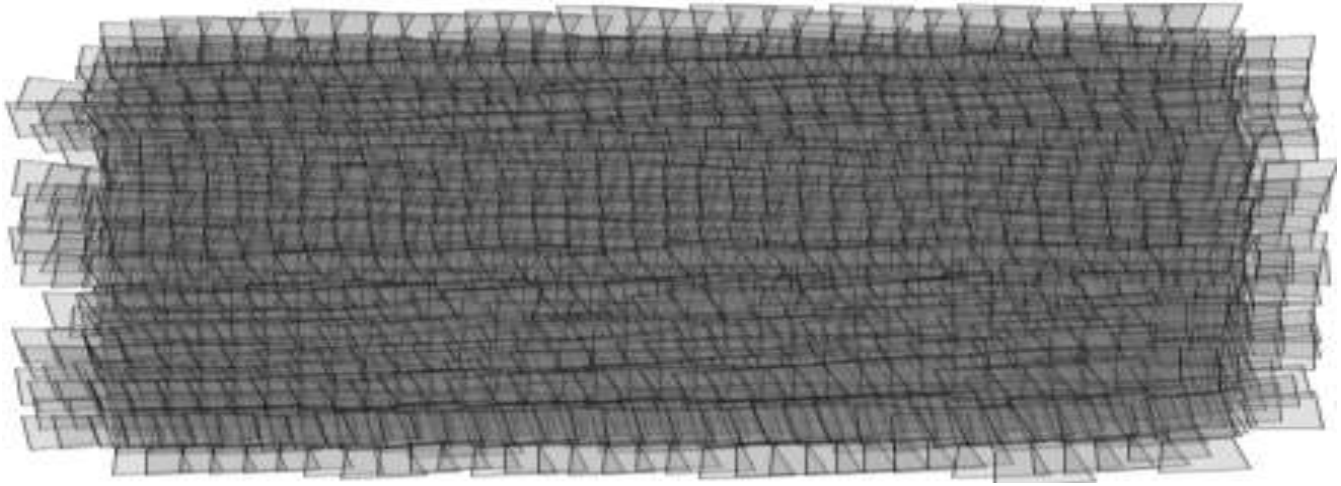
Data Collection

- State-of-the-art is 5 images for every “acquisition position”
- Large image block size (# images)

