UNIVERSITY OF TWENTE.

THE USE OF UAVS FOR EARTH OBSERVATION

FRANCESCO NEX

f.nex@utwente.nl

ITC FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

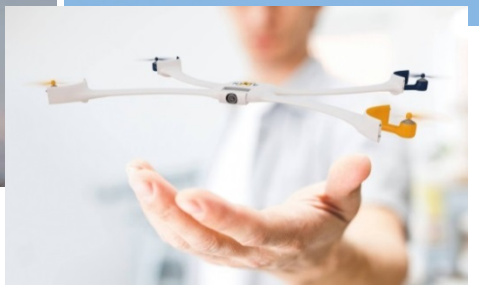
Overview

- Why UAVs for Earth Observation?
- Unmanned Aerial Vehicles classification
- Photogrammetric pipeline with UAVs
- Current applications
- Conclusions and open issues

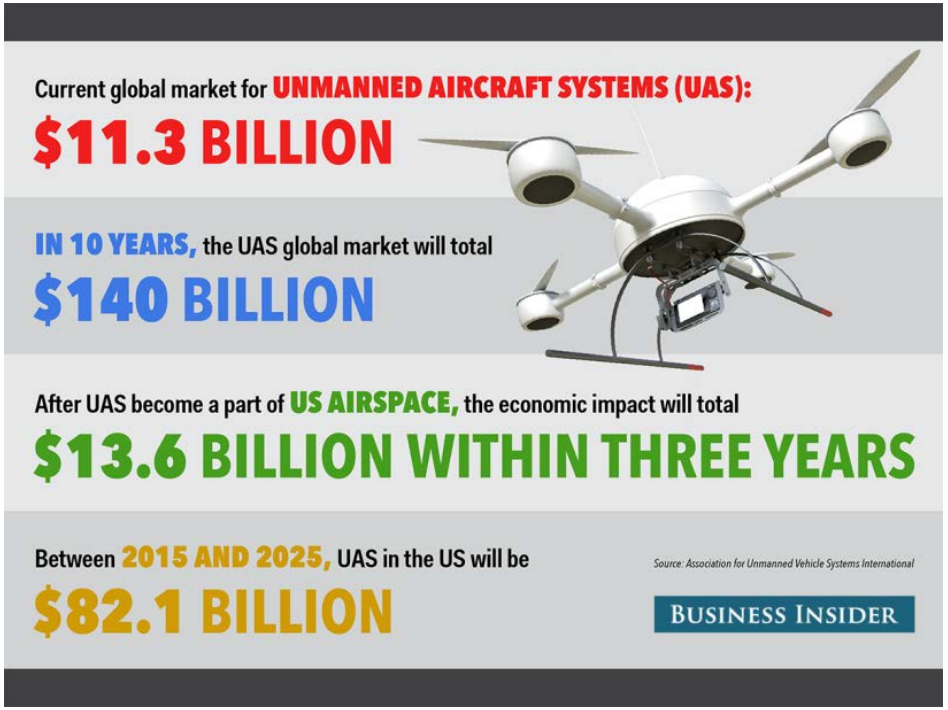
UAV diffusion

- Drones were initially conceived for military applications

- In the last years, drones are becoming new and popular devices for many civil applications



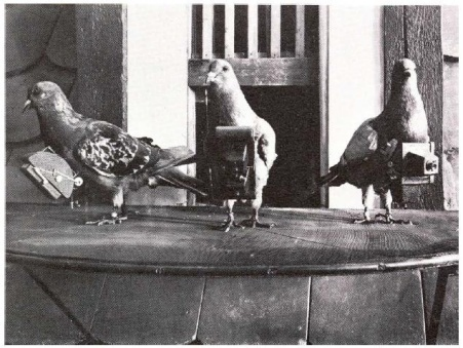
- The marked of drones has increased in the last years and the outlook is very bright

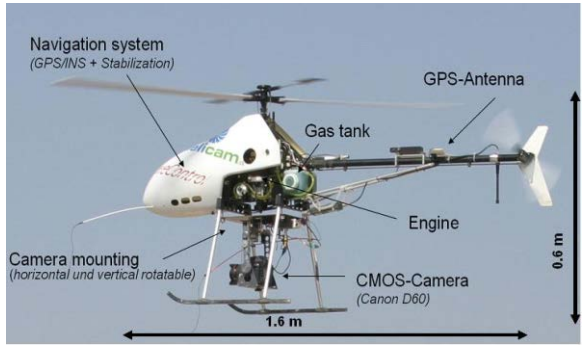


- Among all the civil applications of drones, Earth Observation is one of the most relevant

UAV for Earth Observation

- The potential of UAV for earth observation is obvious in terms of cost, handiness and flexibility





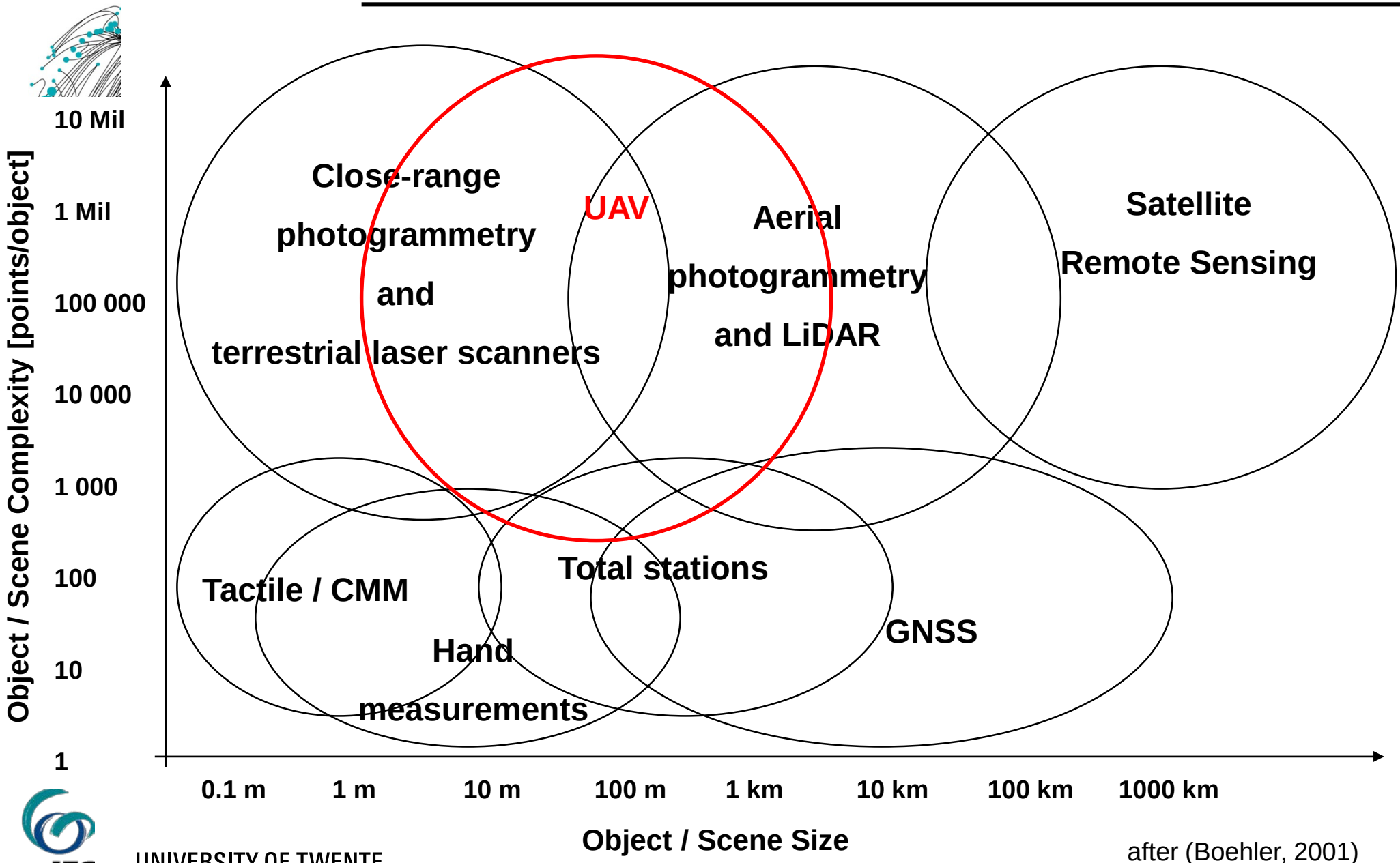
[Neubronner, 1903] [Whittlesley, 1970] [Wester-Ebbinghaus, 1980] [Eisenbeiss, 2004]

- Contribution from different communities: photogrammetry, robotics, computer vision, artificial intelligence, space domain, electronics, navigation, etc.
- Data processing is a combination of terrestrial & aerial techniques
- Possibility to extract 2D and 3D information from acquired images

- More common applications:
  - Urban monitoring (heat losses, change detection, city modelling, etc.)
  - General surveying and mapping
  - Environmental monitoring (fires, energy fluxes, natural hazards, etc.)
  - Archaeological documentation
  - Agriculture / forestry inventories and monitoring

- Some pros and cons:
  - Possibility to fly everywhere and every time (regulation under creation)
  - Flexibility in the installed sensors on board
  - Reduced costs compared to traditional devices
  - Technological and legislative problems and limitations are still existing…

UAV for 3D Data Recording



after (Boehler, 2001)

UAV platforms & classification (cont.)

