OBLIQUE MULTI-CAMERA SYSTEMS

Orientation and dense matching issues

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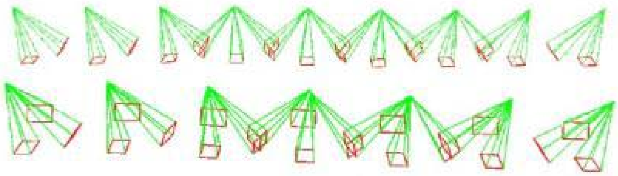
FONDAZIONE BRUNO KESSLER

3DOM 3D OPTICAL METROLOGY

http://3dom.fbk.eu/

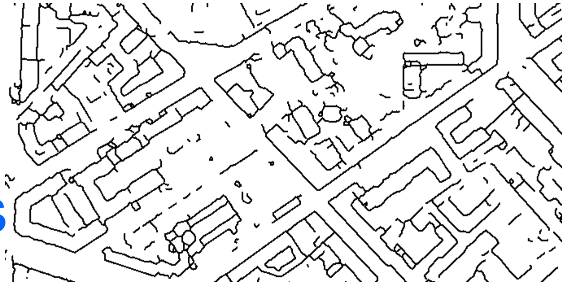
This presentation reports:

- Motivations / state of the art



- Large image block Orientation
- Point Cloud generation and processing

- Achieved results
- First examples of feature extraction



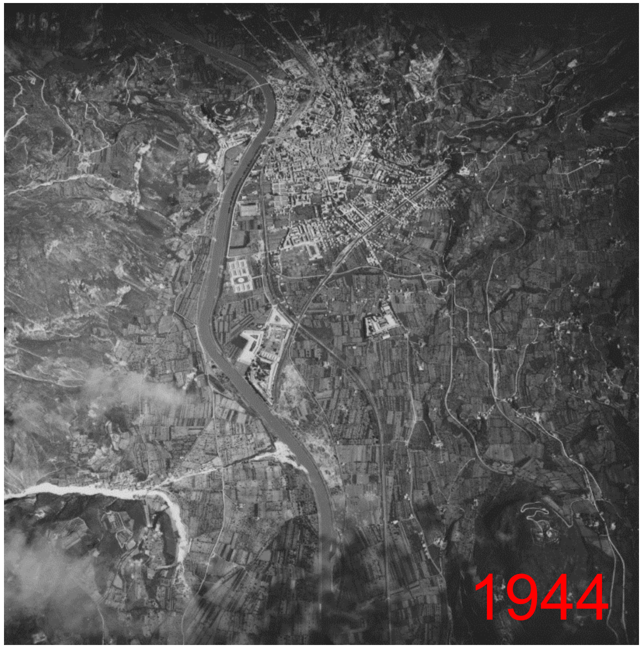
- Learned lessons and future developments

BACKGROUND

First recorded aerial photo in the US (1860) by James Wallace Black was an oblique shot.

Oblique images were mainly used for military purposes thanks to their easiness in the interpretation.

In the "analogue times" these systems were too expensive.



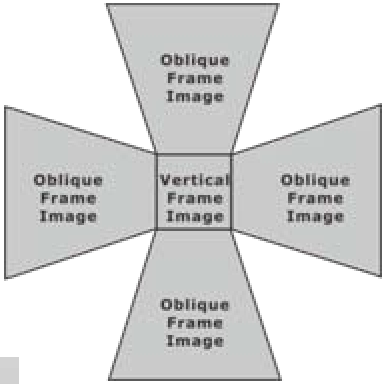
But a «second life» started in the last decade, with the development of digital aerial cameras.

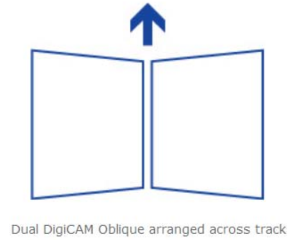
Oblique images were initially used just for visualization purposes.

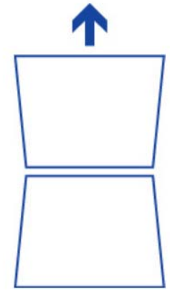
In the last years, several oblique camera systems have been developed.

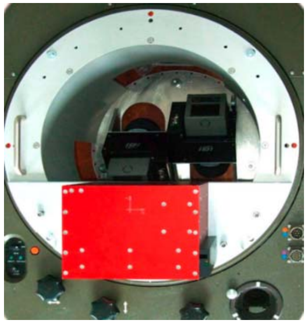
AVAILABLE OBLIQUE IMAGES SYSTEMS

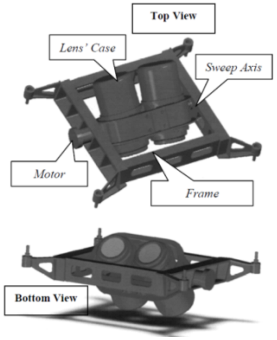
Oblique imagery systems can be classified in "Maltese Cross" (or similar) and Fan (static or sweeping) configuration.











- Pictometry
- Track'Air MIDAS
- IGI Penta DigiCam
- Leica RCD30 Penta
- UltraCam Osprey
- Icaros IDM1000

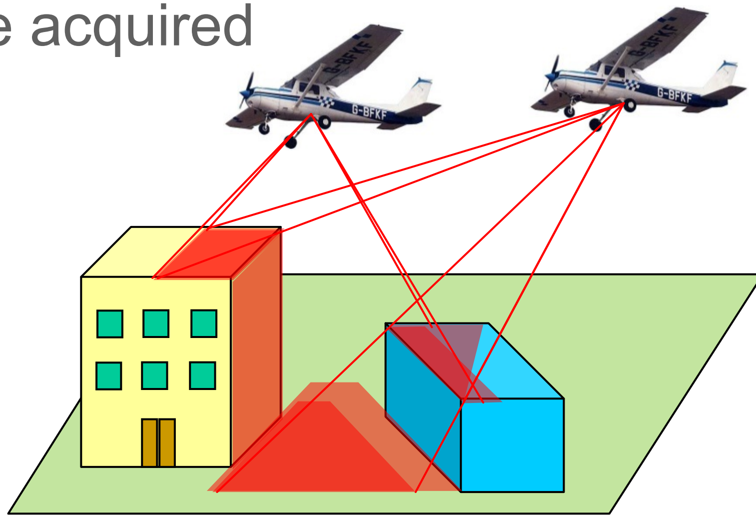
- IGI Dual DigiCaAM
- Visionmap A3 Edge
- Leica RCD30 Trio

RGB + (NIR) image bands
Small – medium – large format
Wide – narrow angle lens
Modular vs fixed

PROS / CONS

Oblique images are acquired over great part of the European cities:

- 4-5 years between acquisitions
- More recently → overlapping images are acquired



PROS / CONS

- Different occlusions compared to nadir images
- Different accuracy (Gerke, 2009)
- Images can provide additional information on building facades (n° floors, window, etc.)
- For footprint extraction: roof overhang estimation (volume and footprint computation)
- 3D vs 2.5D
- Close the gap between aerial and terrestrial

LITERATURE & GOAL OF THE WORK

Research on the use / potential of oblique images are quite recent. These papers separately deal with:

- Large block images orientation
- Point cloud generation
- Feature extraction (verification, updating, building detection, footprint extraction, etc.).
- Monitoring and multi-temporal analysis

In this paper, the development of a complete workflow is presented:

- from image orientation
- through the dense matching
- to feature extraction

This methodology is an ongoing work and the first results using both Maltese cross and Fan systems are presented in the following.

AVAILABLE DATA

The following datasets were used:

	MIDAS BLOMOBLIQUE	VISIONMAP	INTERATLAS
City	Milano, Italy	Netanya, Israel	Paris, France
n° camera	5	2	4 (+ 1 Ultracam)
f [mm]	80 - 100	250	100
camera format [pixel]	5616 x 3744	4004 x 2662	8176 x 6132
N° images	550	260	206
Overlaps [%]	80 - 50	~ 90	80 - 60
GSD_{nadir} [cm]	10	6	10
Flight Height [m]	1000	2000	1200
Area [km^2]	15	1	3

AVAILABLE DATA

MIDAS / BLOMOBLIQUE

VISIONMAP

INTERATLAS

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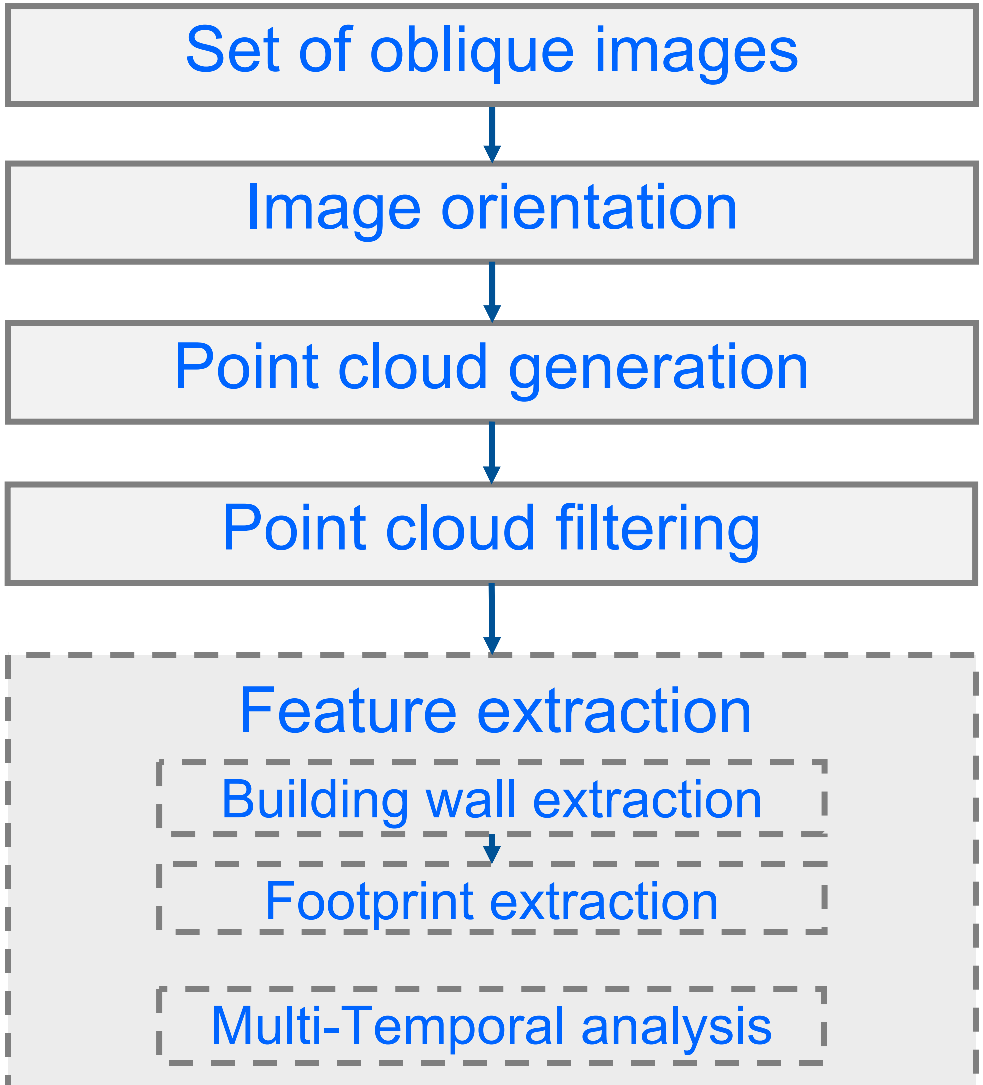
OBLIQUE IMAGES WORKFLOW