Nadir



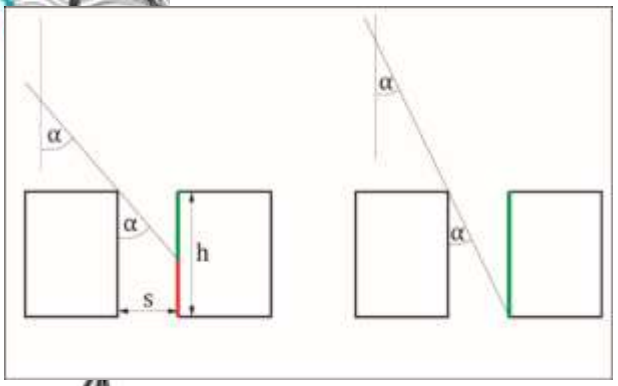
Nadir & oblique

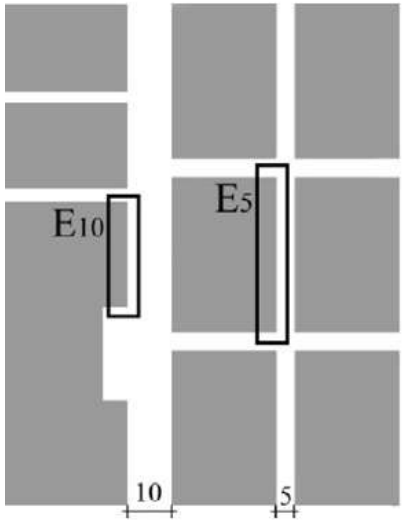


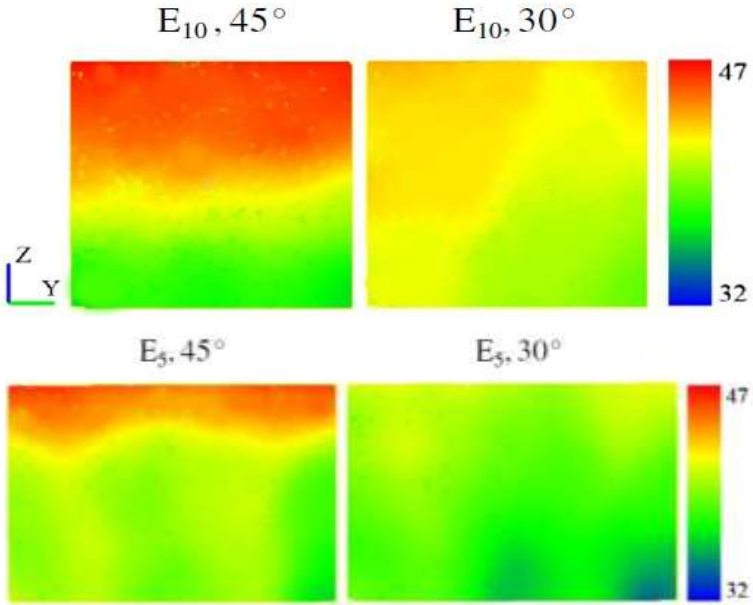
Source: Ordnance and Survey UK

Data Collection

- Choose the right overlaps if a complete 3D model of the urban area is needed





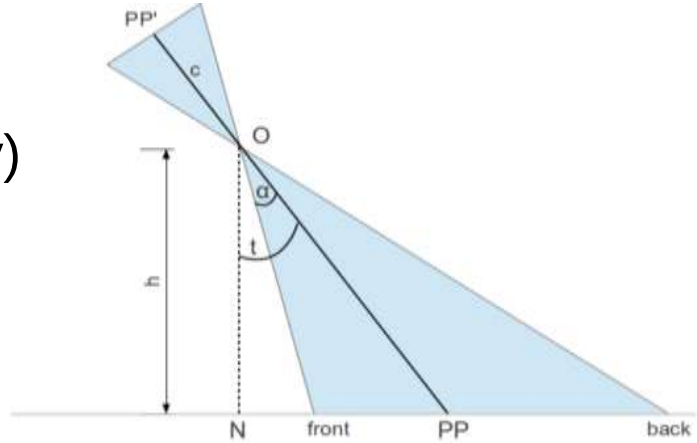


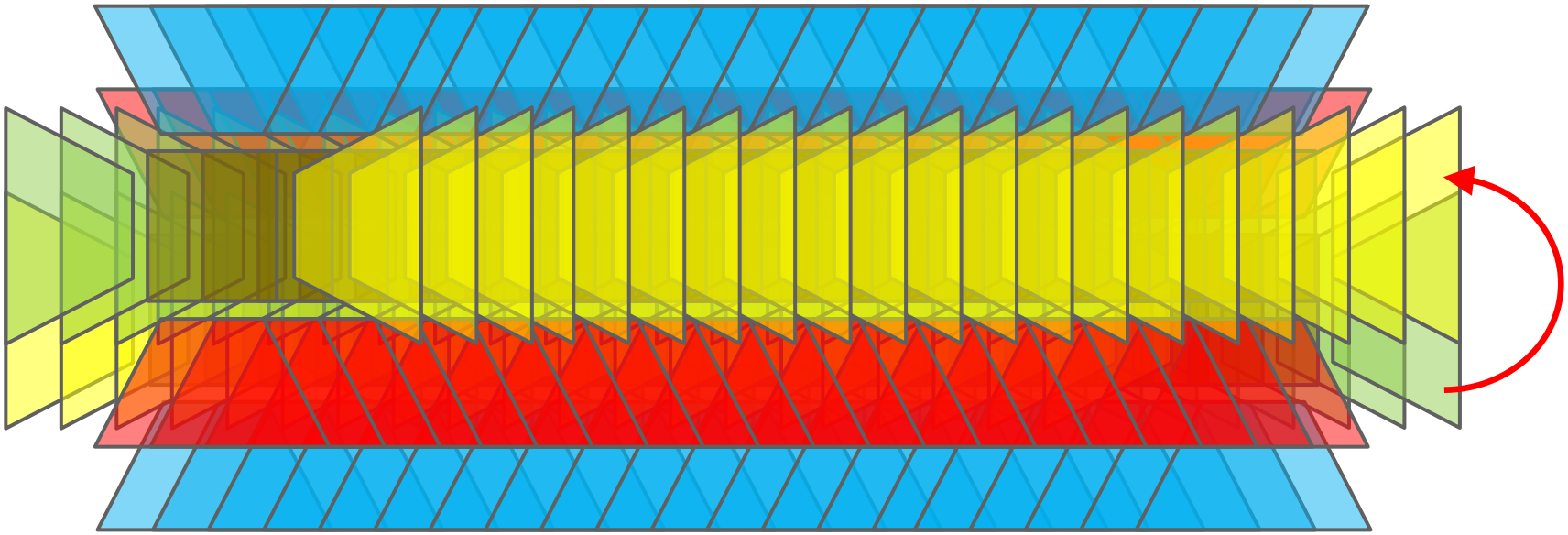
- The street's width and the building's height play a major role in planning a successful urban survey campaign.
- The taller the architectures, the lower the camera incidence angle must be.
- A compromise should be found between the camera tilt setting, focal length, sensor size, overlap and geometry of the area.

[Rupnik, E., Nex, F., Toschi, I., Remondino, F., 2015: **Aerial multi-camera systems: Accuracy and block triangulation issues**. *ISPRS Journal of Photogrammetry and Remote Sensing*, Vol. 101, pp. 233–246]

Data Processing – Image orientation

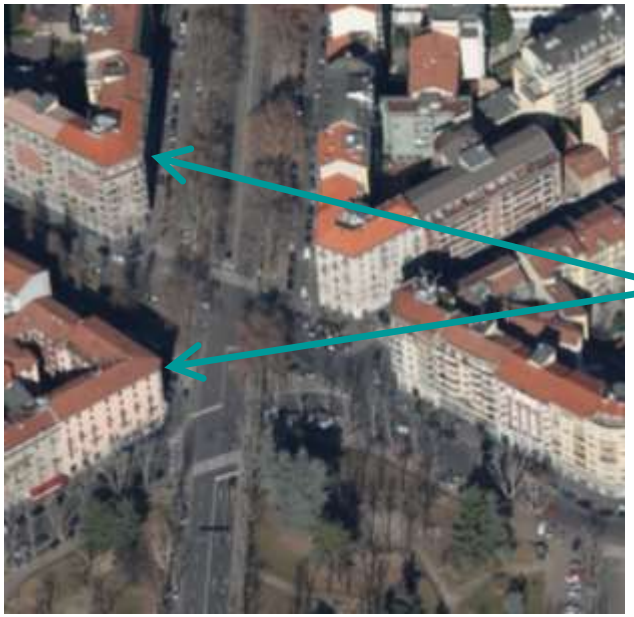
- Problems for traditional photogrammetric tools / approaches:
  - Convergent images
  - Varying image scale / resolution (GCPs measured with diff. accuracy)
  - Large perspective distortions (interest operators are less efficient)
  - Long processing time