❑ **Terminology** according to their propulsion system, altitude / endurance and the level of automation in the flight execution:

- Drone ← Newspaper and Military applications
- Remotely Piloted Aerial Systems (RPAS) ← EU level

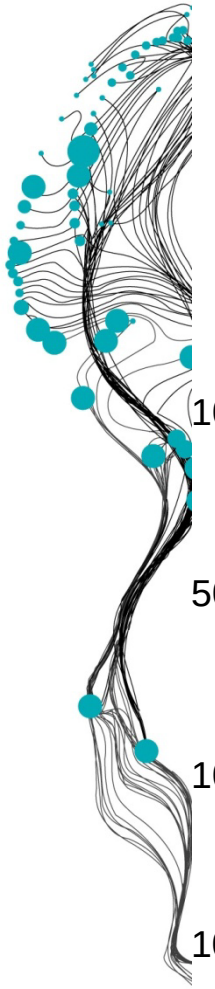
- Remotely Piloted Vehicle (RPV) ← Without autopilot

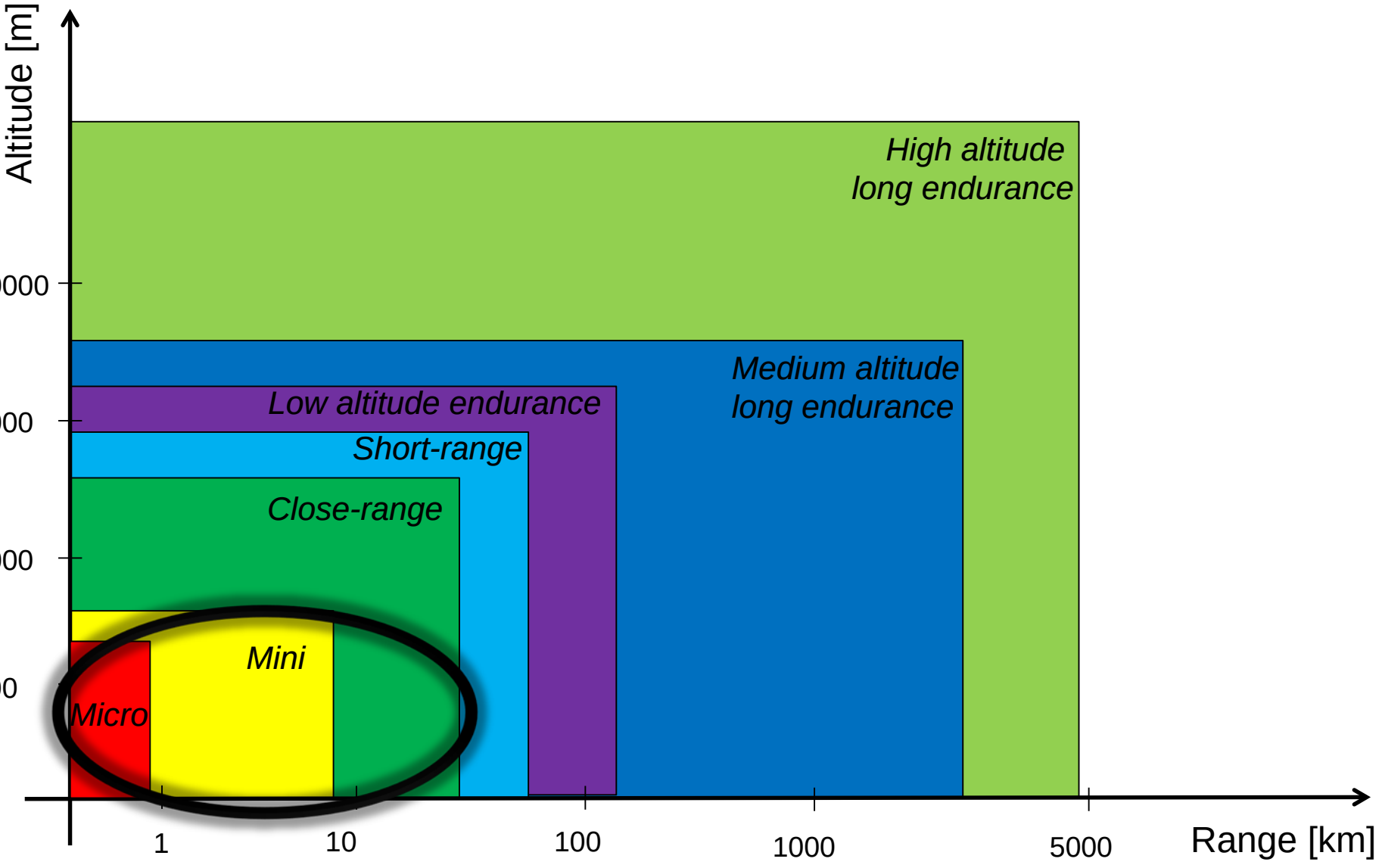
- Remotely Operated Aircraft (ROA)
- Micro Aerial Vehicles (MAV)
- Unmanned Combat Air Vehicle (UCAV)
- Small UAV (SUAV)
- Low Altitude Deep Penetration (LADP) UAV
- Low Altitude Long Endurance (LALE) UAV
- Medium Altitude Long Endurance (MALE) UAV

According to size, flight height and application

- Remote Controlled (RC) Helicopter
- Model Helicopter

UAV platforms & classification (cont.)





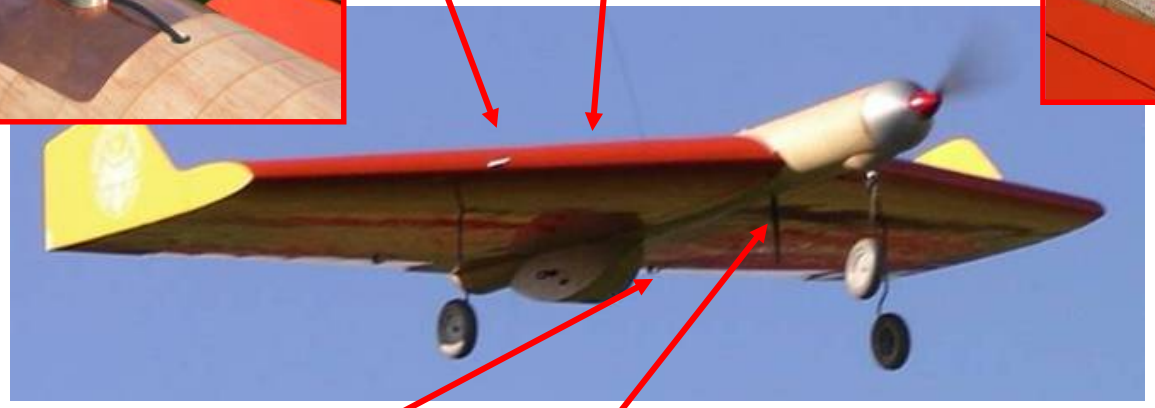
[after Blyenburg, 1999]

UAV platforms & classification (cont.)

- For EO applications, UAV could be classified according to:
  - *Engine / propulsion:*
    - ✓ unpowered platforms, e.g. balloon, kite, glider, paraglide;
    - ✓ powered platforms, e.g. airship, glider, propeller, electric, combustion engine.
  - *Aerodynamic and "physical" features:*
    - ✓ lighter-than-air, e.g. balloon, airship
    - ✓ rotary wing, either electric or with combustion engine, e.g. single-rotor, coaxial, quadcopter, multi-rotor
    - ✓ fixed wing, either unpowered, electric or with combustion engine, e.g. glider or high wing
- Platforms equipped with navigation units on board, digital camera or active sensors (laser scanner, Kinect, etc.)

Standard UAV configuration

GPS Antenna + IMU



Autopilot

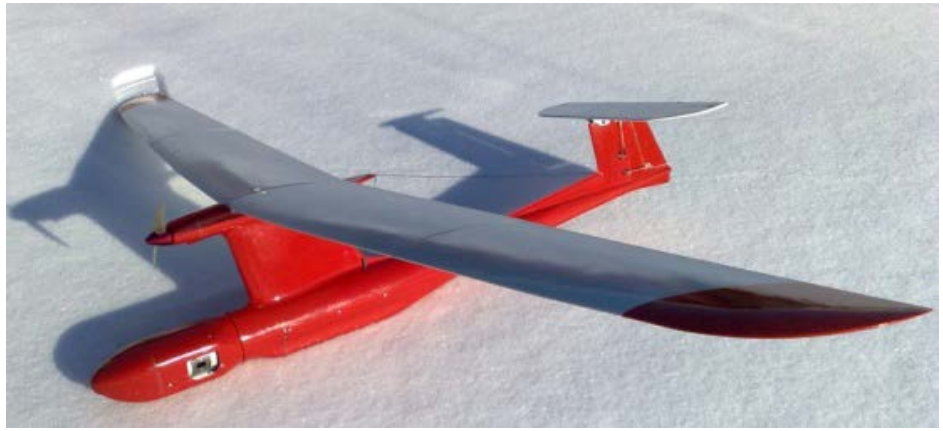
Payload

Radio-modem Antenna

Ground Control Station

UAV platforms (cont.)

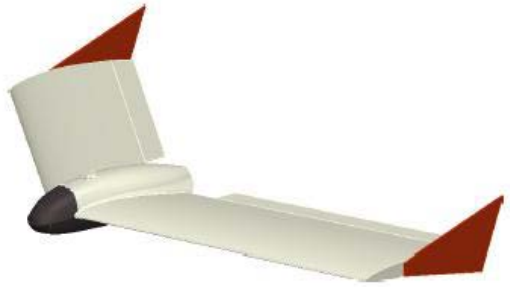
- Large variety of platforms for EO (i.e. camera onboard) – Swinglet-like



Pteryx

Aeromao

Mavinci Sirius



SmartPlanes

SenseFly

Gatewing

UAV platforms (cont.)