The proposed methodology can be divided in several steps:



3DOM

OBLIQUE IMAGES WORKFLOW

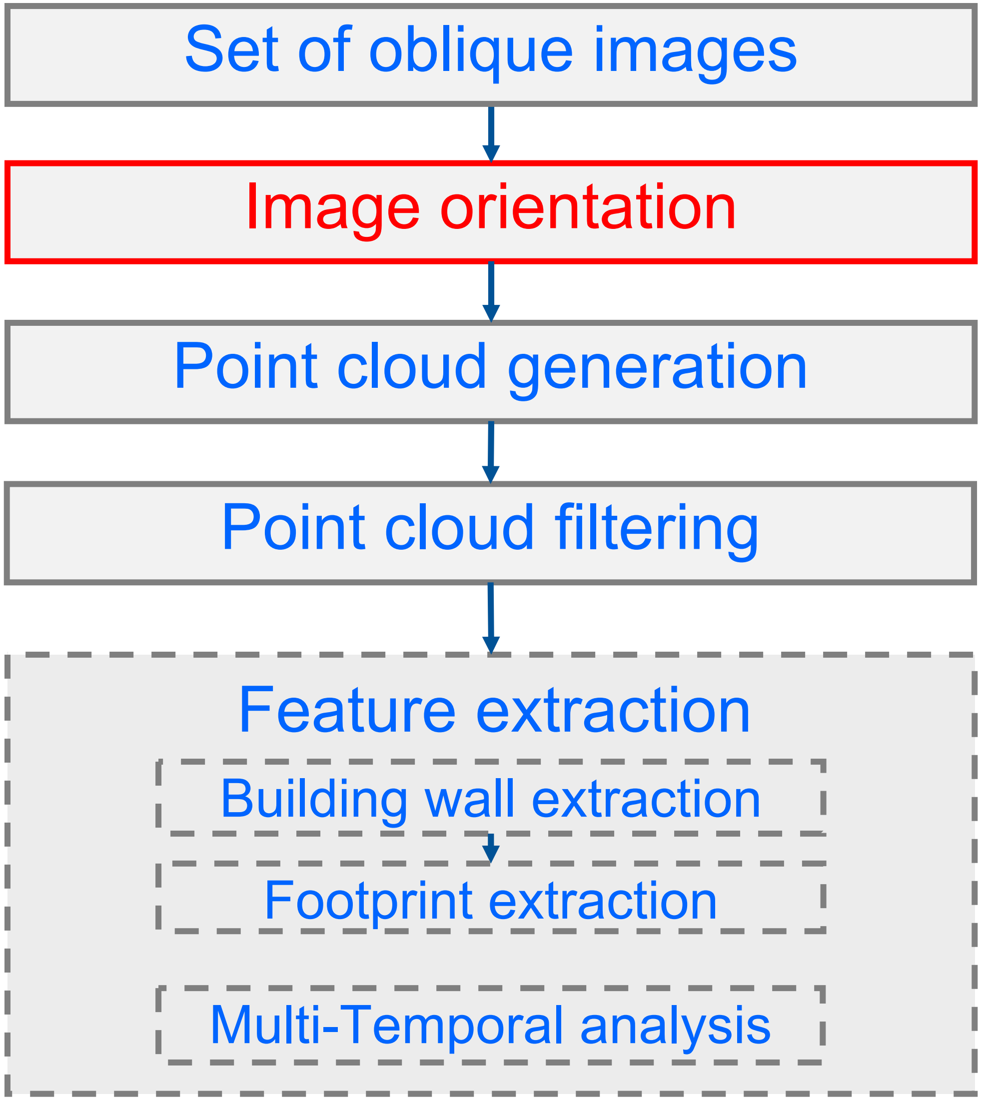


IMAGE ORIENTATION

Open-source Apero tool (IGN) is used for the BBA process

- Tie point extraction
  - SIFT operator
- Concatenation
  - Direct methods (resection + essential matrix)
  - Orientation built step by step
  - General solution (for terrestrial, aerial images)

With oblique images:
•High risk of divergence
•Careful concatenation necessary

→

- perspective distorsions
- SIFT less reliable

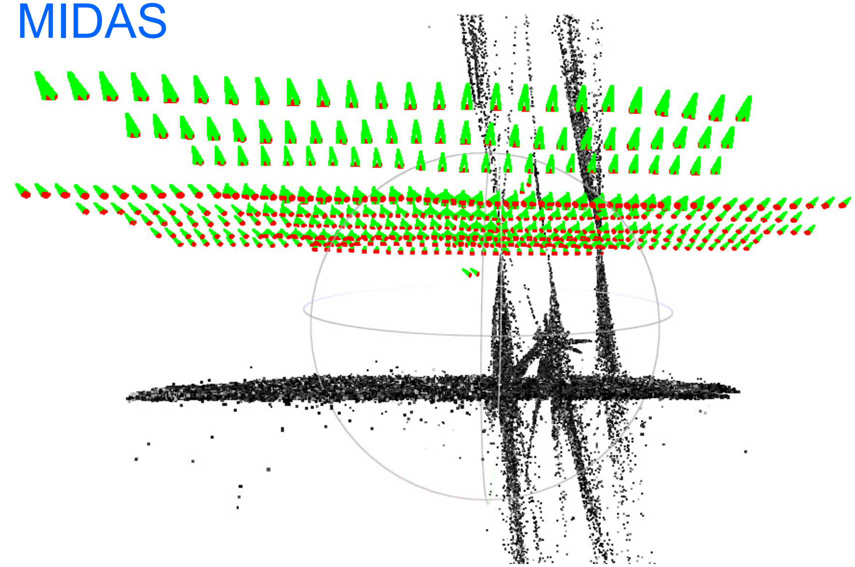
- BBA relative
  - Gauss-Newton algorithm
- Geo-referencing
  - GNSS/IMU or Ground Control Points to georeference the images

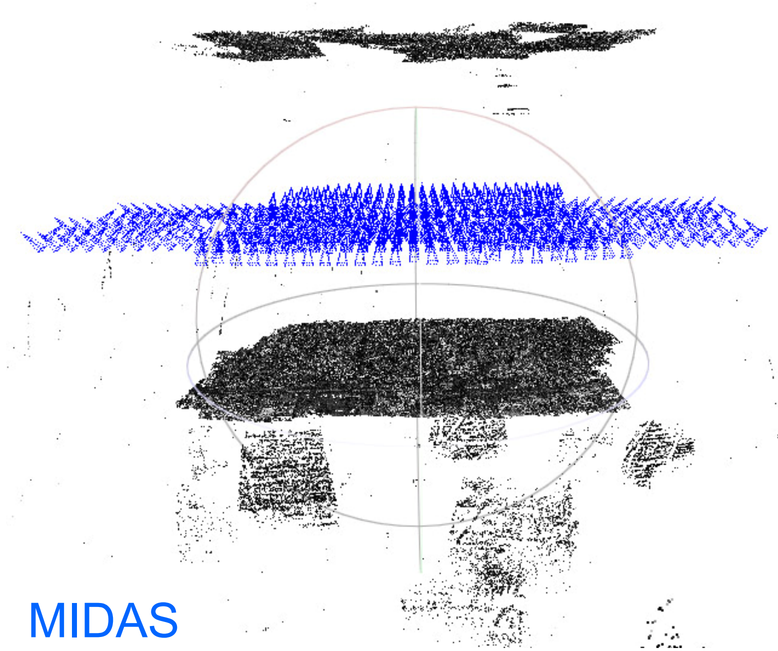
OBLIQUE IMAGES WORKFLOW

Some results without using the connectivity

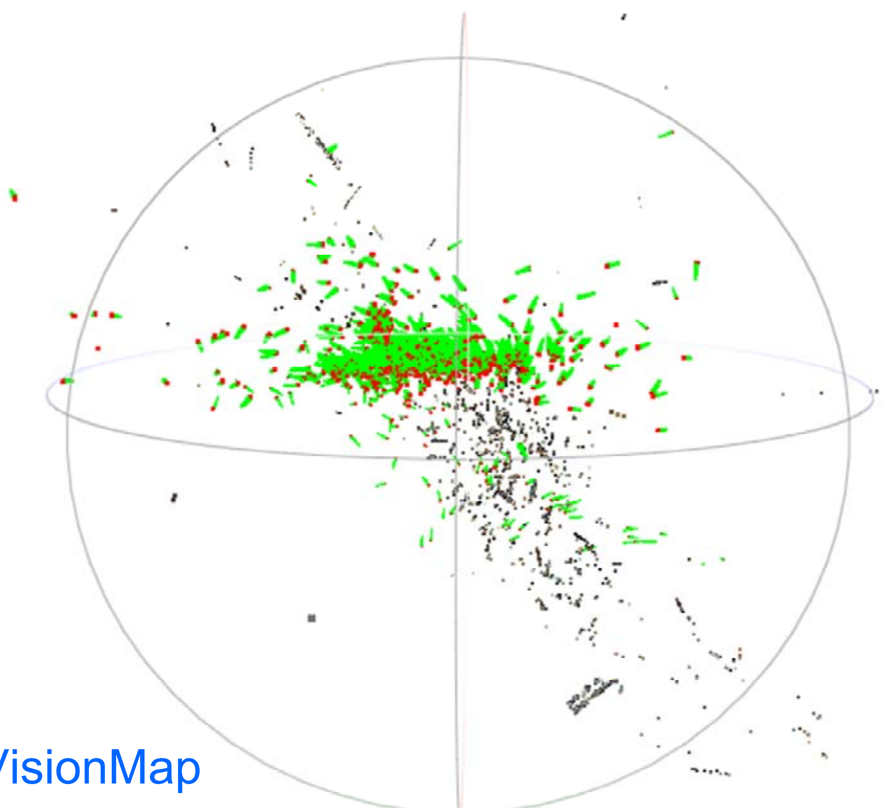
Some images are completely disconnected from the block