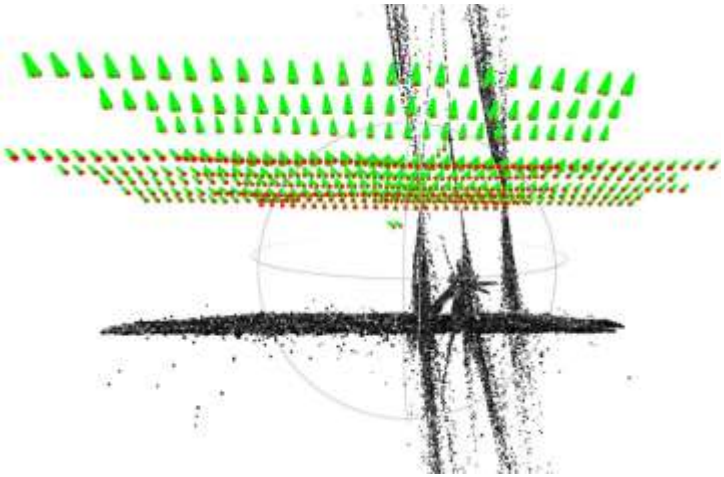
Data processing – image orientation

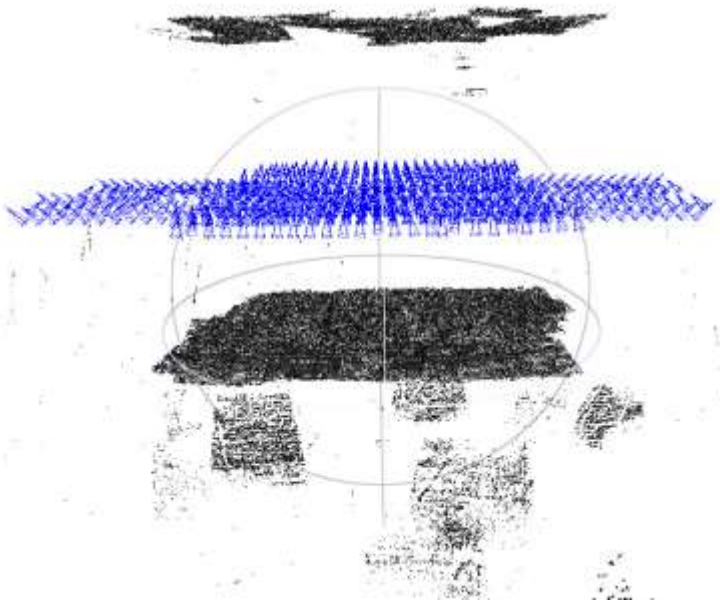
- Different perspectives and illuminations in different image views



Data processing – image orientation

- The final results will be many (separated) blocks, without a good strategy of concatenation of the images.





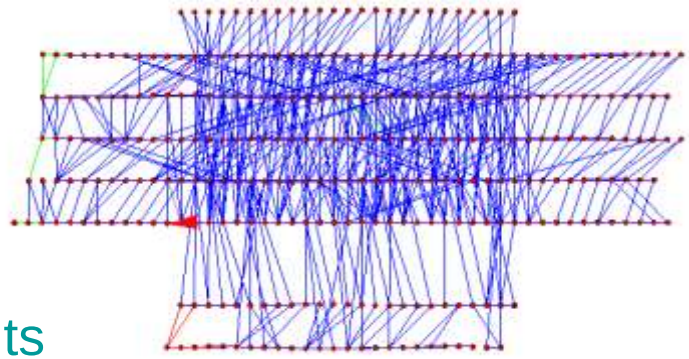
	Right	Back	Front	Left	Nadir
Right	740	-	-	800	21
Back	-	566	767	-	39
Front	-	-	588	-	34
Left	-	-	-	711	7
Nadir	-	-	-	-	865

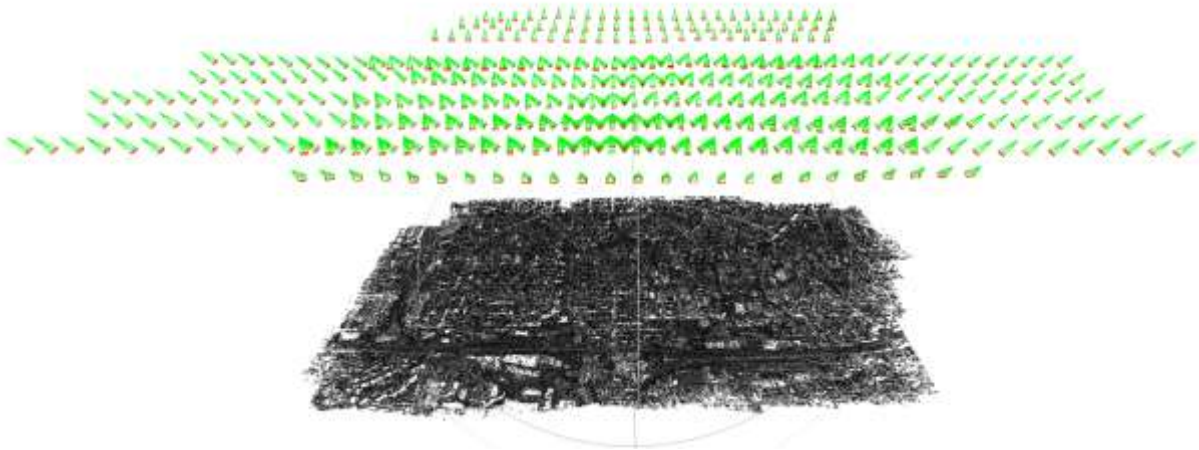
- The traditional approaches lose the connection between different sub-blocks acquired from different looking directions

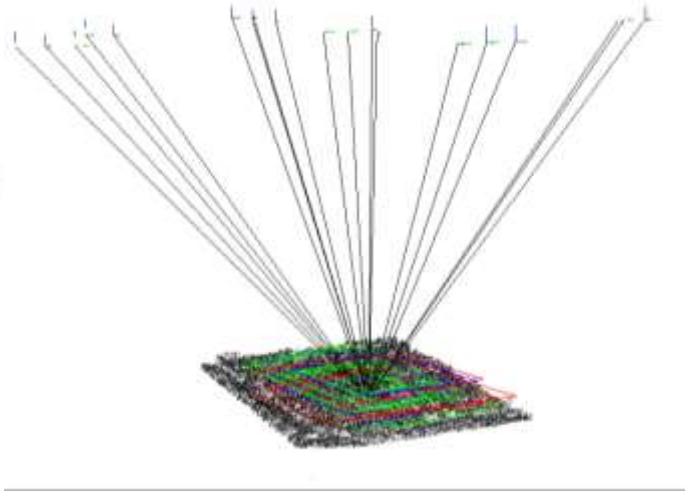
[Gerke, M., F. Nex, F. Remondino, K. Jacobsen, J. Kremer, W. Karel, H. Hu, W. Ostrowski, 2016. **Orientation of oblique airborne image sets - experiences from the ISPRS/EUROSDR benchmark on multi-platform photogrammetry**, ISPRS Archives, to be published]