- Platforms for Geomatics (i.e. camera onboard) – RC / Model helicopter-like

Helicam

Autocopter

SYMA

Edmonton

SurveyCopter

Aeroscout

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UAV platforms (cont.)

- Large variety of platforms for Geomatics (i.e. camera onboard) – Multirotor-like

Droidworx

NuvAero

Heliprocam

OktoKopter

Aibotix

Microdrones

DraganFly

ASCTEC

GAUI

Falcon

ITC

Evaluation of UAV platforms for Earth Observation

	Kite / Balloon	Fixed Wing		Rotary wings	
		electric	ICE engine	electric	ICE engine
Payload	3	3	4	2	4
Wind resistance	4	2	3	2	4
Minimum speed	4	2	2	4	4
Flying autonomy	-	3	5	2	4
Portability	3	2	2	3	3
Landing distance	4	3	2	4	4

The evaluation is from 1 (low) to 5 (high)

Payload: sensors on board

- **RGB cameras**

Sony Nex 7

Canon 600D

GoPro

- **Multi-Hyper-spectral cameras**

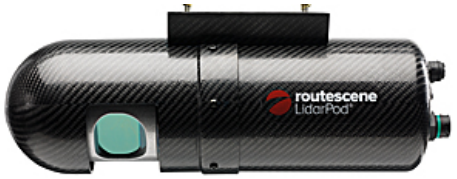
TetraCam

HeadWall Hyper

Flir Vue

- **LiDAR**

Yellow Scan



Route Scene Pod

- **GNSS & IMU**

SBG Ellipse-D

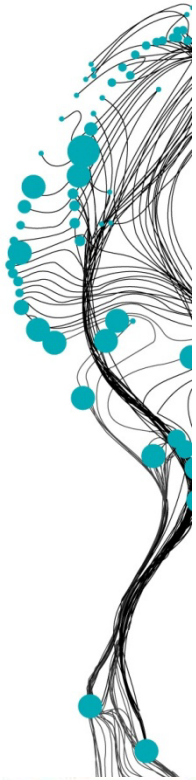
X-sens MTI-G

- **Other sensors**

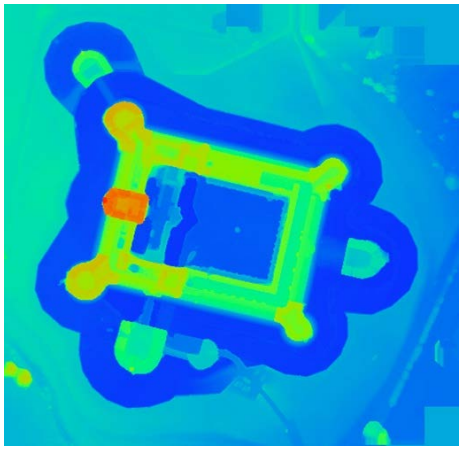
Gas (VOC) sensors

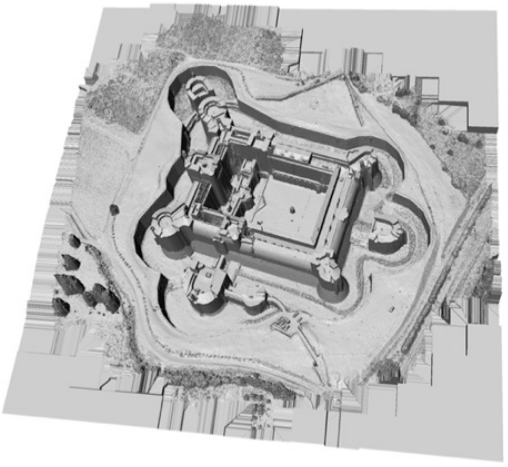
- Limitation on weight → miniaturization of devices

Photogrammetric pipeline with UAV images



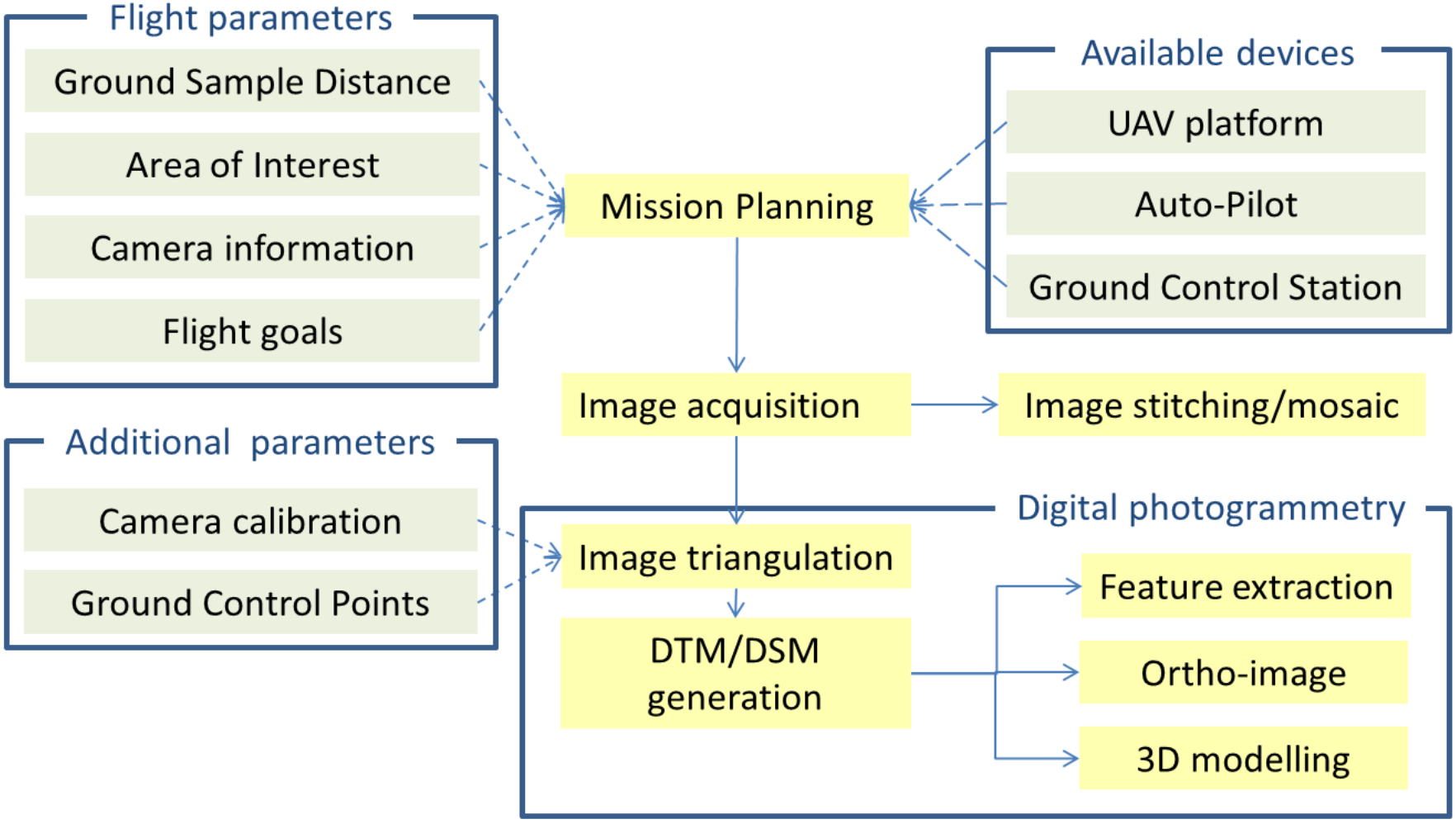
- ❑ Flight planning (designing, requirements, system performances, etc.)
- ❑ Image acquisition (autonomous, manual, GSM-based, waypoint navigation, etc.)
- ❑ Image triangulation & geo-referencing
- ❑ Dense point cloud and Digital Surface Model generation
- ❑ Ortho-image generation
- ❑ Feature extraction





[Architectural Image-based Modeling web portal - http://www.map.archi.fr/aibm/]