MIDAS





MIDAS



VisionMap

IMAGE ORIENTATION

Open-source Apero tool (IGN) is used for the BBA process

- Tie point extraction
  - SIFT operator
- Concatenation
  - Direct methods (resection + essential matrix)
  - Orientation built step by step
  - General solution (for terrestrial, aerial images)
  - High risk of divergence
  - Careful concatenation necessary → OBLIQUE VIEWS → Ad hoc CONNECTIVITY
- BBA relative
  - Gauss-Newton algorithm
- Geo-referencing
  - GNSS/IMU or Ground Control Points to georeference the images

Ad hoc connectivity helps to:

1) Faster & more reliable tie points extraction

- Reduce the number of images to match

GNSS/IMU

2) Guide image concatenation in BBA

connectivity

Initial values of exterior orientation are computed using direct methods and step-by-step
- Optimize image sequence
- Build concatentation in the graph

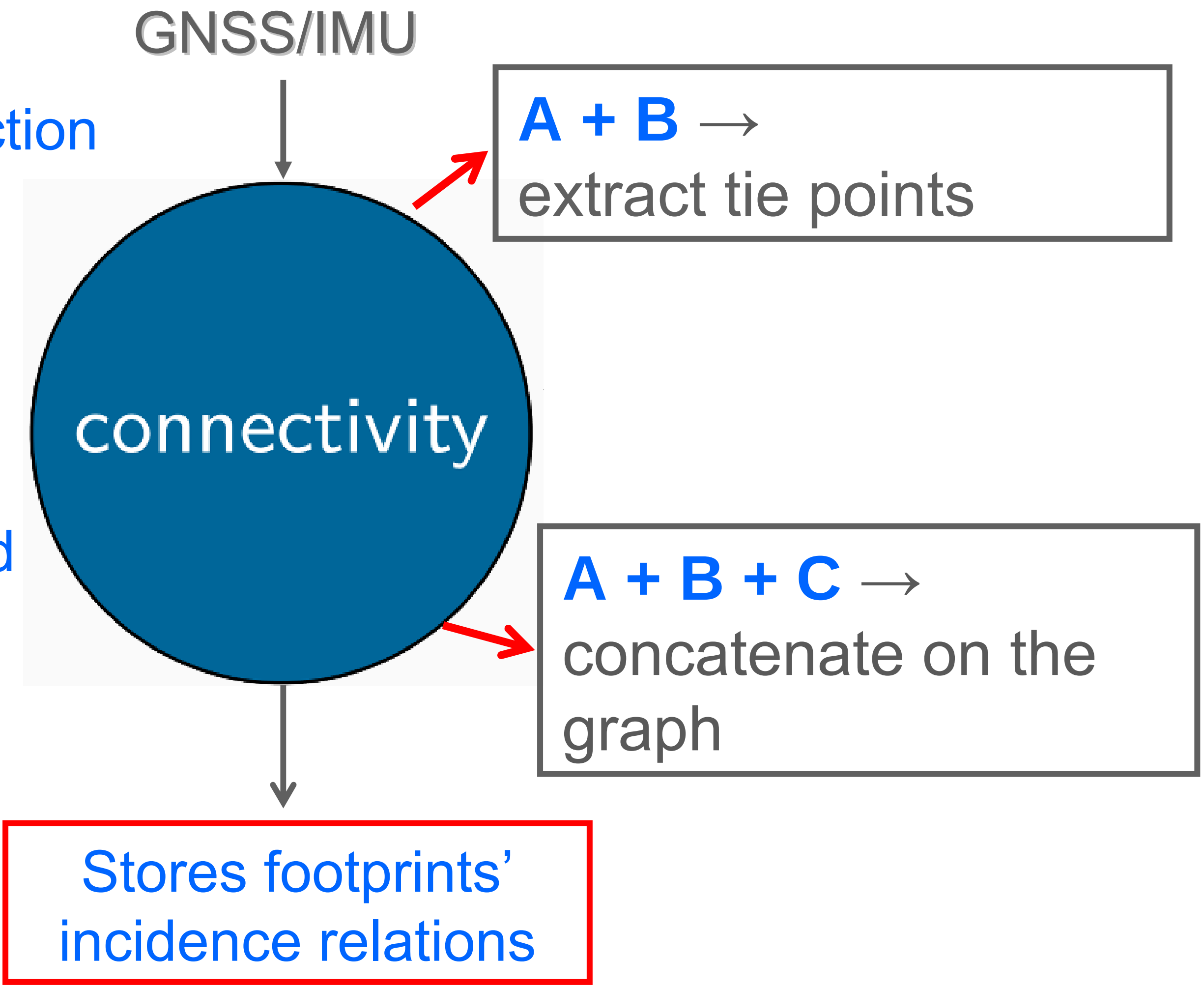
3) Guide reference / slave images in the matching

- Homogenous overlap
- NO occlusions

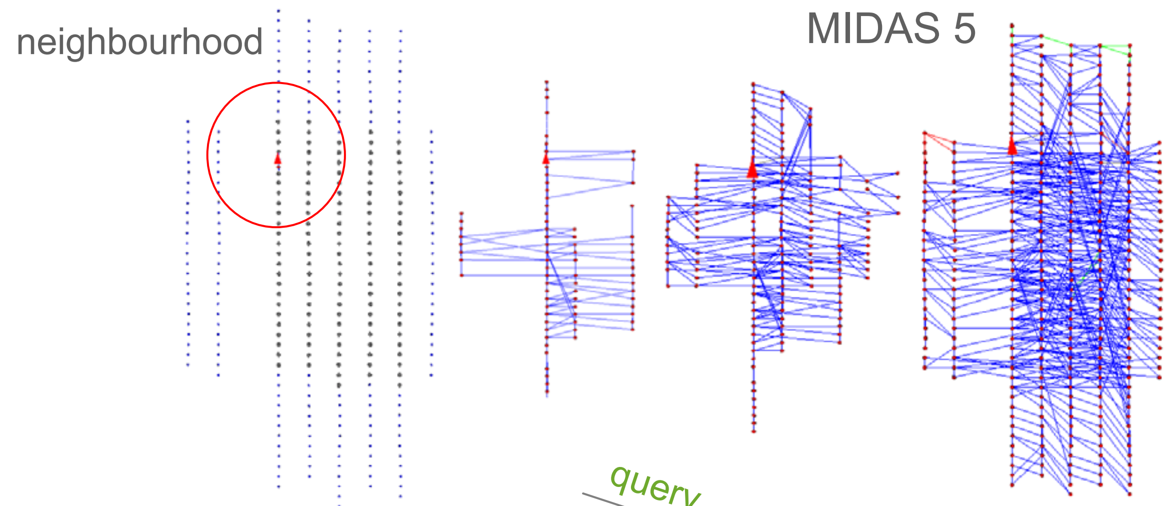
Stores footprints' incidence relations

Three constraints are used in the connectivity graph:

- Constrain **A** overlap
- Constrain **B** look direction
  - Nadir → all
  - Oblique → nadir all
  - Oblique → oblique only similar look dir
- Constrain **C** minimum no. of extracted features



Concatenation steps

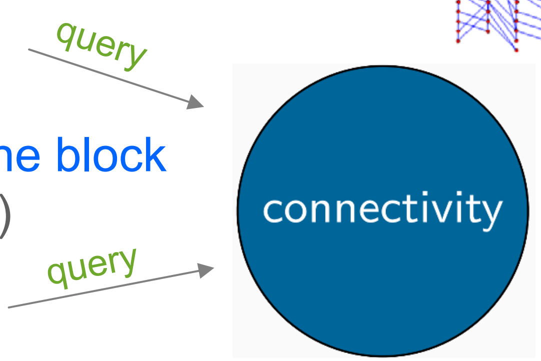


1) Initialization

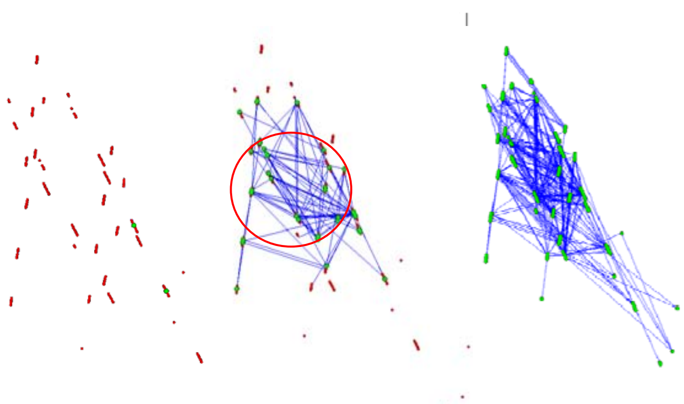
- Fix the datum
- Tie images to 1st pair

2) Concatenate the block

- Start following the flight trajectory or from the middle of the block
- Scale ambiguity → tie triples slave → (master1, master2)
- Analyse only neighbourhood