Data processing – image orientation

- Rely on GNSS/INS data
- Create a connectivity map/graph
- Use constraints like: overlap, looking direction, min num. of extracted tie points
- Exploit large observations' redundancy



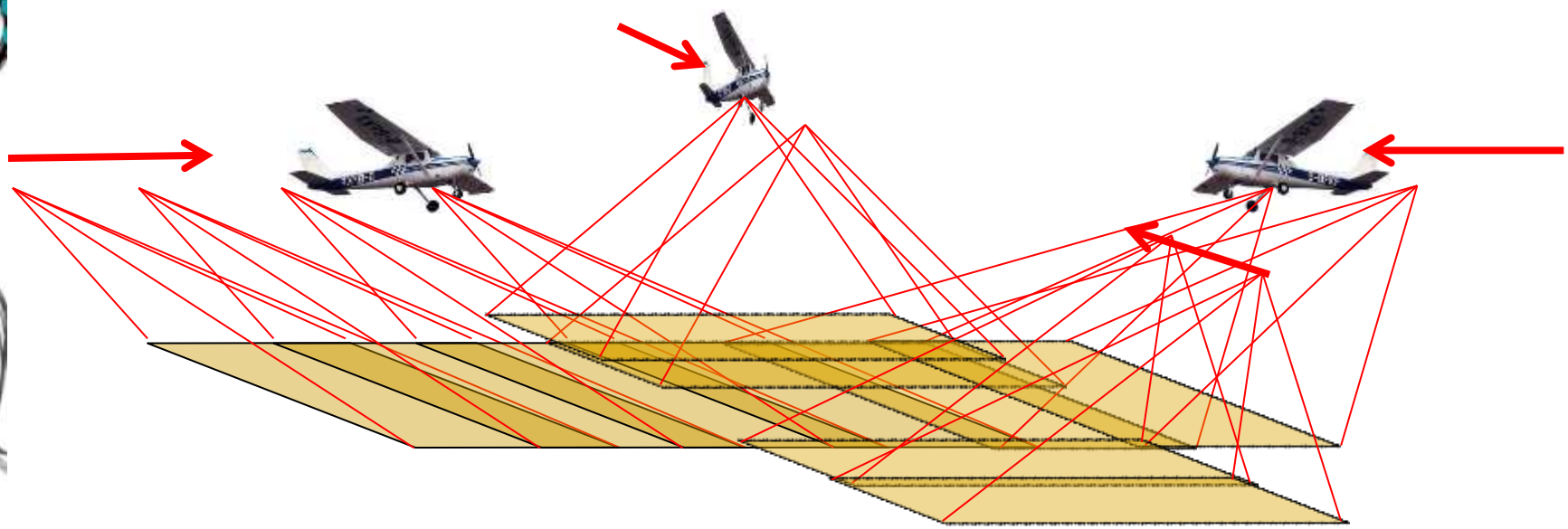




[Rupnik, E., Nex, F., Remondino, F., 2013: **Automatic orientation of large blocks of oblique images**. *ISPR Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, ISPRS Hannover 2013]

Data processing – Point cloud generation

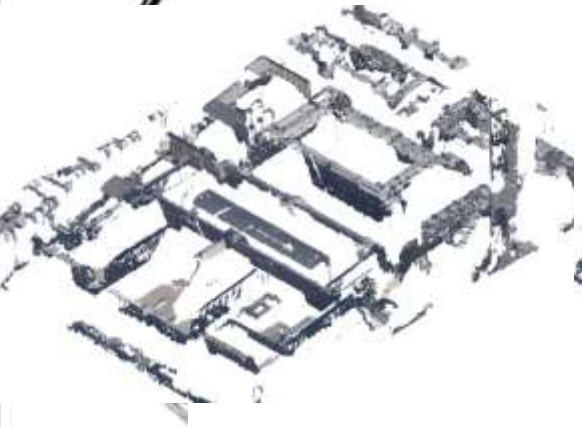
- Use connectivity map/graph
- Use only images with same look direction and large overlaps in the matching process



[Rupnik, E., Nex, F., and Remondino, F., 2014: **Oblique multi-camera systems - orientation and dense matching issues**. ISPRS Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-3/W1, pp. 107-114]

Data processing – Point cloud generation

- Use connectivity map/graph
- Prefer images with same look direction
- Point cloud filtering
- Merge multiple point clouds (from every looking direction)



1 view

2 views

4 views

[Rupnik, E., Nex, F., and Remondino, F., 2014: **Oblique multi-camera systems - orientation and dense matching issues**. ISPRS Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-3/W1, pp. 107-114]

Data processing – Point cloud generation

Dense Image Matching point cloud (MicMac)