Photogrammetric pipeline with UAV images



Flight planning

- Flight planning software installed on PC and smartphones

- Specific solutions designed for each platform

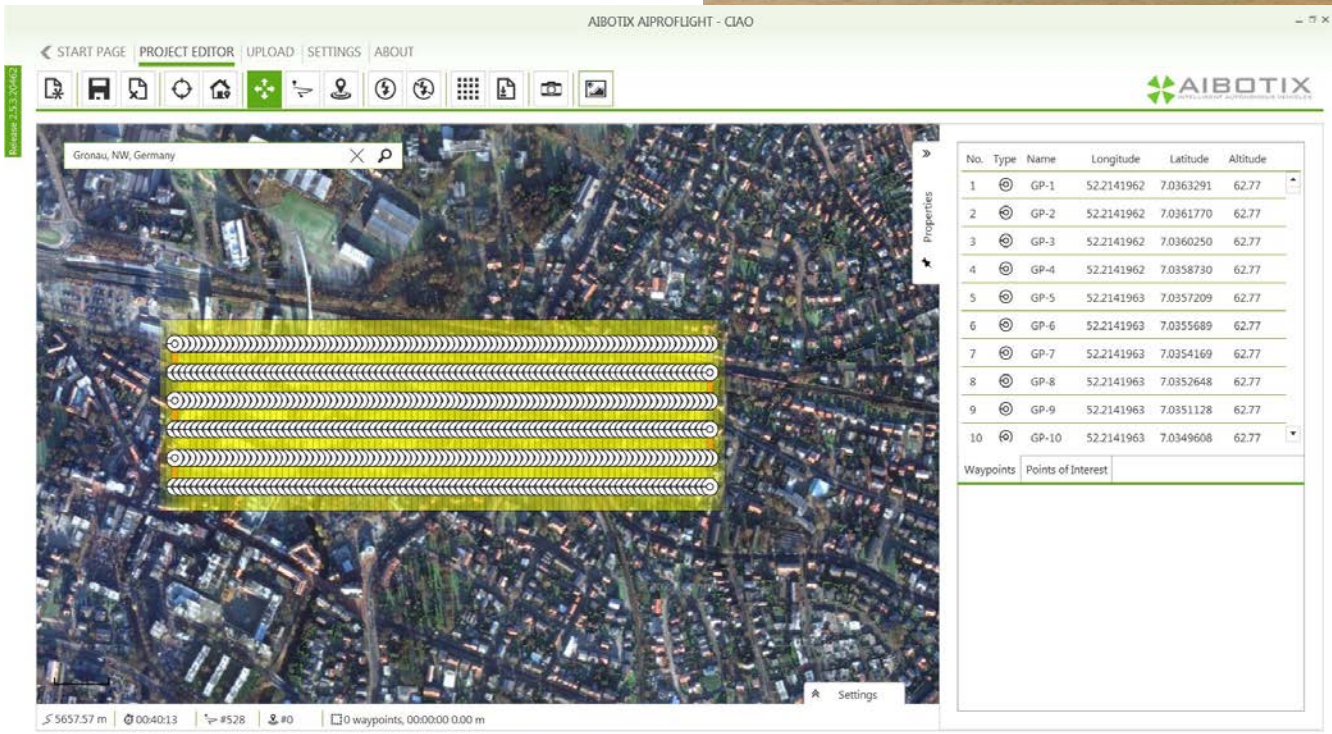
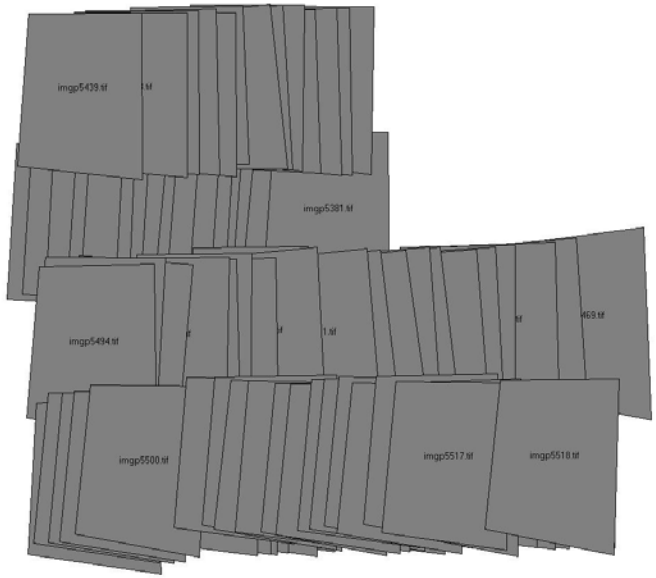


Image acquisition

- UAV image blocks have different geometries depending on the application
  → nadir and oblique images are usually acquired

Unordered images with no GNSS/INS navigation control and manual control

Almost ordered image block acquired with low-cost GNSS/INS navigation control and flight plan



Classical image block with image strips achieved with high-quality GNSS/INS navigation system and flight plan

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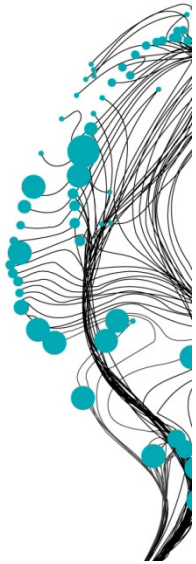
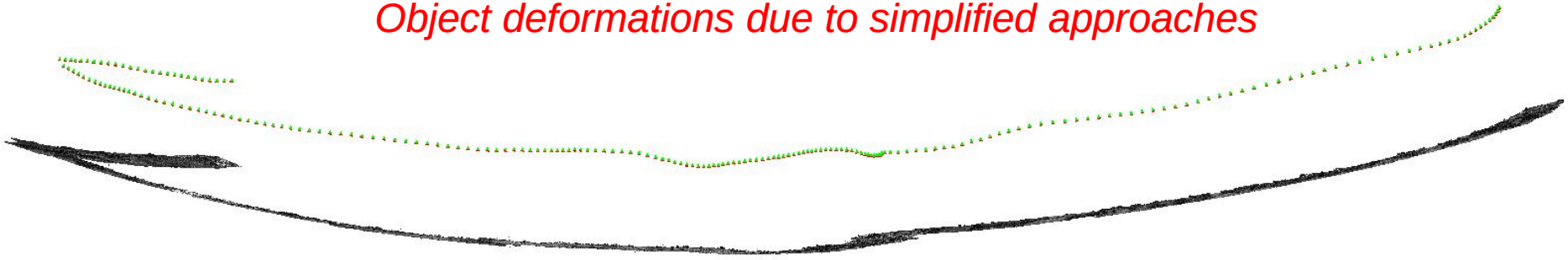


- Need of a rigorous procedure to avoid image block deformations
  - Need of good image distribution and overlap
  - Use of oblique images can improve the results
  - Huge amount of data to process

How to manage big dataset without reducing the quality of the achieved results → **eScience Project**

Object deformations due to simplified approaches



Rigorous photogrammetric Bundle Block Adjustment

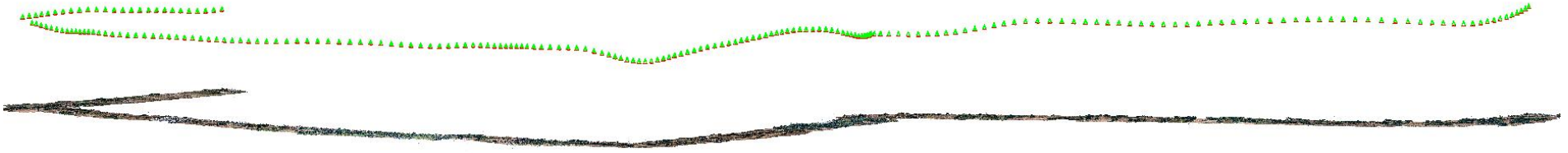
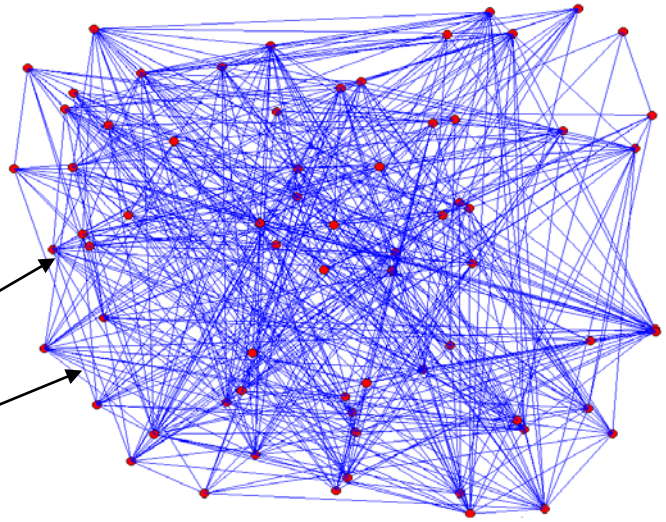


Image orientation - georeferencing

- Ground control points (GCP)
  - When high accuracy is needed

- Direct geo-referencing
  - Need very good GNSS/INS observations
  - High-cost navigation sensors needed
  - Not sufficient with very high resolution images (<1 cm)
  - Possible use of GNSS or total station to track / follow the UAV [Blaha, 2011]

- GNSS / INS observations
  - Helpful to assist the identification of homologous points [Barazzetti el al., 2011]
  - Can provide a first scale and georeferencing