VisionMap



INTERATLAS + UltraCam

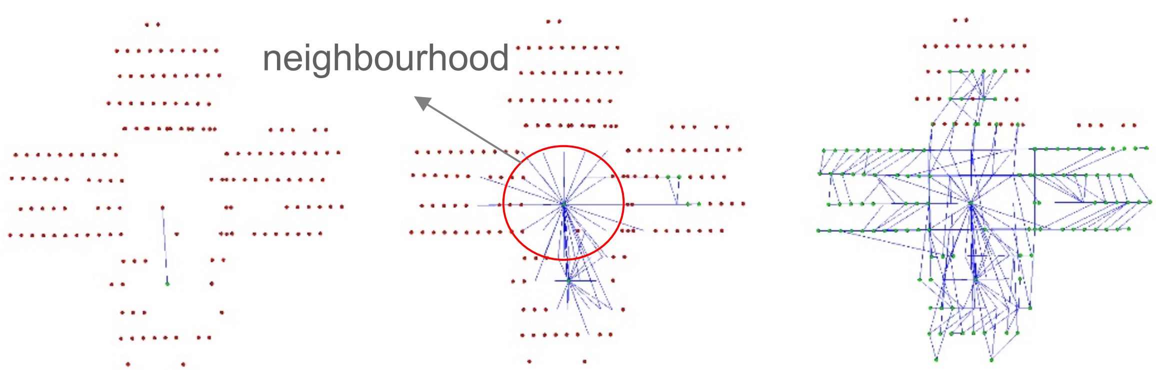
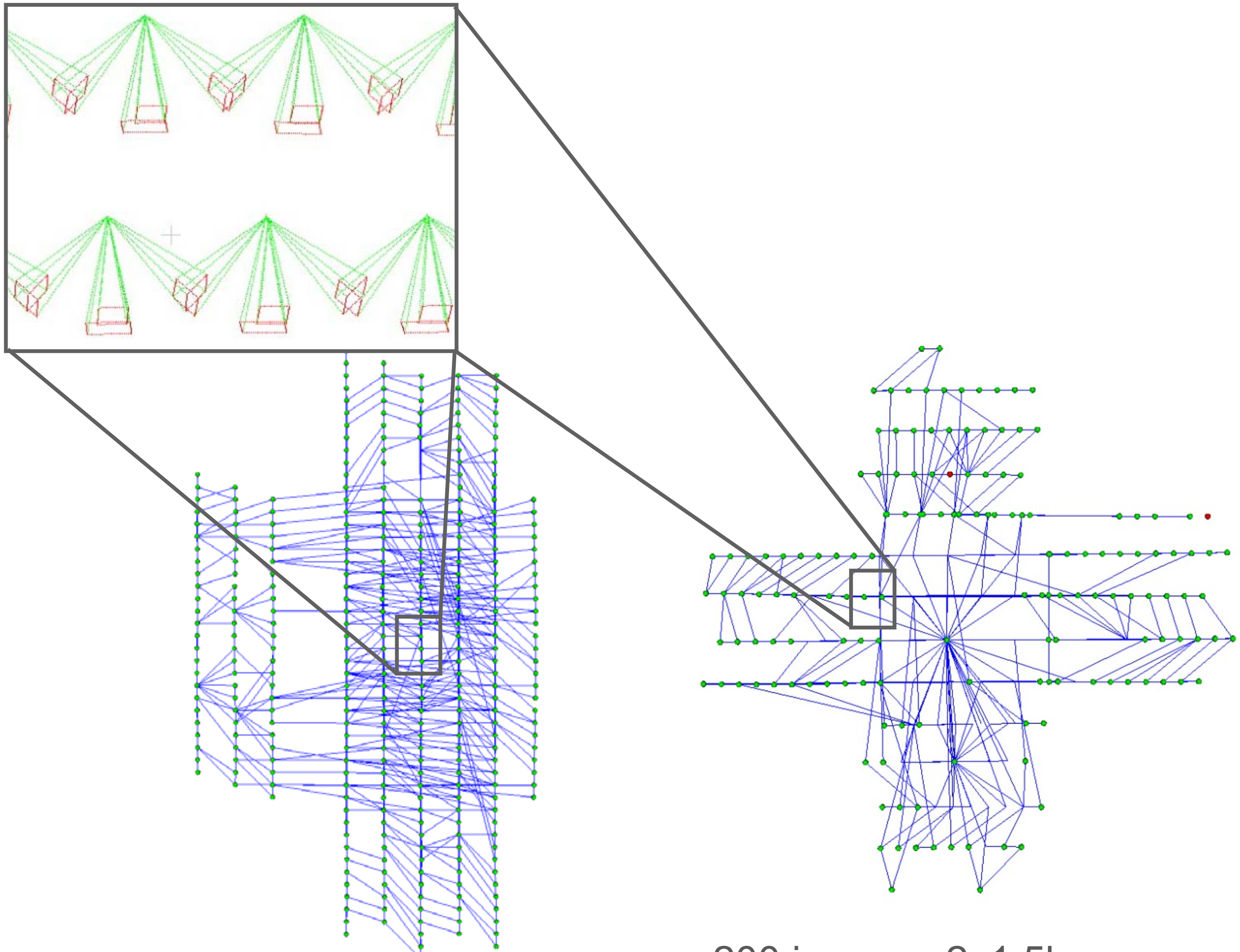


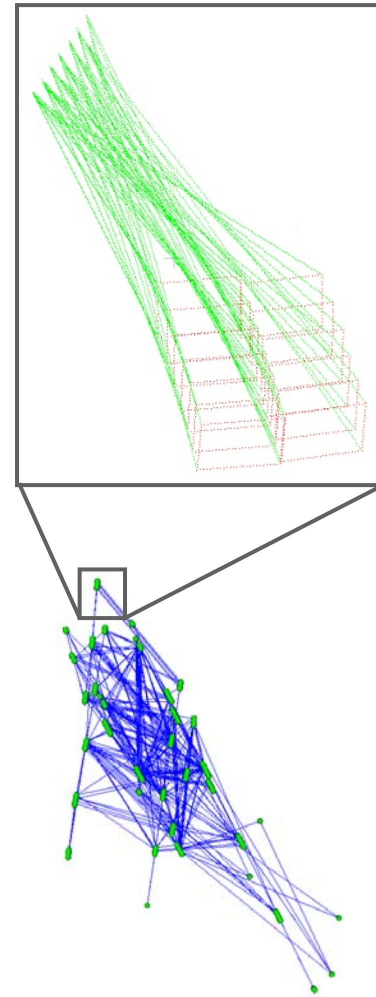
IMAGE ORIENTATION

Some examples of concatenation:



~550 images, 7x3.5km
Milano, Italy
Midas 5

~200 images, 2x1.5km
Paris, France
InterAtlas+ UltraCam

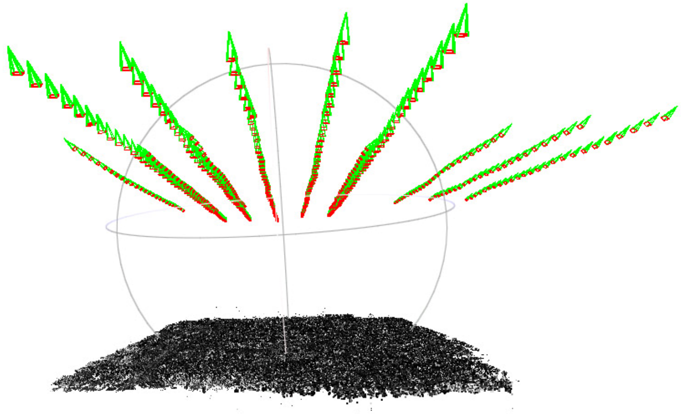


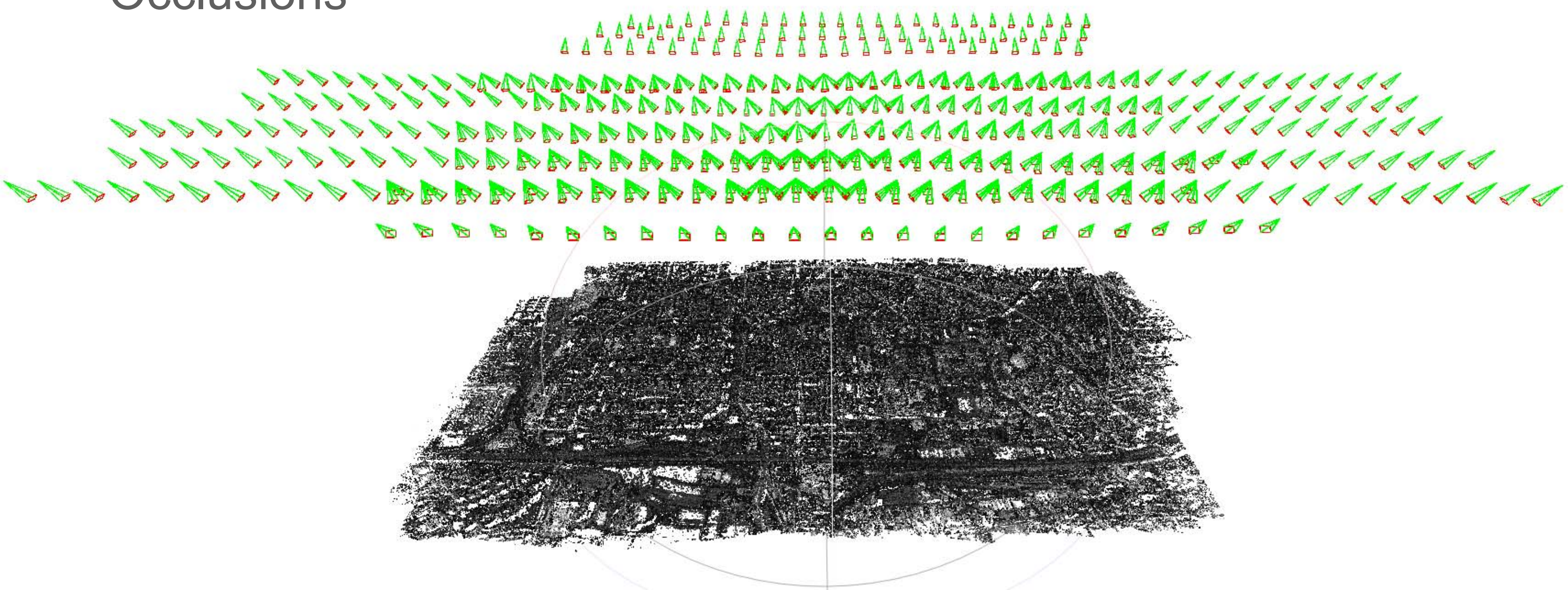
~260 images, 0.7x0.7km
Netanya, Israel
VisionMap A3