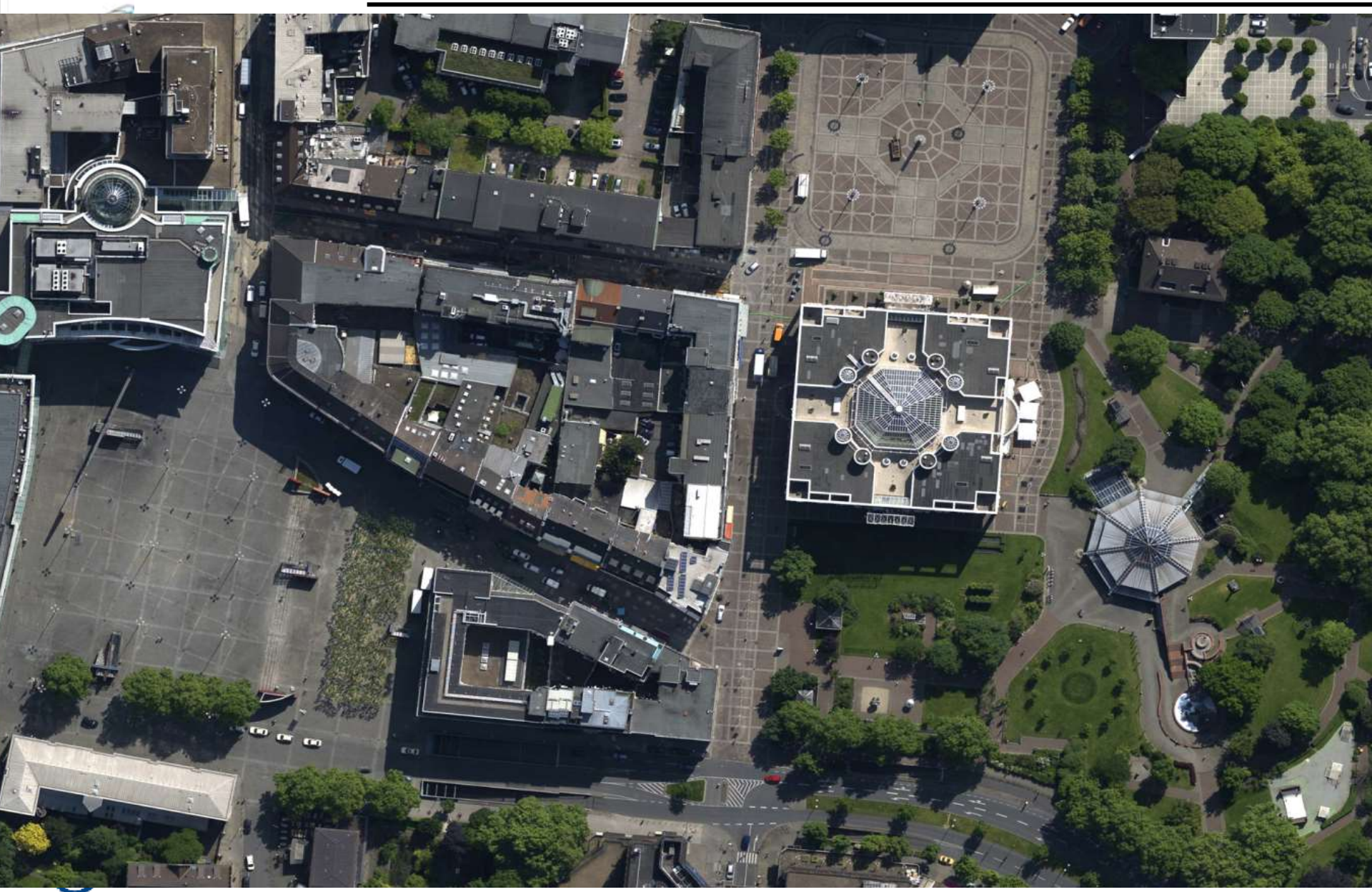
Data processing – point cloud generatio

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

[Haala, N., Rothermel, M. & Cavegn, S., 2015. **Extracting 3D Urban Models from Oblique Aerial Images.** JURSE 2015 Joint Urban Remote Sensing Event, Lausanne, Switzerland]