Point cloud and DSM generation

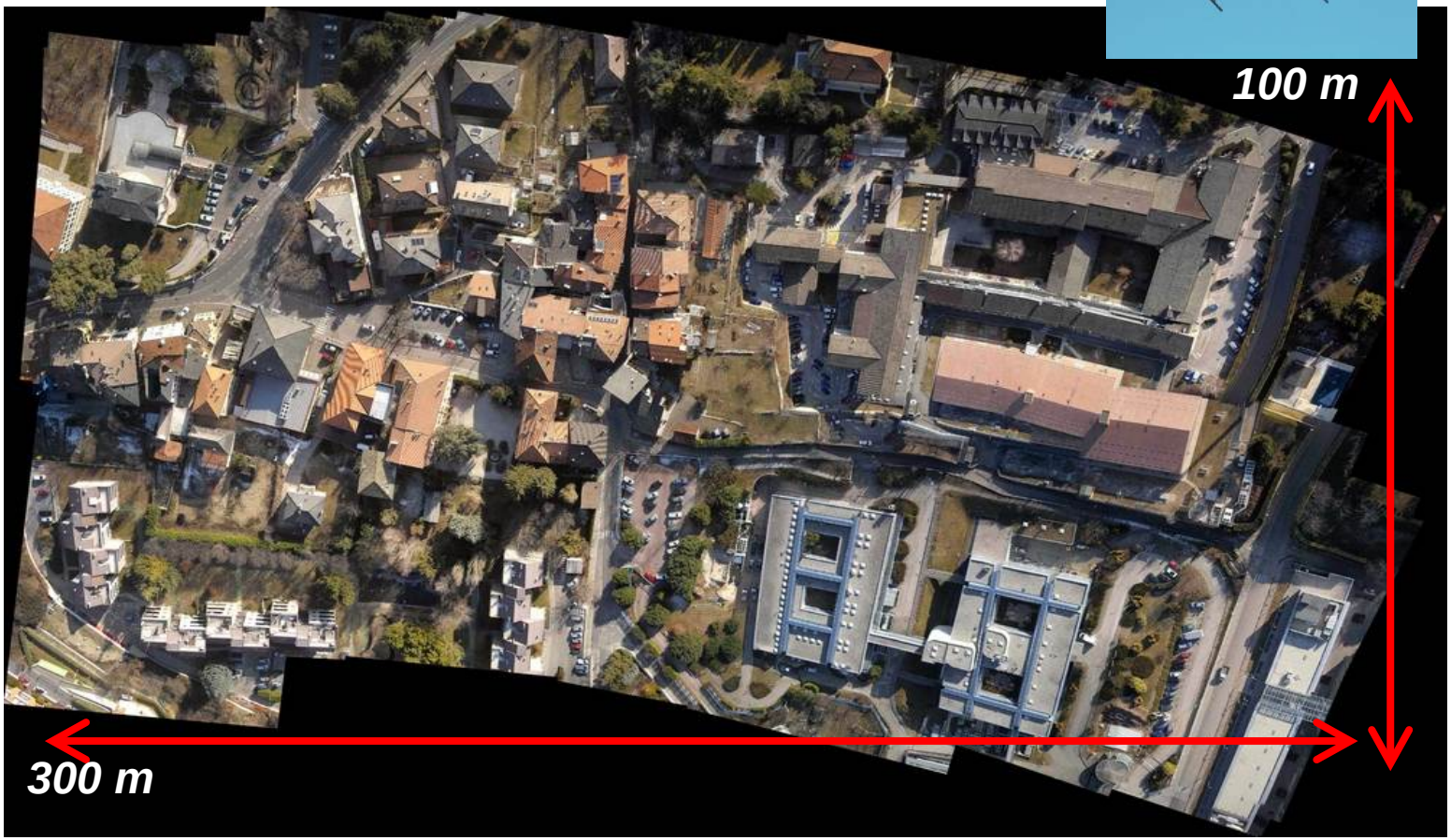
- Automated *DSM generation* for mapping, documentation, monitoring, visualization issues
- Different commercial, open-source and web-based solutions
  - *Open-source* solution: MicMac
  - *Commercial* solution: Pix4D
  - Web-based approaches not reliable, not metric, not satisfactory for mapping applications

Point cloud and DSM generation

- Dense image matching for 3D reconstruction

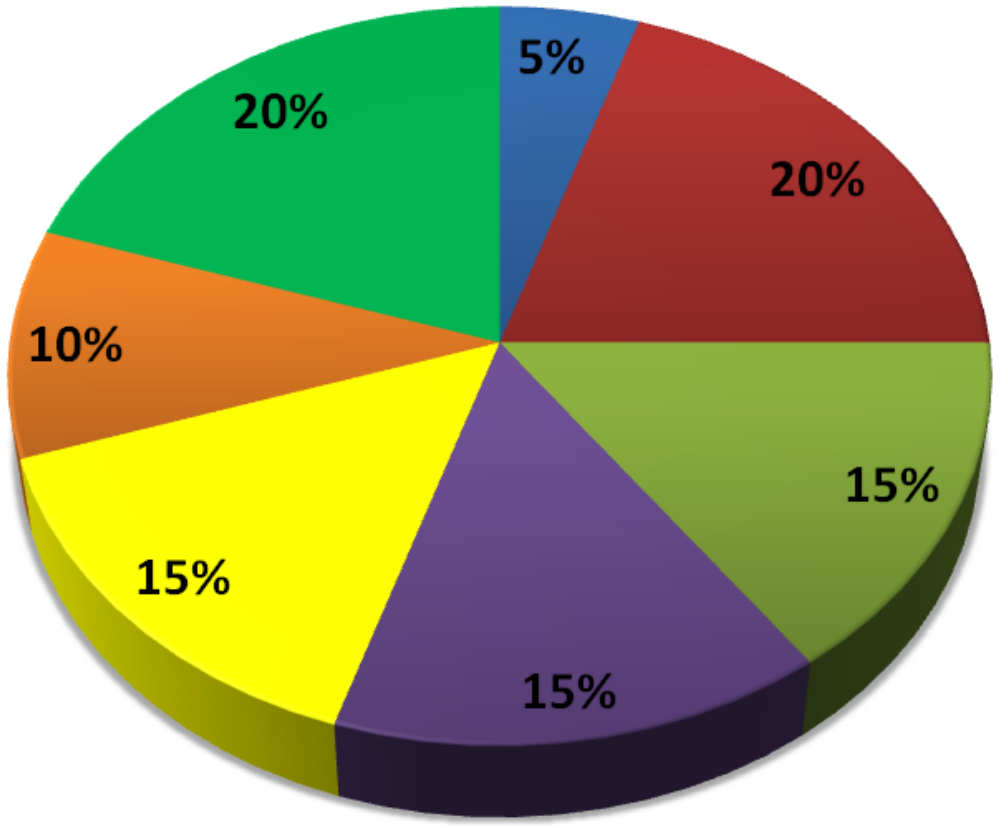
Orthophoto generation

- Urban area surveyed for 3D building reconstruction



- Microdrone platform MD4-200
- Flight height ca 100-125 m => 4 cm GSD
- Overlap 80%-40%

Time effort in UAV-based photogrammetric workflow



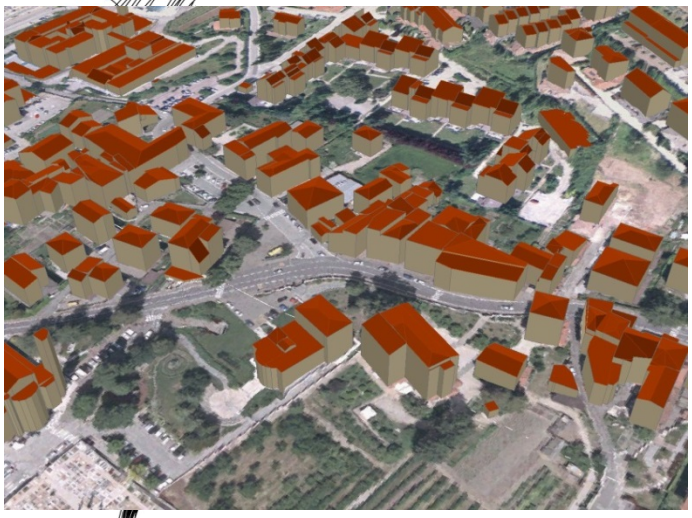
[Nex and Remondino, 2014]

Urban applications

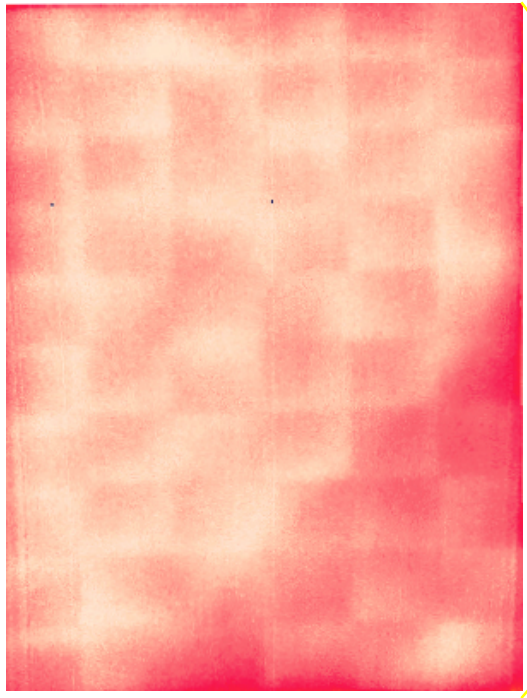
- Very high spatial resolution

Urban applications

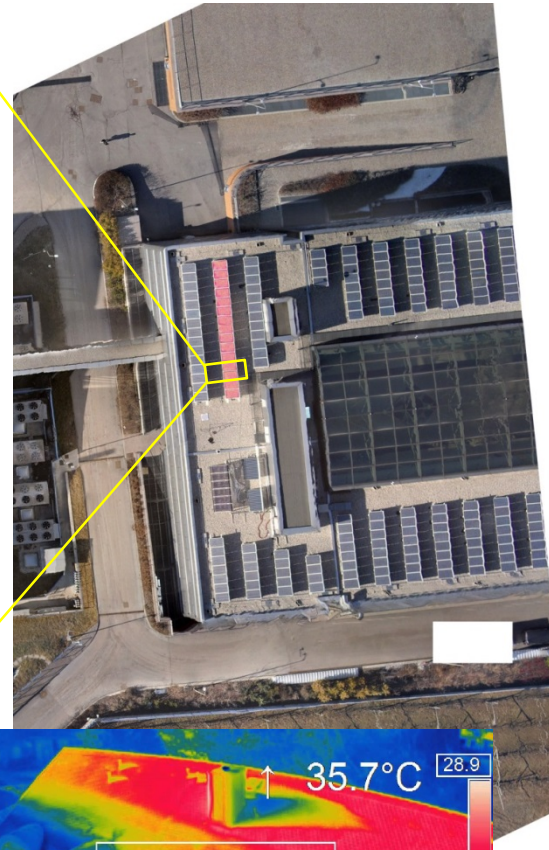
- 3D building models, maps, PV panel inspections