MIDAS

GSD$_{nadir}$= 10cm

- Regular coverage
- Radiometric changes
- Occlusions



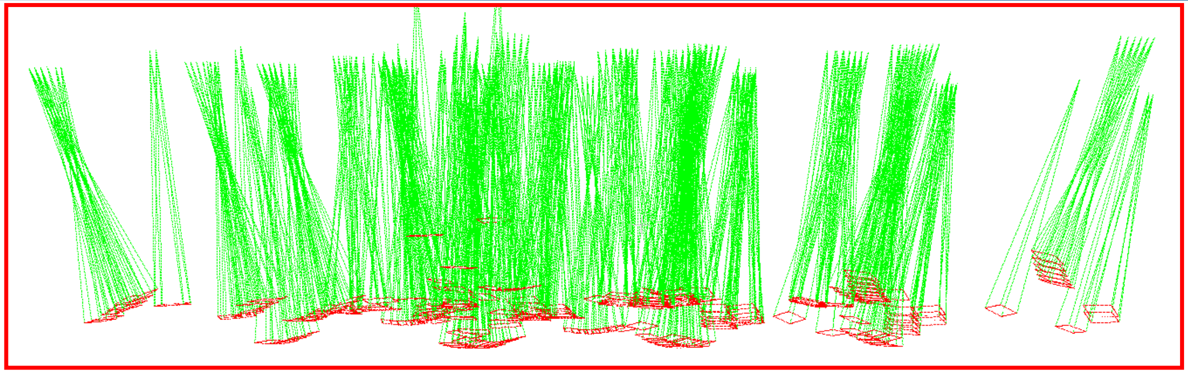


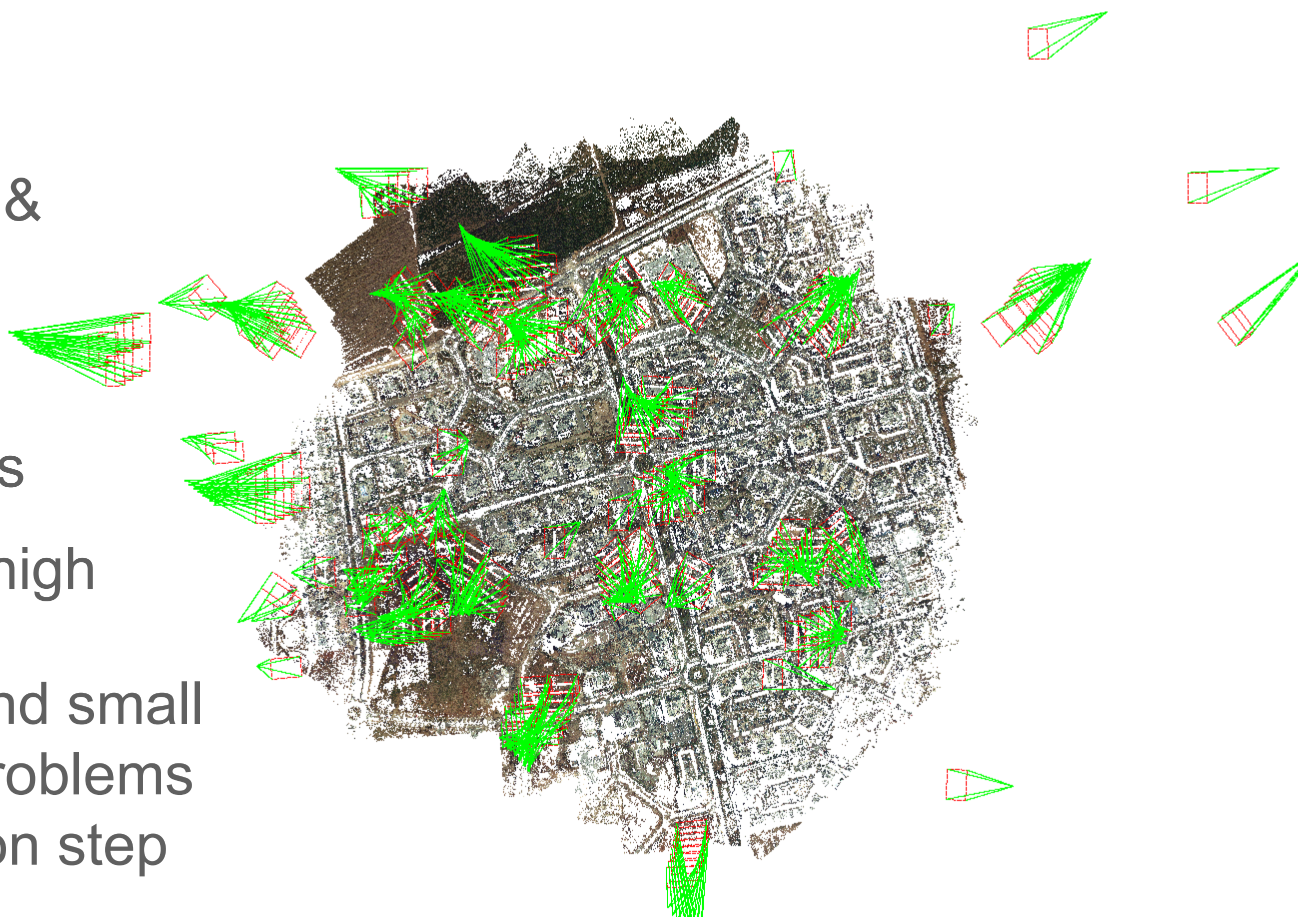
Rupnik, E., Nex, F., Remondino, F., 2013. *Automatic orientation of large blocks of oblique images*, Int. Archives of Photogrammetry, Remote Sensing and Spatial Information, ISPRS Hannover 2013.

VisionMap

GSD_{nadir}= 6 cm

- Long focal length & flight height
- Redundant images & high overlaps
- NO blur but radiometric changes
- n° images / area = high
- Long focal length and small format could give problems during the orientation step





OBLIQUE IMAGES WORKFLOW

The proposed methodology can be divided in several steps:

Set of oblique images

↓

Image orientation

↓

Point cloud generation

↓

Point cloud filtering

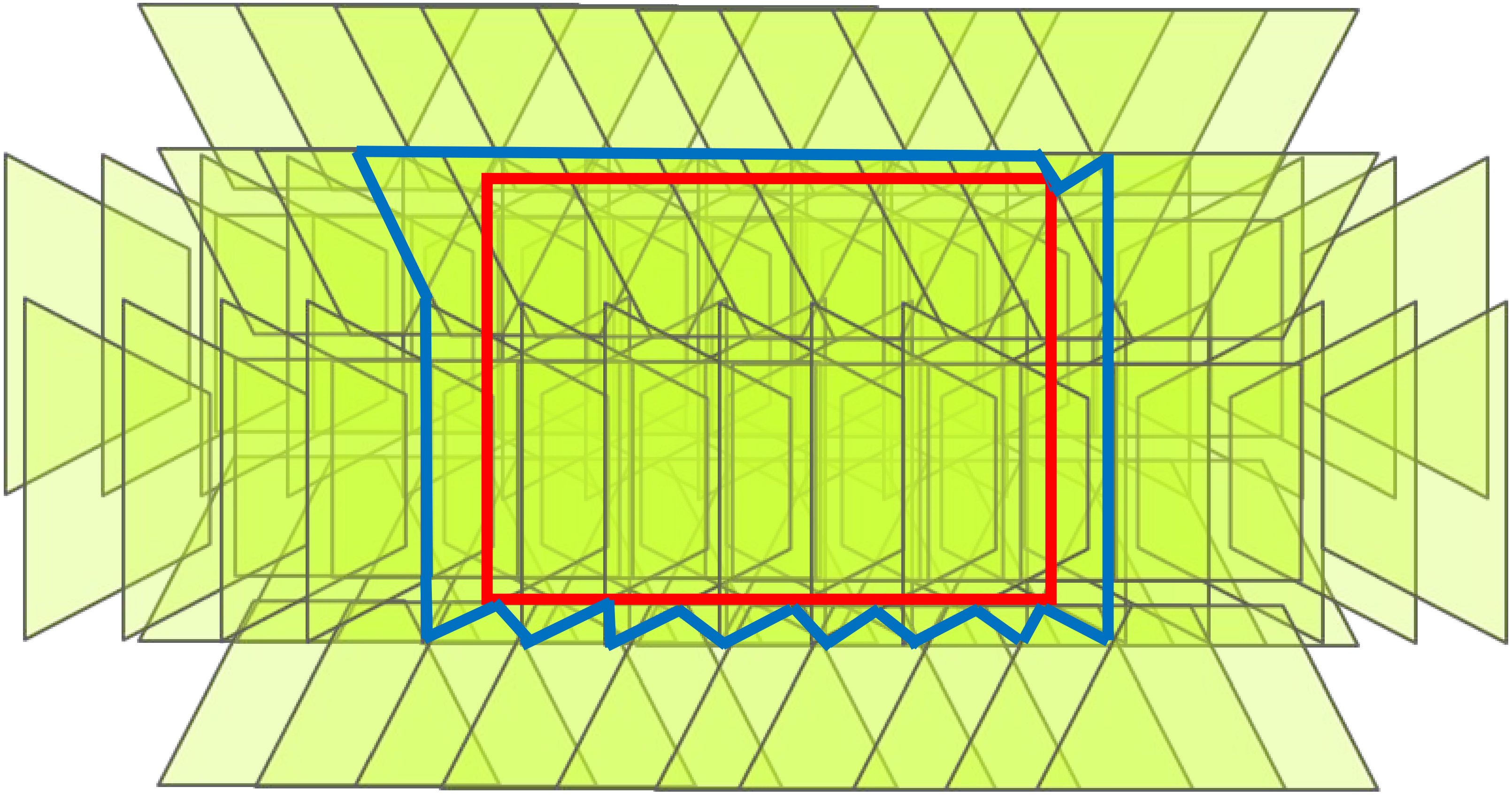
↓

Feature extraction

- Building wall extraction
  ↓
- Footprint extraction
- Multi-Temporal analysis

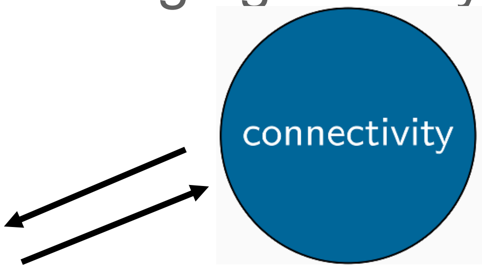
POINT CLOUD GENERATION

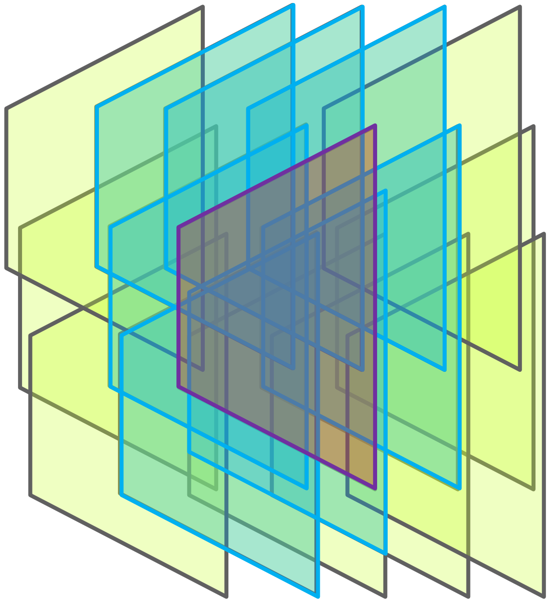
- All building facades → dense reconstruction in image geometry
- Definition of ROI
- Intersection of ROI with image footprints (IF)



POINT CLOUD GENERATION

- All building facades → dense reconstruction in image geometry
- Definition of ROI
- Intersection of ROI with image footprints (IF)
- Identification of masters and slaves in ROI