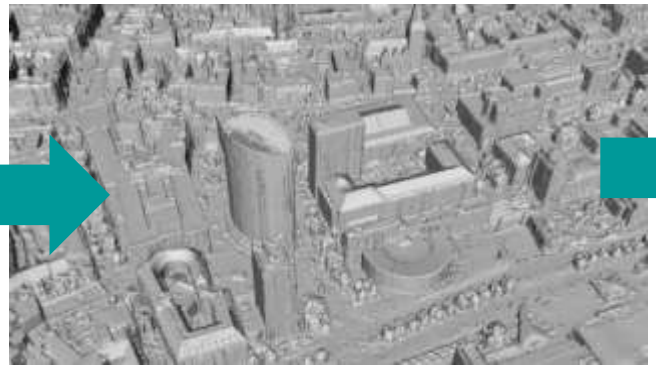

Courtesy: *nFrame*

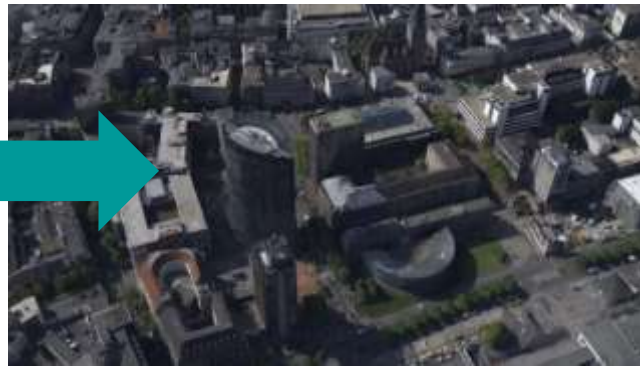
Data processing – True-ortho generation

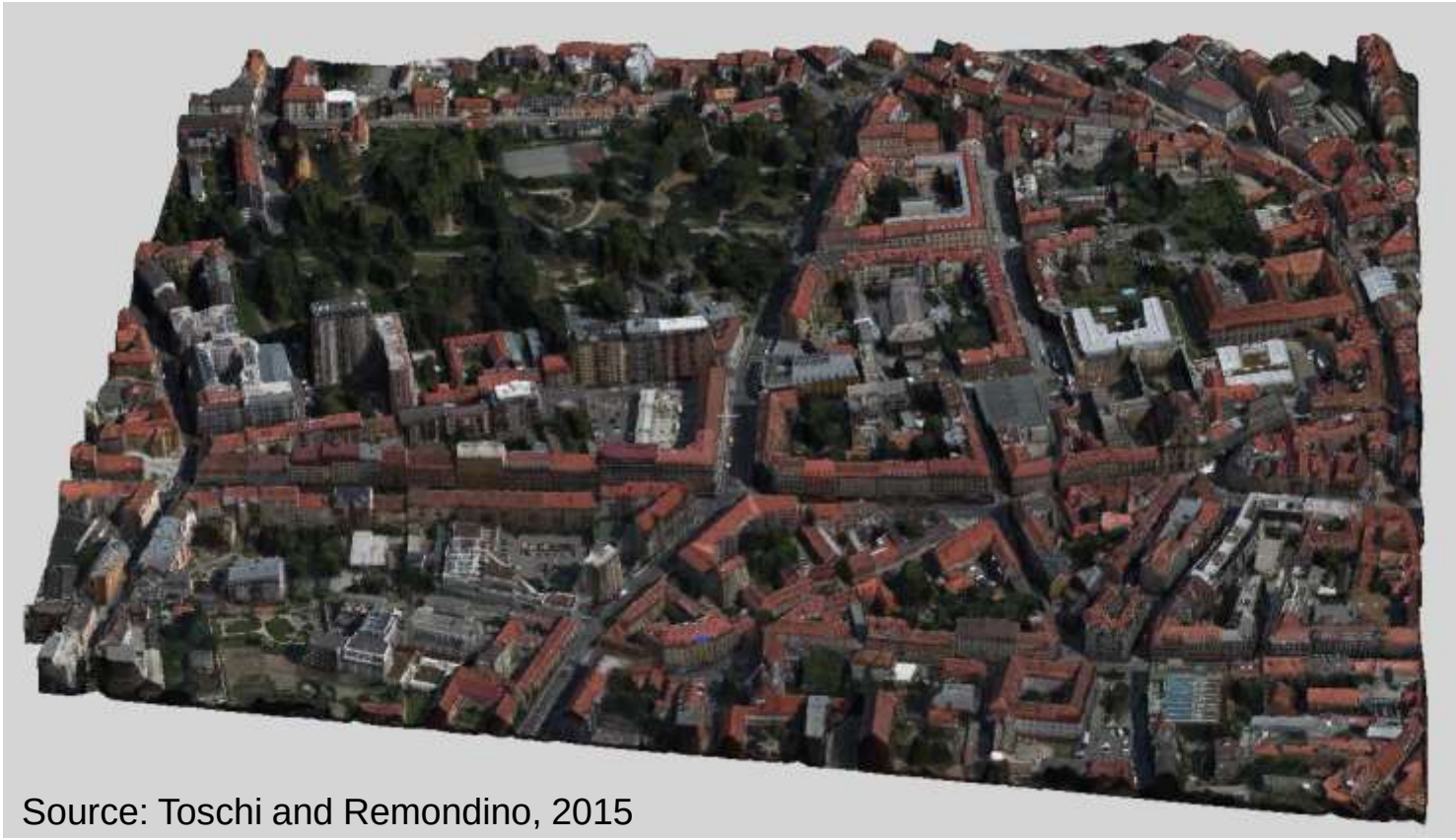


Courtesy: *nFrame*

Applications - 3D mesh / polygonal models

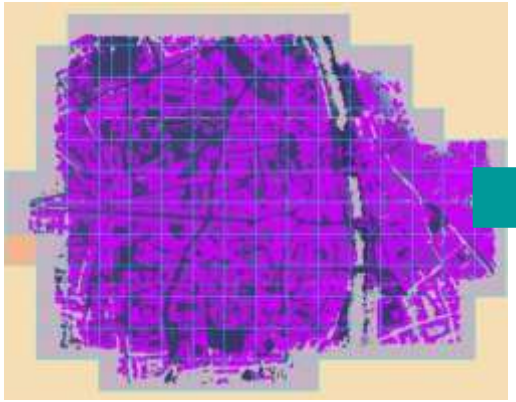




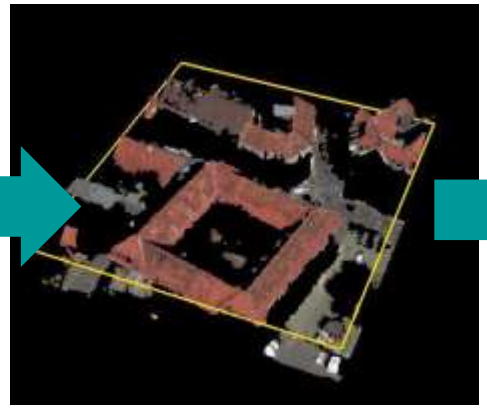


Source: Toschi and Remondino, 2015

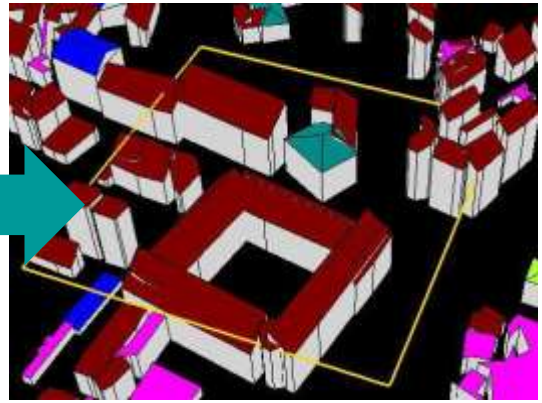
Applications - 3D building models



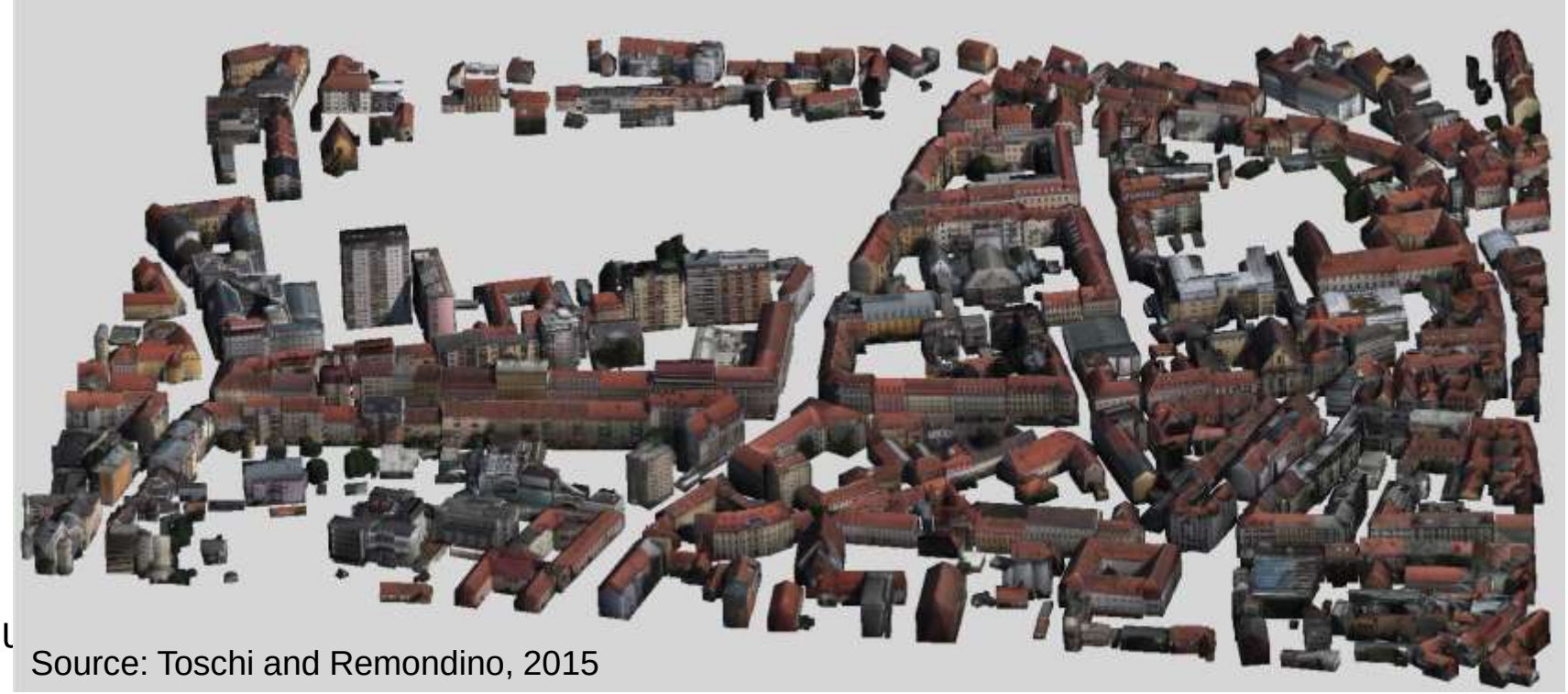
Point cloud



Roof segmentation and classification



Building models



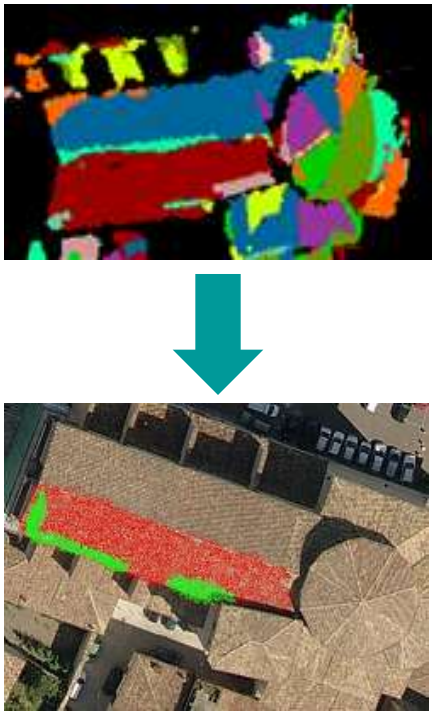
Source: Toschi and Remondino, 2015

Applications – Urban Monitoring

2008 2009

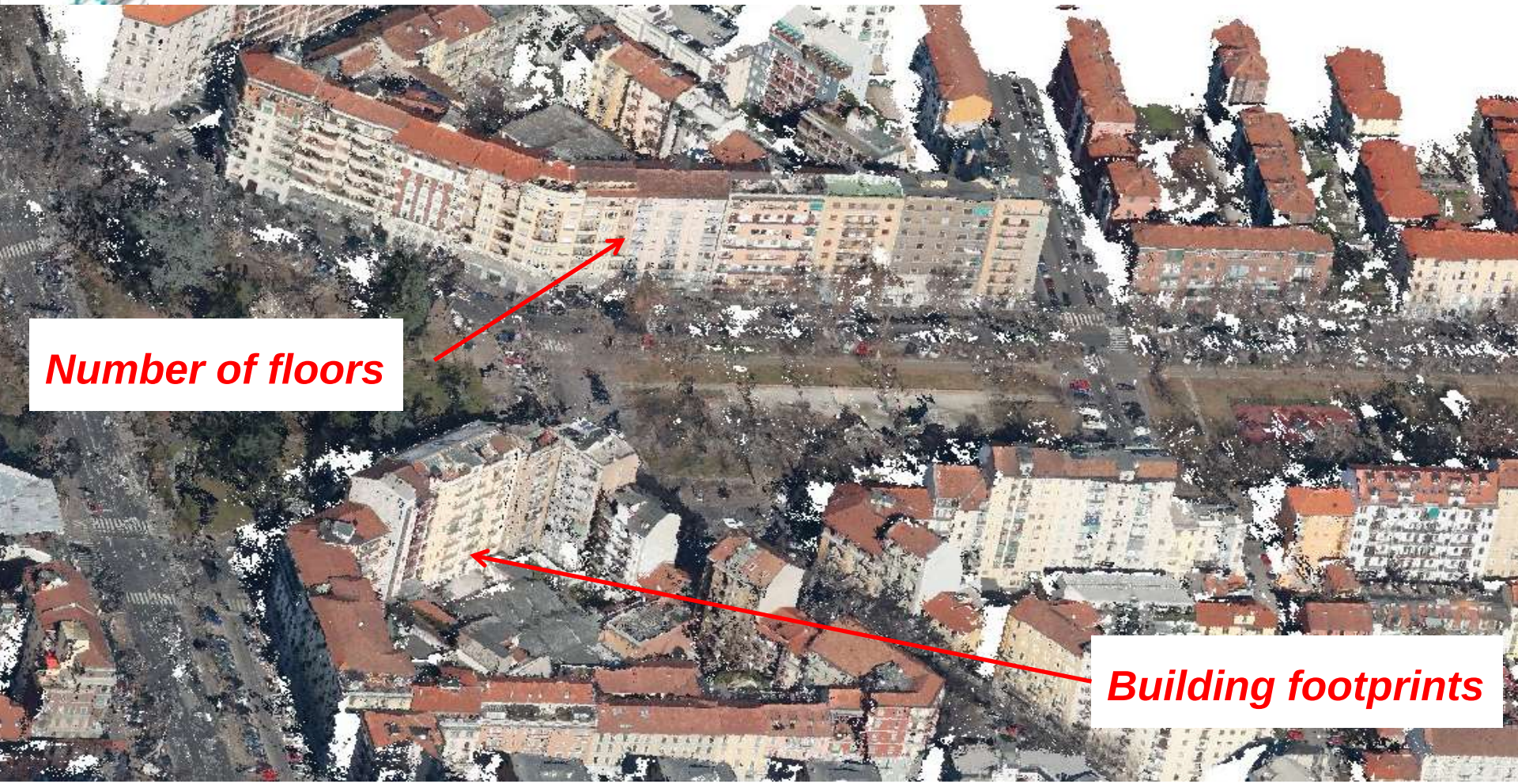
L'Aquila earthquake

- Automated delineation of damages



[Vetrivel, A., Duarte, D., Nex, F., Gerke, M., Kerle, N., Vosselman, G., 2016. **Potential of multi-temporal oblique airborne imagery for structural damage assessment**. ISPRS Annals, to be published]

Applications – Cadastral monitoring

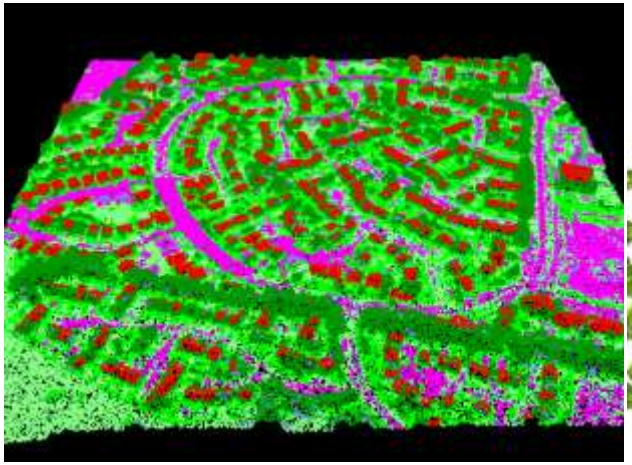