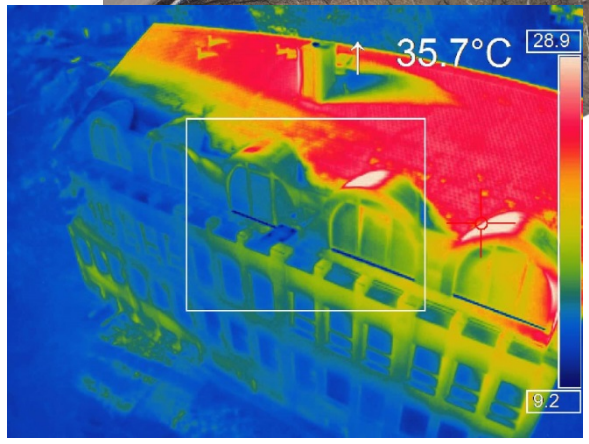


3D building models

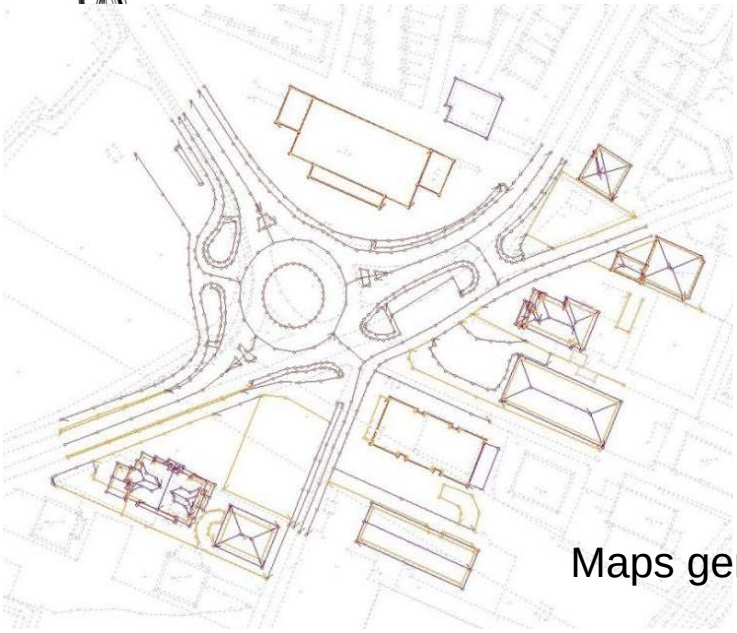


PV panel inspections





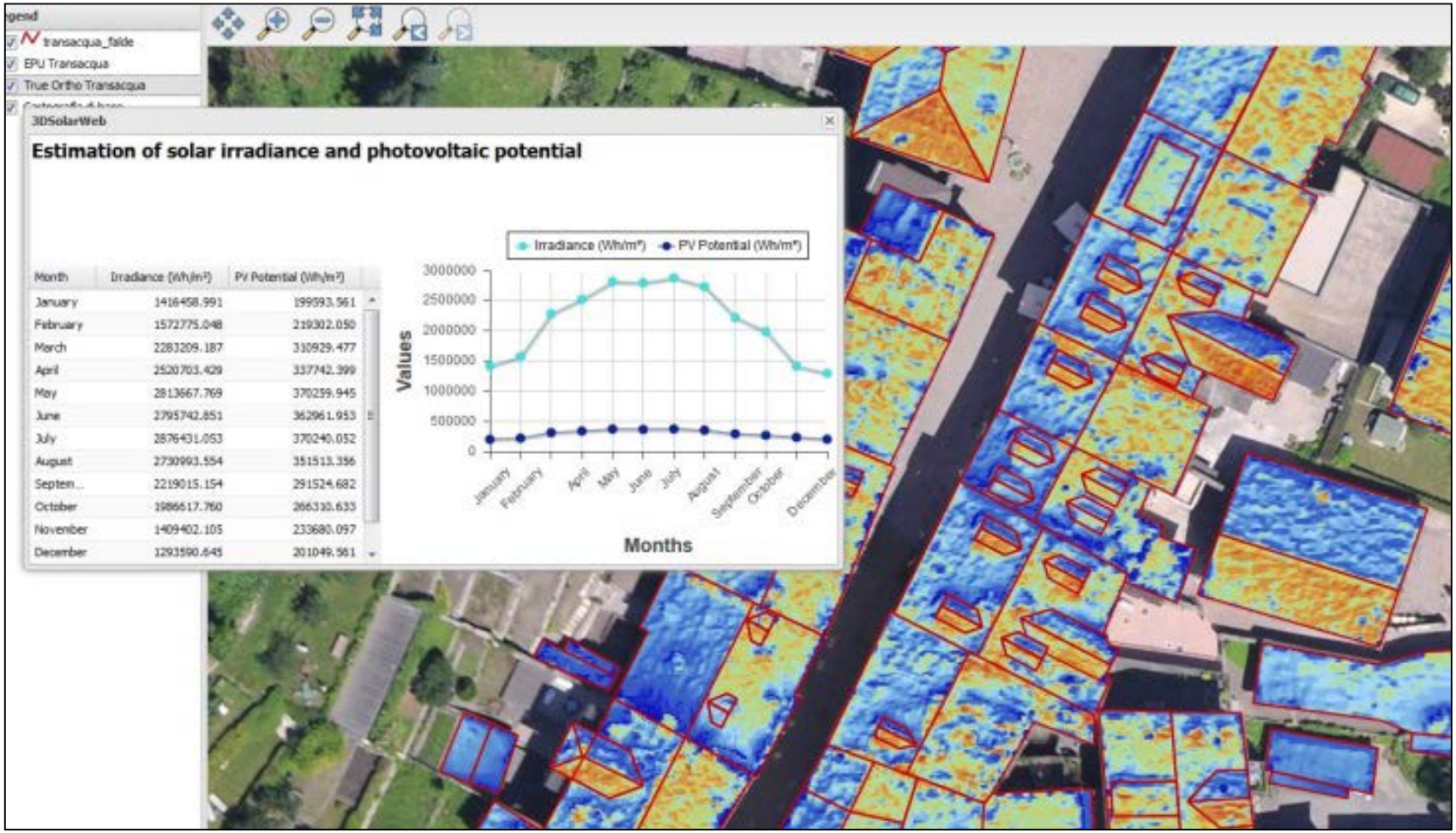
Heat losses



Maps generation

Urban applications – Solar potential

- High resolution → reconstruction of building installations (i.e. chimneys, etc.)



Month	Irradiance (Wh/m²)	PV Potential (Wh/m²)
January	1416458.991	199593.561
February	1572775.048	219302.050
March	2283209.187	310929.477
April	2520703.429	337742.399
May	2813667.769	370259.945
June	2795742.851	362961.953
July	2876431.053	370240.052
August	2730993.554	351513.356
Septem...	2219015.154	291524.682
October	1986617.760	266330.633
November	1409402.105	233680.097
December	1293590.645	201049.561

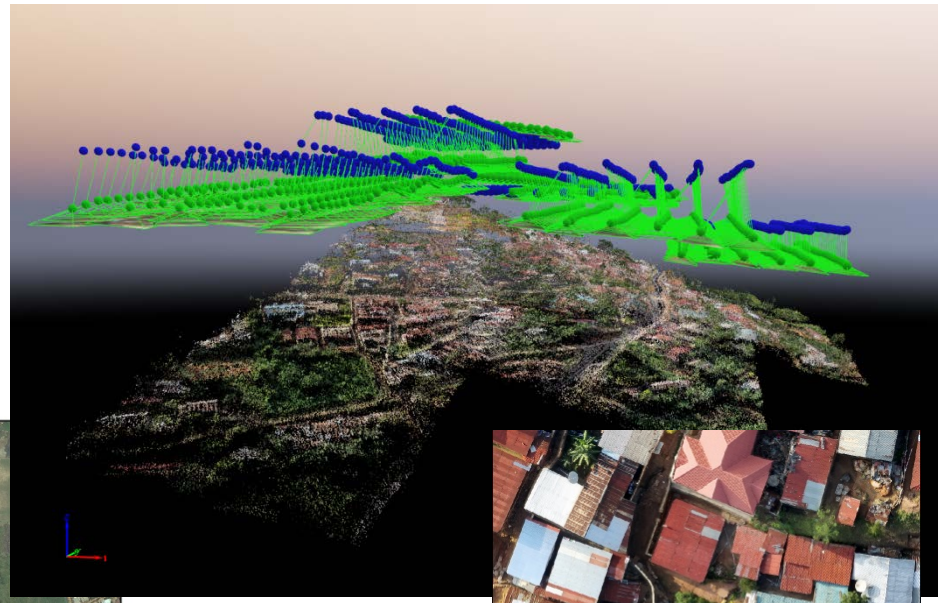
- Interactive system to check the PV potential of building roofs