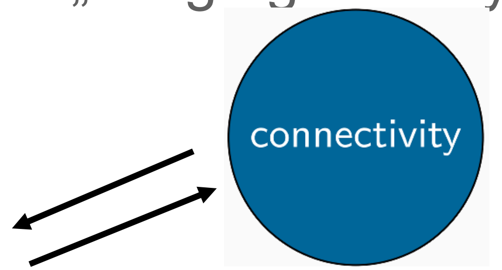


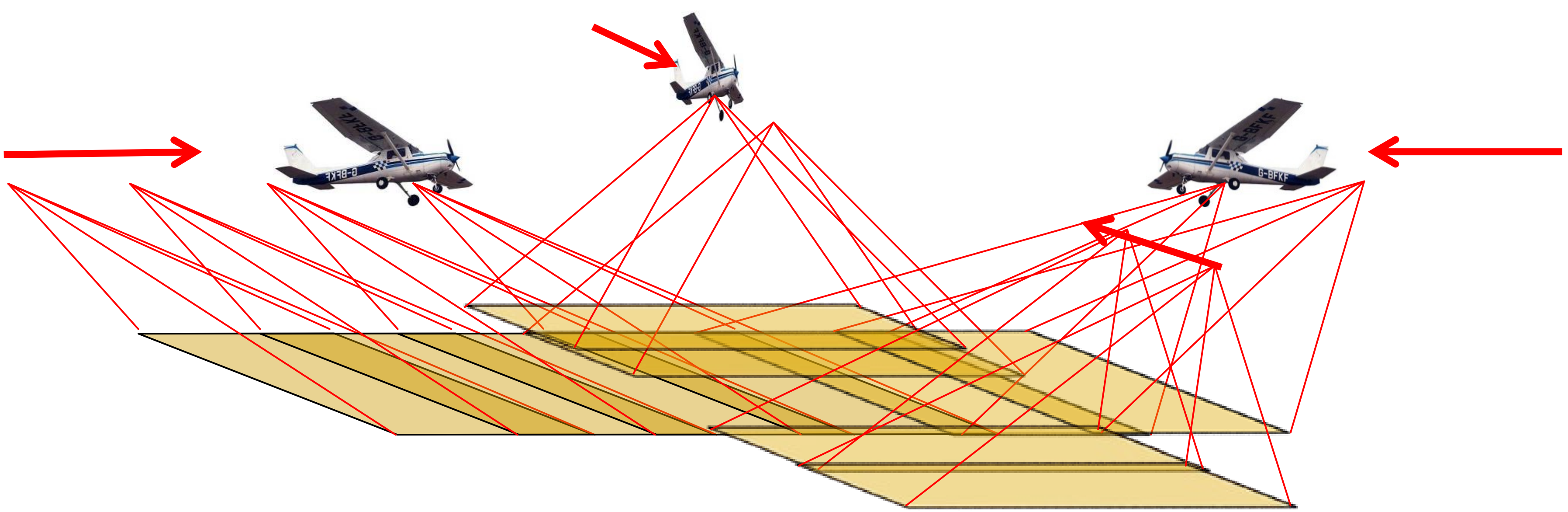


- Same looking direction
- Minimum overlap with reference image: 20%

POINT CLOUD GENERATION

- All building facades → dense reconstruction in „image geometry”
- Definition of ROI
- Intersection of ROI with image footprints (IF)
- Identification of masters and slaves in ROI
- 30-40% overlap between reference images to reduce occlusions in urban canyons





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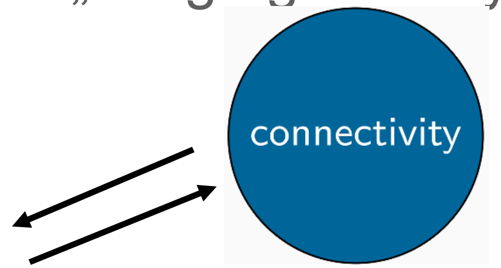
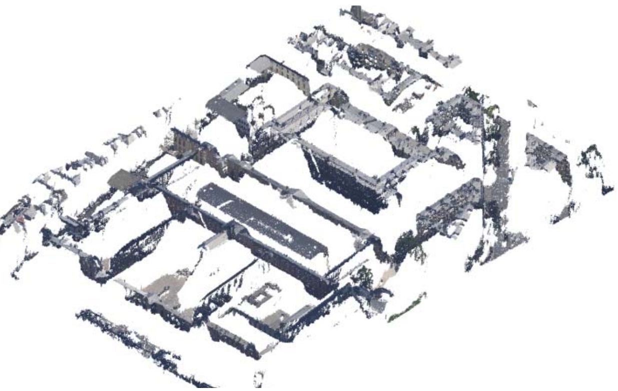
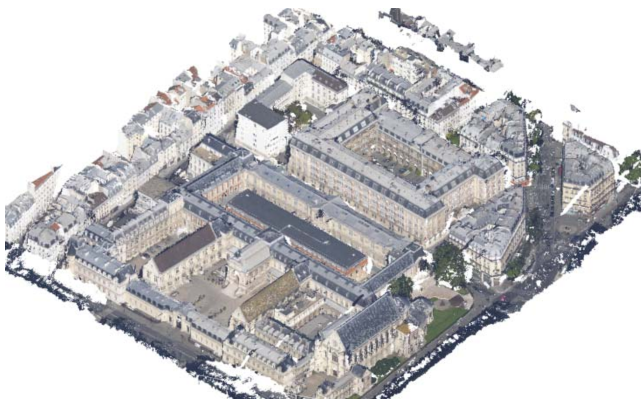


- 30-40% overlap between reference images to reduce occlusions in urban canyons
- 4 oblique views to complete 3D reconstruction of building facades


1 view


2 views


4 views

Software MicMac: 1 pt/pixel

1 pt/pixel ≈ too many points!

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OBLIQUE IMAGES WORKFLOW

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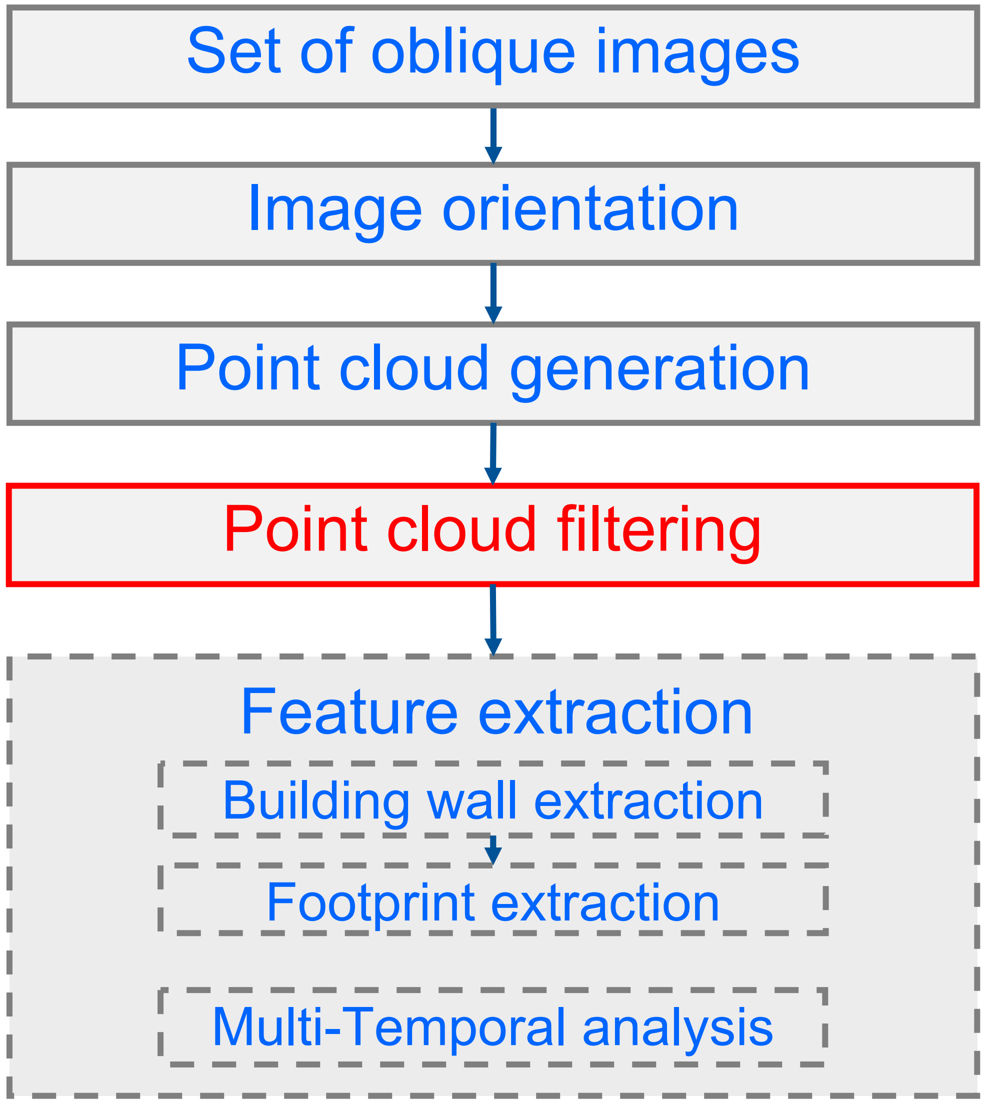
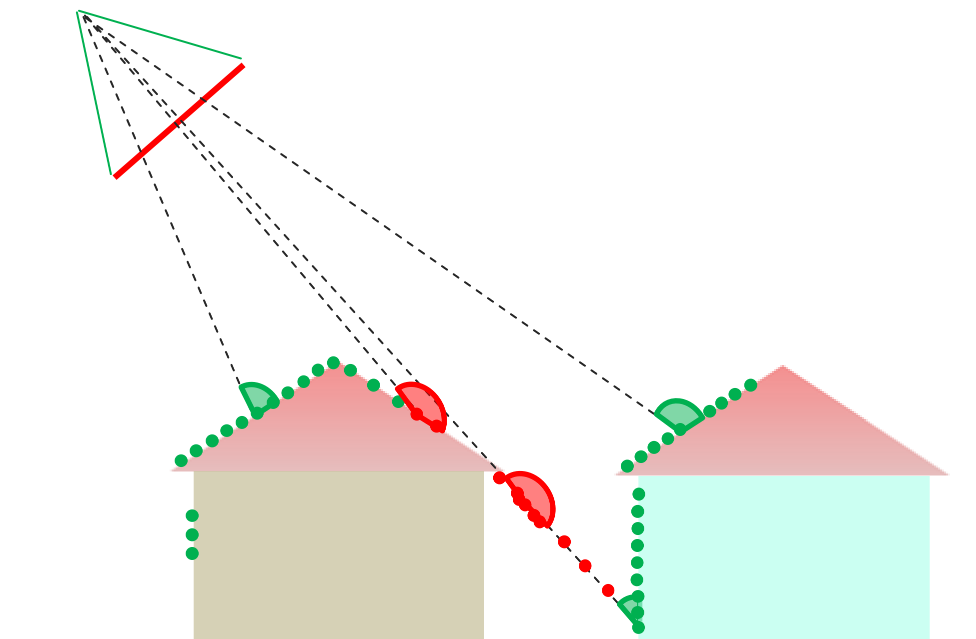