[Remondino, F., Toschi, I., Gerke, M., Nex, F., Holland, D., McGill, A., Talaya Lopez, J., Magarinos, A., 2016. **Oblique aerial imagery for NMA – Some best practices**. ISPRS Archieves, to be published]

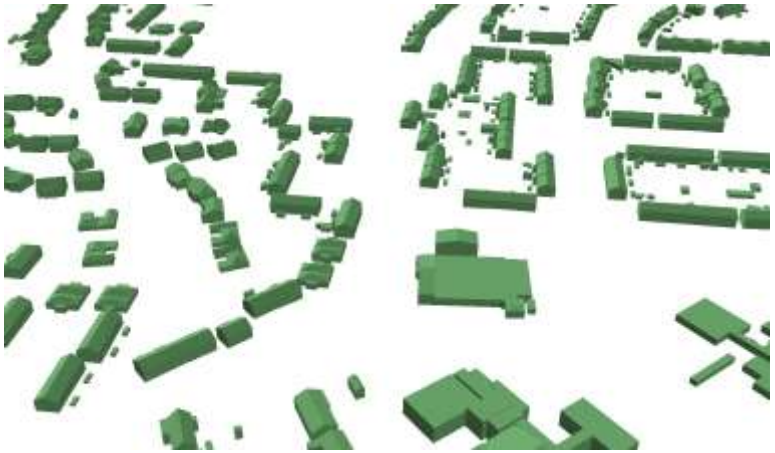
Early NMCA experiences

Ordnance & Survey UK

- ❑ Classification
- ❑ 3D building model without prior knowledge



Ordnance & Survey Ireland



- ❑ Map updating and systematic comparison existing methologies

Early NMCA experiences

Institut Cartogràfic i Geològic de Catalunya

- ❑ Texturing 3D models and visual inspection

General remarks

- ❑ Use of available commercial solutions (i.e. Tridicon)
- ❑ No need building footprint for 3D city modelling ☺
- ❑ More accurate modelling ☺
- ❑ Texture and additional information of façades ☺
- ❑ Huge amount of data to be managed ☹

Final remarks and outlook

- Many systems and new ones might come out soon (sensor size?)
- Oblique requires a new approach in the photogrammetric pipeline
- Oblique airborne images could become a standard, complementary to traditional large format nadir images (especially in urban areas)
- Oblique are complementary to traditional nadir and UAV images
- Many possible applications: map update, 3D city modeling, inspection and interpretation, 3D cadaster, real estate, etc.
- NMCAs are thinking to adjust their production pipeline to cope with oblique
- Additional costs of oblique flights (especially additional flight lines) might be compensated by additional outcomes and benefits:
  - Easier object identification / interpretation
  - generation of point clouds on vertical elements
  - More reliable generation of true-orthophotos
  - Extension from 2D to 3D GIS data

Final remarks and outlook

- Room for improvement in the use of oblique imagery:
  - Management of scale and radiometric changes;
  - Reliable and fast identification of homologues points, also across viewing directions;
  - Processing time and reliable big-data processing
  - Fusion of point clouds coming from different viewing directions (and with different accuracy)
  - Feature extraction and automation in interpretation in complex scenes
  - Integration of Oblique images with other data (UAV, MMS)

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