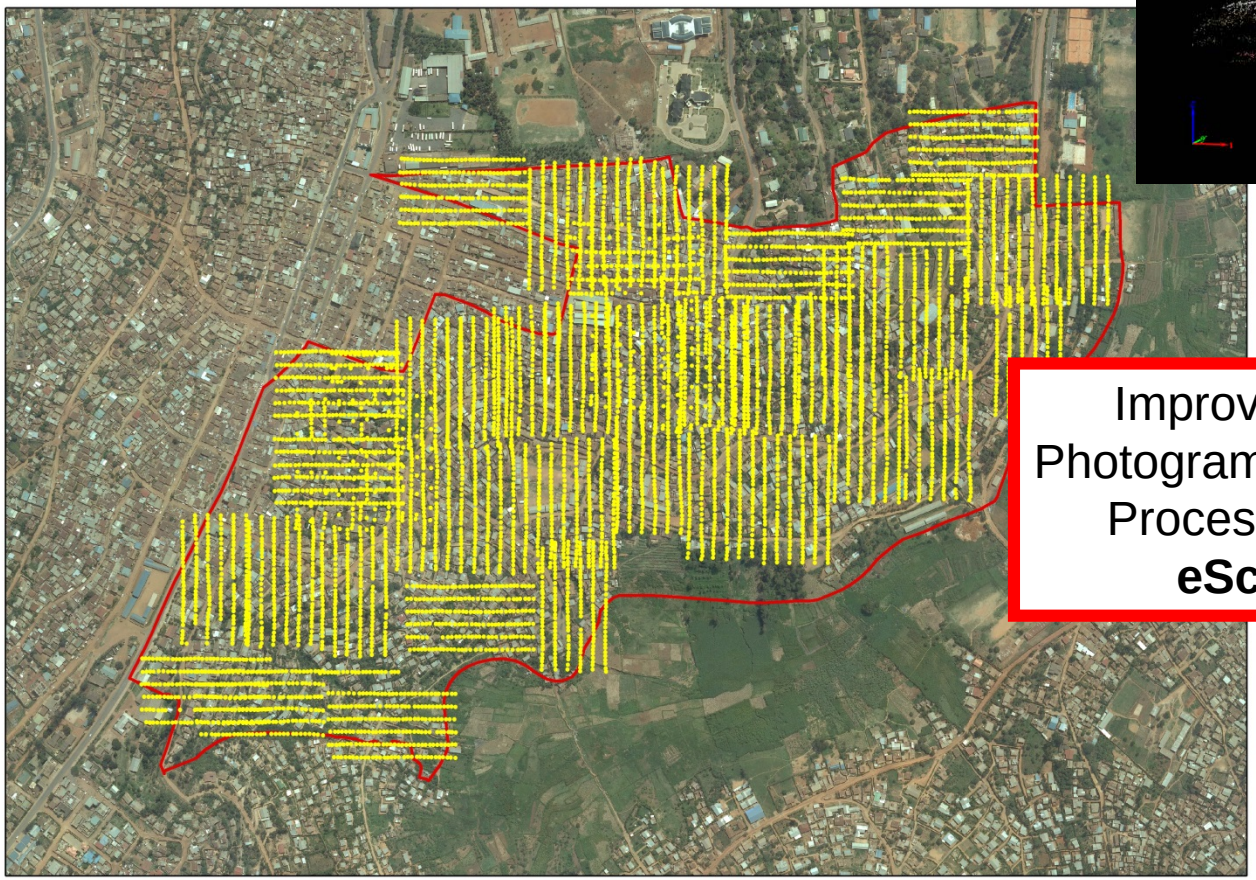
[Nex et al., 2013]

Quick map generation and updating

Large UAV block (Kigali, Rwanda)

- 18000 UAV images
- 3 cm GSD resolution
- 80% along track overlap
- 40% across track overlap





Improving Open-Source Photogrammetric Workflows for Processing Big Datasets
eScience Project

[source: Gevaert – UT, ITC]

Quick map generation and updating

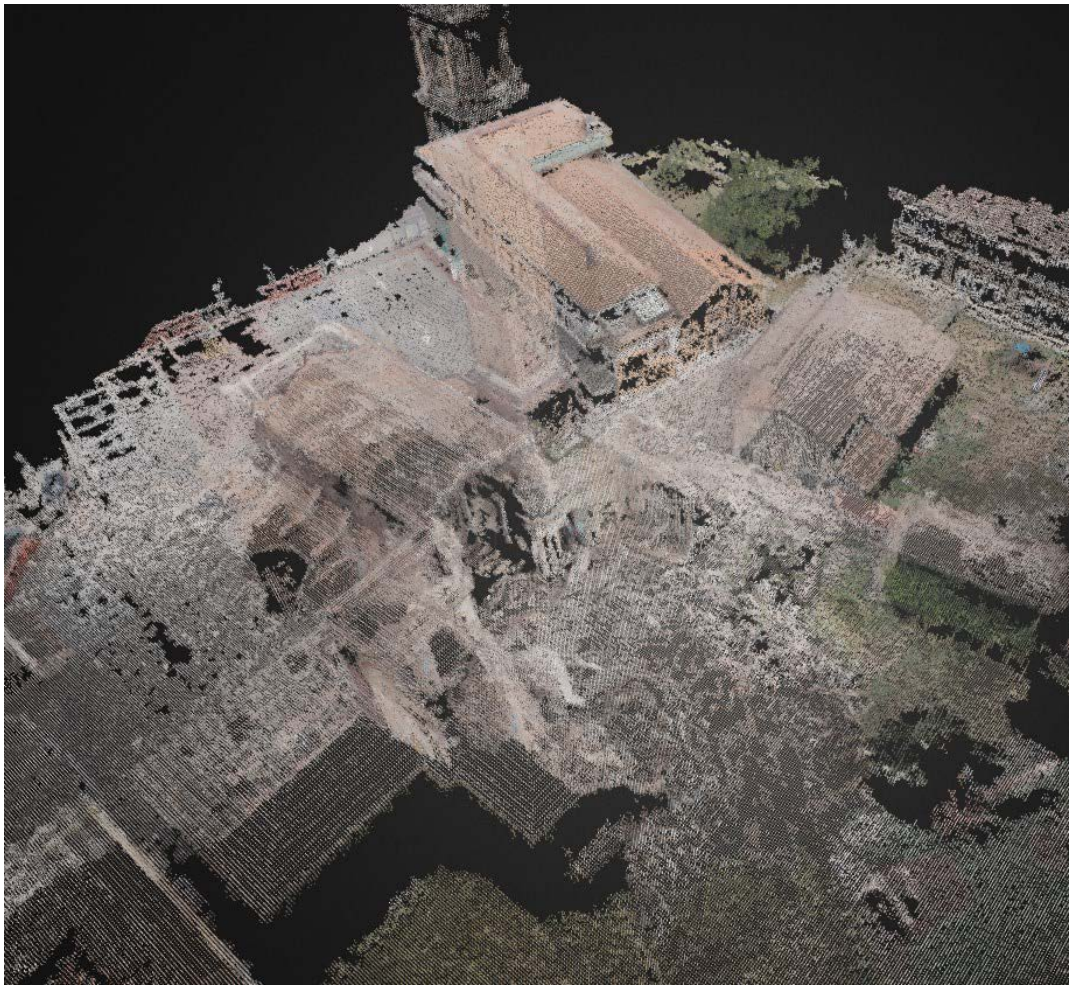
- Change detection and map updating in new built areas

- Semi-automated methodologies to reduce field work and map generation

[Muneza, 2015 – UT, ITC Master Thesis]

Post-event damage assessment

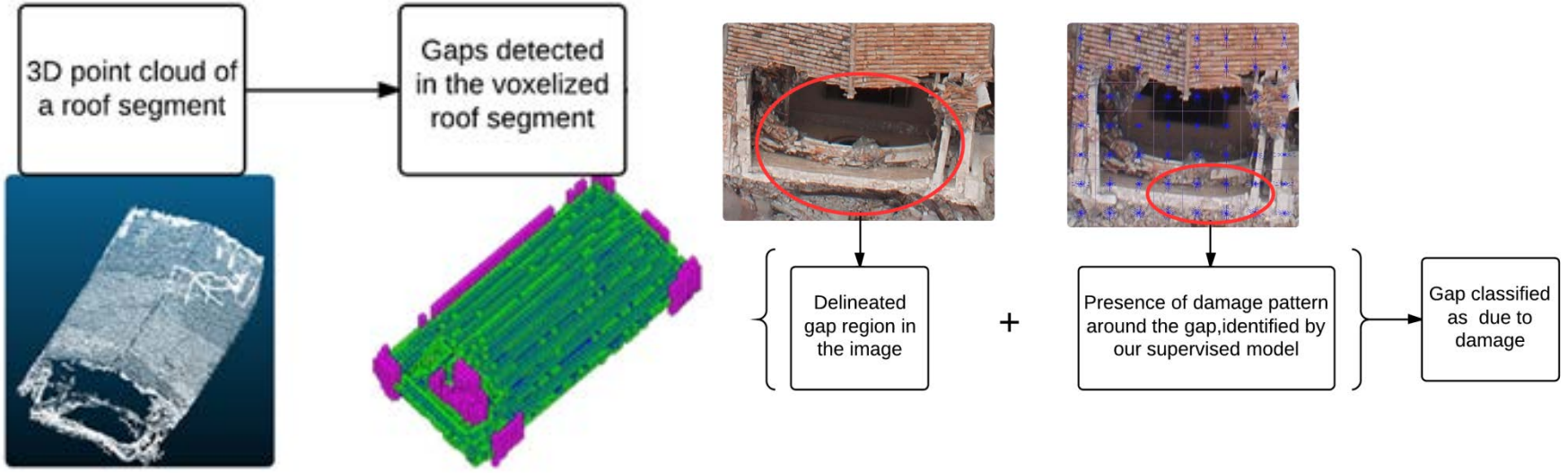
- 3D reconstructions of post-earthquake buildings for monitoring and damage assessment



Post-event damage assessment

- 3D reconstructions of post-earthquake buildings for monitoring and damage assessment