POINT CLOUD FILTERING

Possible presence of «mixed pixels» in correspondence of building borders

Developed filter: consider the reference image position, its orientation and the local shape of the point cloud



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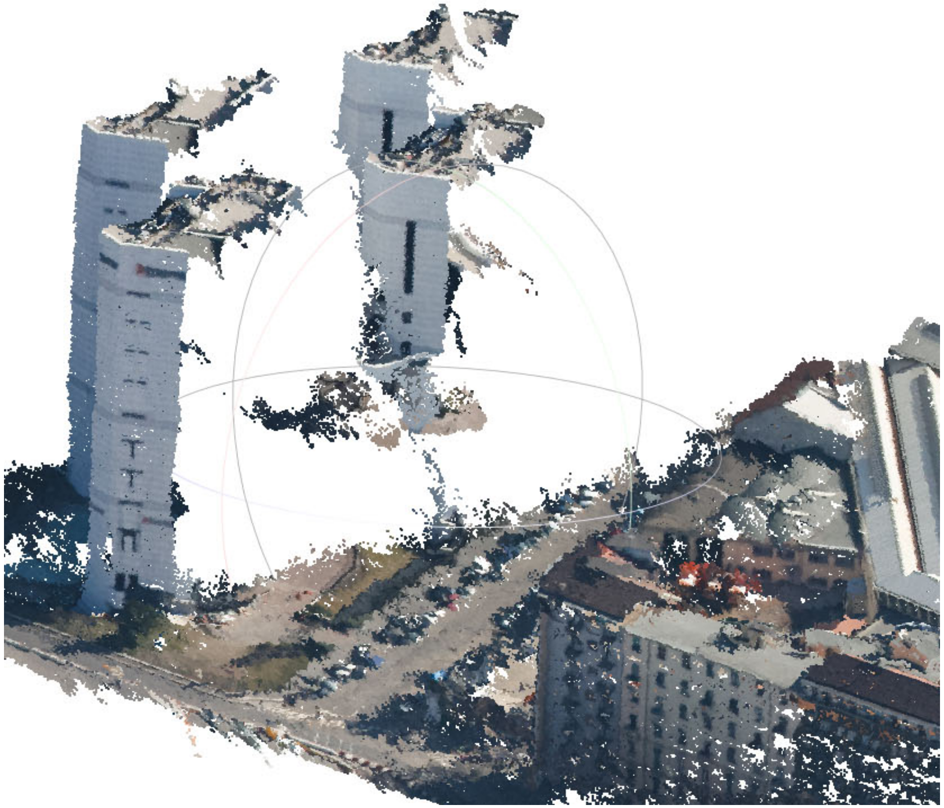


The level of noise is quite high: a noise filtering is applied too

GENERATED POINT CLOUDS - Milano

Point clouds can be assembled together to achieve a complete result

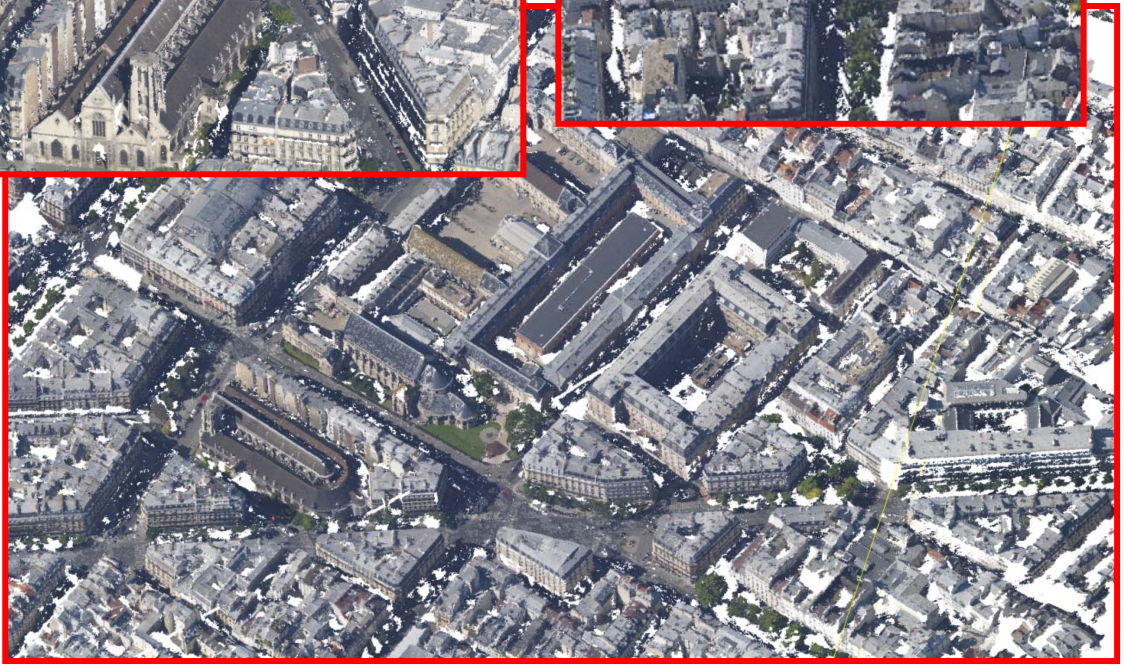
Area: Milano (Italy)
$GSD_{oblique}$ = 14 cm

GENERATED POINT CLOUDS - Milano

The point cloud quality is usually high but…

Repetitive pattern and lack of texture can reduce the point cloud quality

GENERATED POINT CLOUDS - Paris

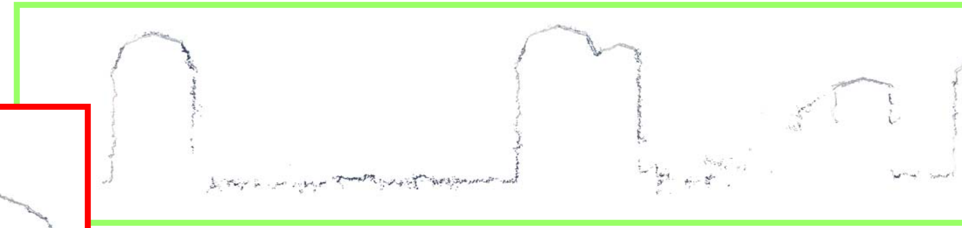


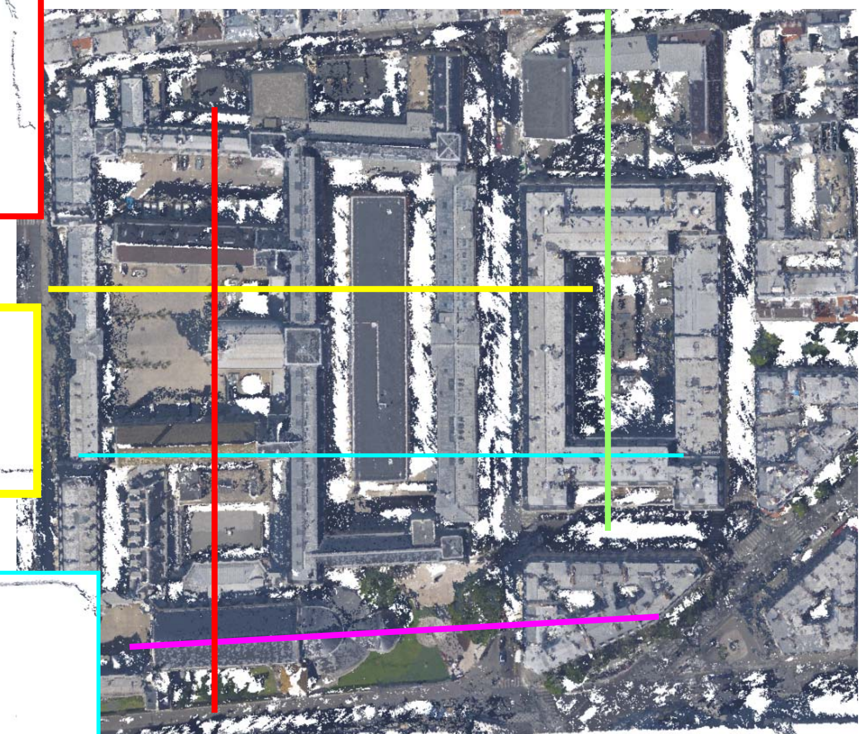
Area: Paris (France)

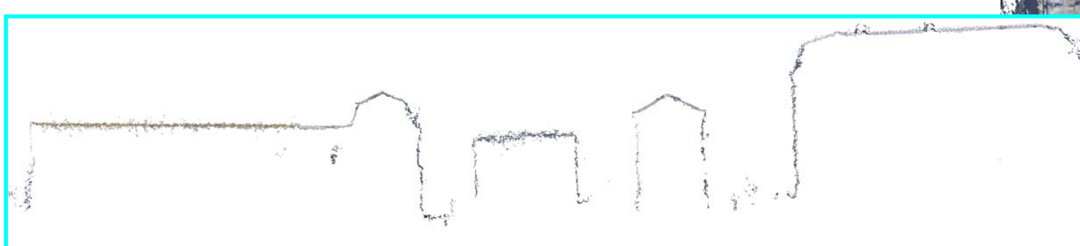
$GSD_{oblique}$ = 13 cm

QUALITATIVE ASSESSMENT

Point cloud sections:







OBLIQUE IMAGES WORKFLOW

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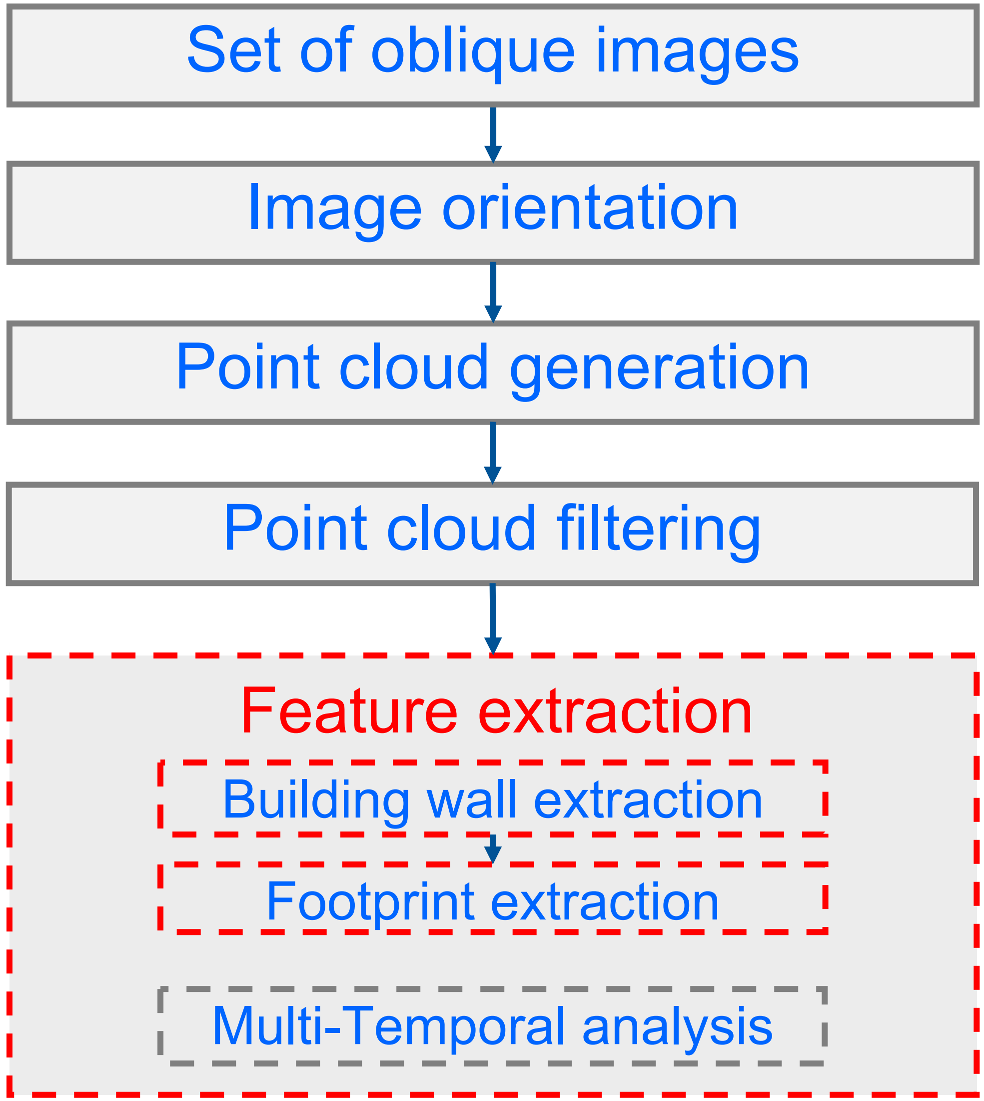
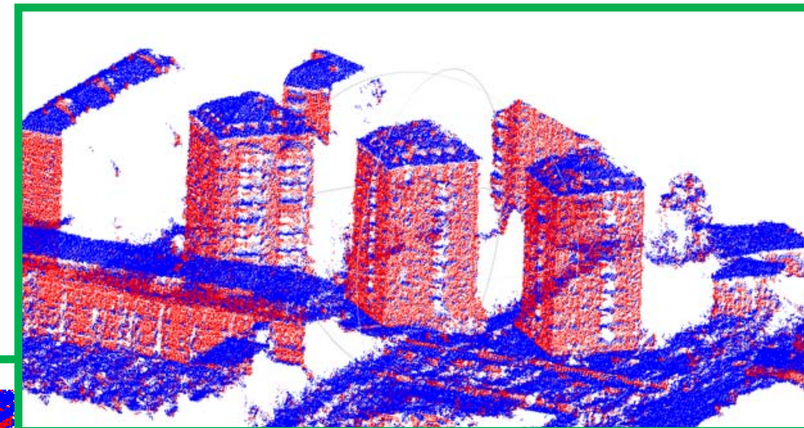
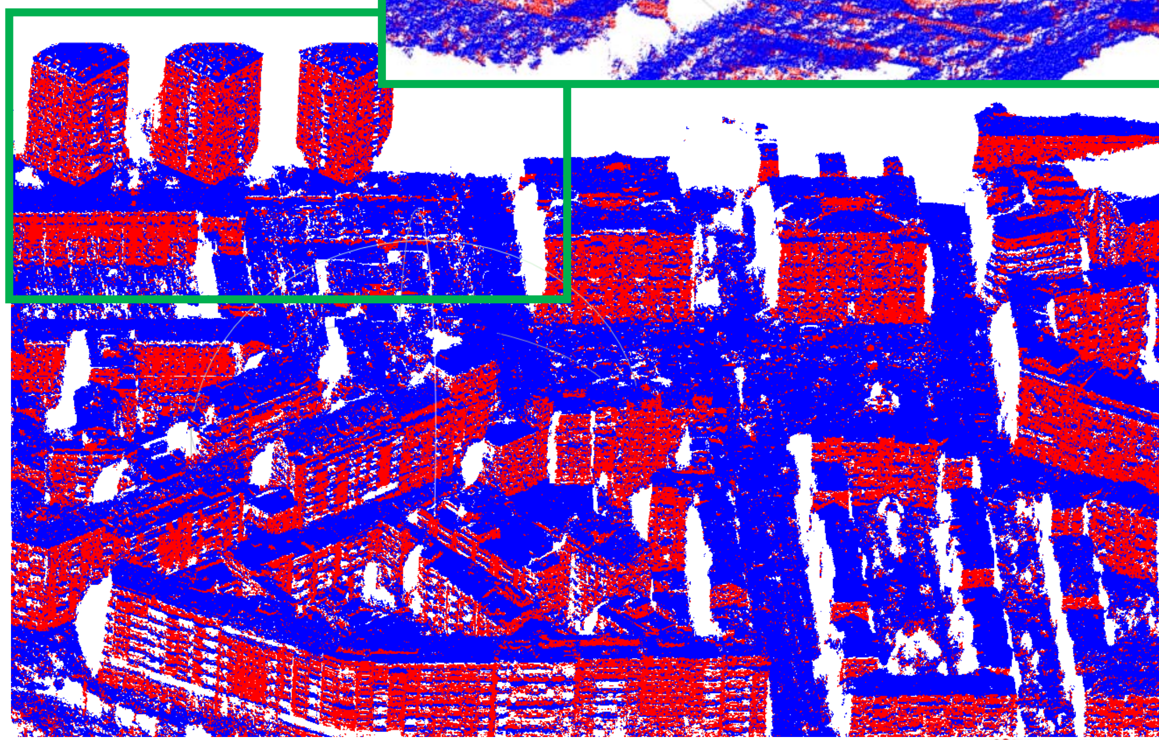


FOOTPRINT EXTRACTION

- It is asumed that facades are vertical ~ horizonal normal vector (± 10°)
- The main planes of the facade are detected, while some points on the balconies are removed
- An outliers removal is then adopted to remove isolated points and trees
- The building outlines can be extracted from these planes





FOOTPRINT EXTRACTION

85% main footprint lines correctly detected

Add nadir images

Nex F., Rupnik E., Remondino F., 2013. *Building footprints extraction from oblique imagery.* Int. Annals of Photogrammetry, Remote Sensing and Spatial Information, CMRT'13, Antalya, Turkey

LEARNED LESSON AND…

- Oblique images allow a fully 3D information of urban areas.
- Both orientation and point cloud generation need methodologies able to manage:
  - Huge amount of data (10^2 – 10^3 images)
  - Very different looking direction
  - Variable overlaps between images
  - Different illumination and image qualities
  - Different image scales
- Point clouds can be sometimes noisy and with radiometric variations
- Huge data → surface extraction or feature extraction are critical

TO DO LIST:

- Additional constraints to orientation
- Use of multi-spectral images
- Improvement of the building footprint extraction
- Multi-temporal analysis
- Use of ground truth for quantitative assessment

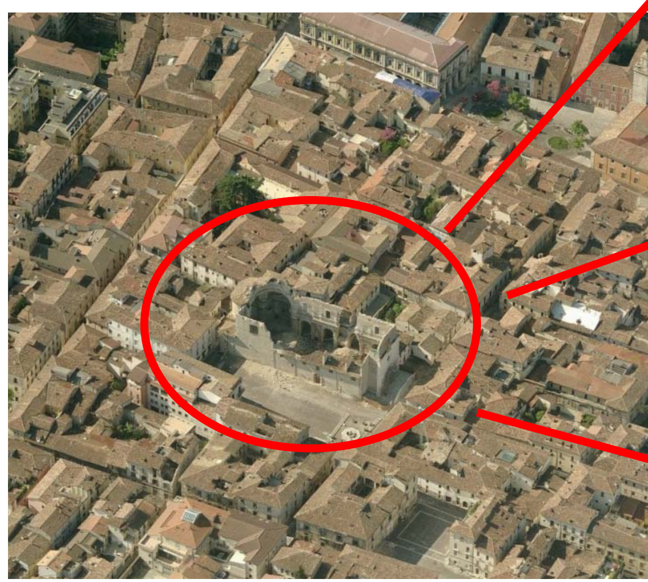
MULTI-TEMPORAL ANALYSIS

2008

2009

RAPIDMAP Project

Multi-temporal damage assessment

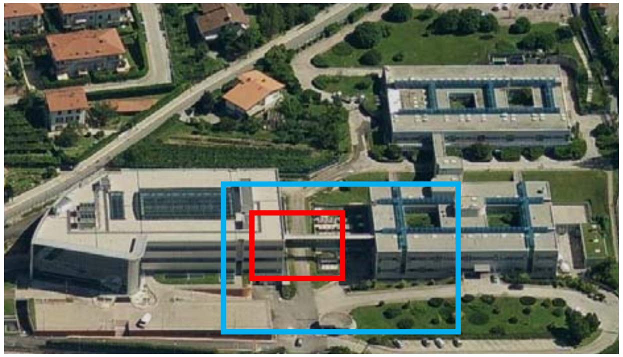


L'Aquila (Italy)

"A NEW BENCHMARK DATASET FOR MULTI-PLATFORM VERY HIGH RESOLUTION PHOTOGRAMMETRY"

On the same urban area, acquisition of images from:

OBLIQUE



TERRESTRIAL

UAV

+ GROUND TRUTH: (GCP, LiDAR)

GOALS: orientation, point cloud generation, geometric assessment

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ITC UNIVERSITY OF TWENTE.

Universität Rostock

http://www.isprs.org/news/newsletter/2013-05/ISPRS-SI-5.pdf

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3DOM 3D OPTICAL METROLOGY

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