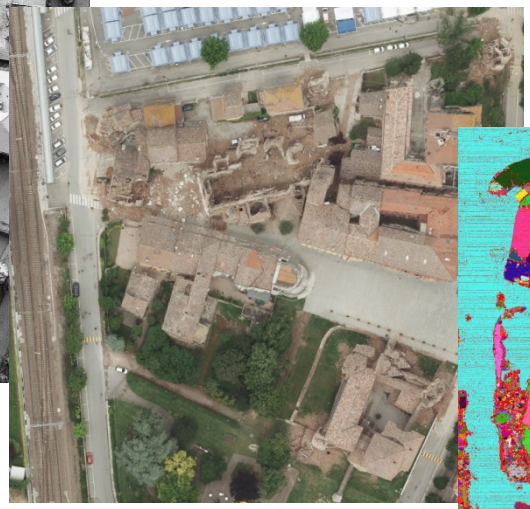
- Automated damage assessment [Vetrivel et al., 2015]



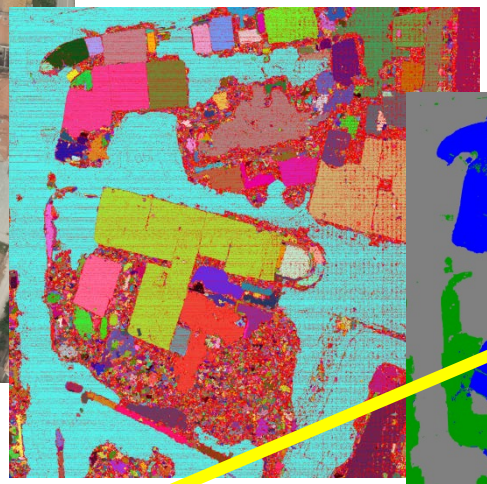
Post-event damage assessment

- Damage assessment on large urban areas

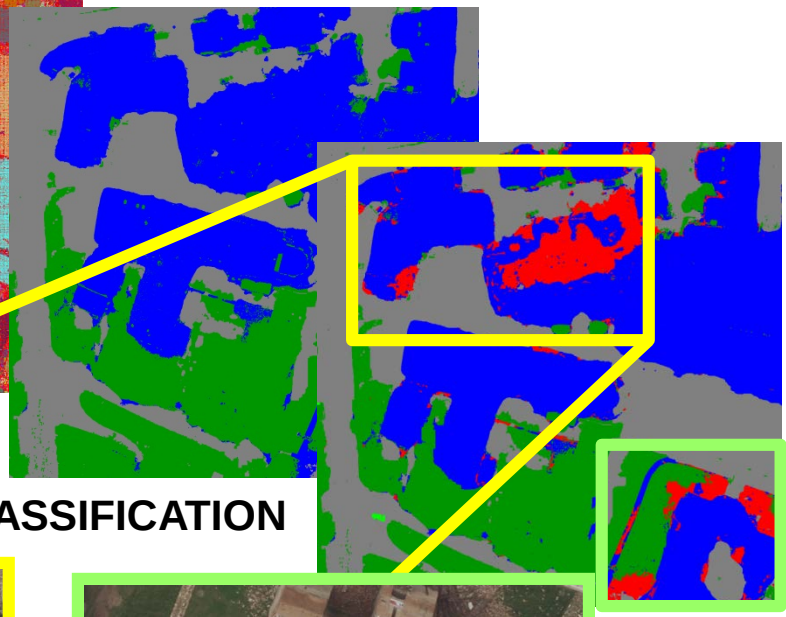
DSM



ORTHOPHOTO



SEGMENTATION

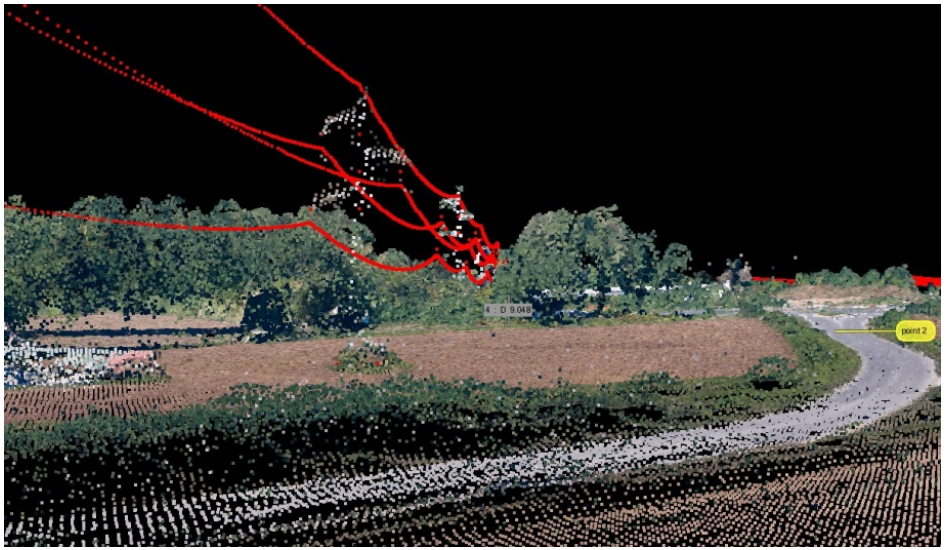


URBAN CLASSIFICATION

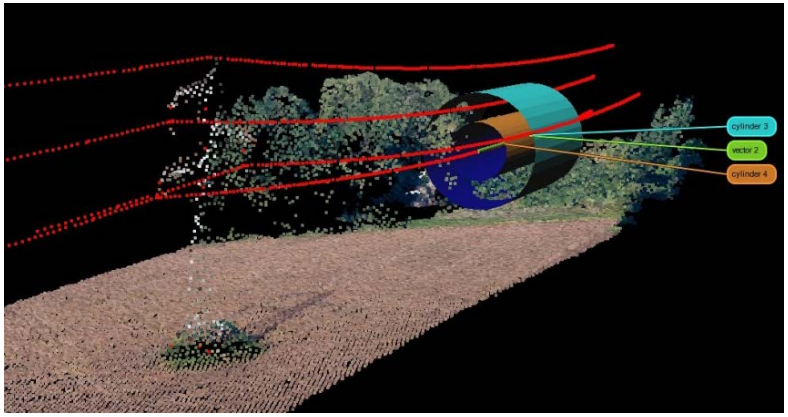
[Nex et al., 2014]

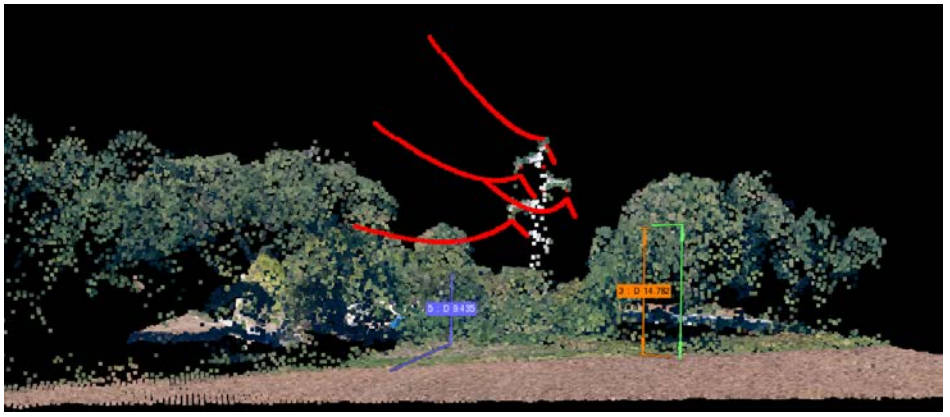
Monitoring applications – Powerline monitoring

- Monitoring of powerlines and vegetation in their neighborhood



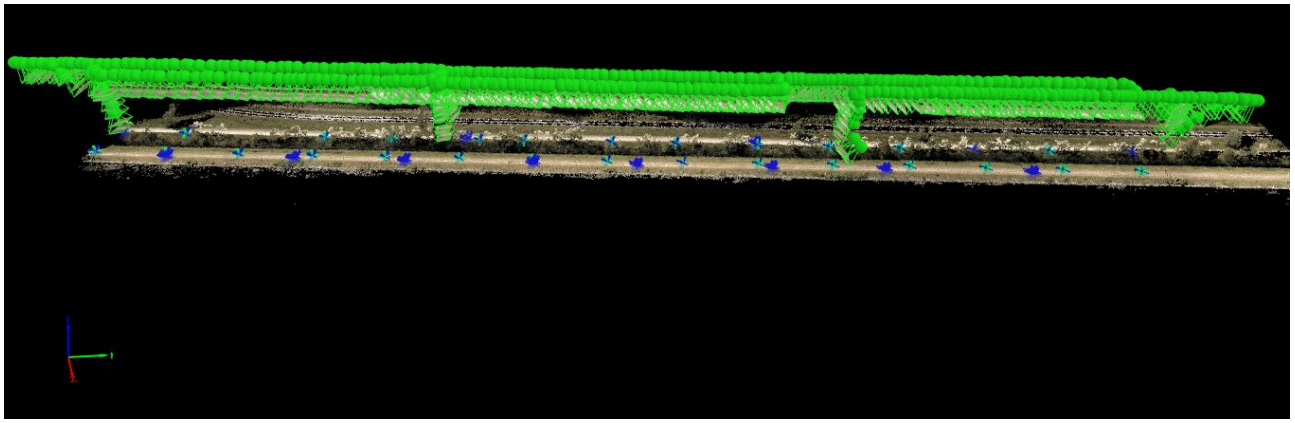
- Visual inspection of the installed devices

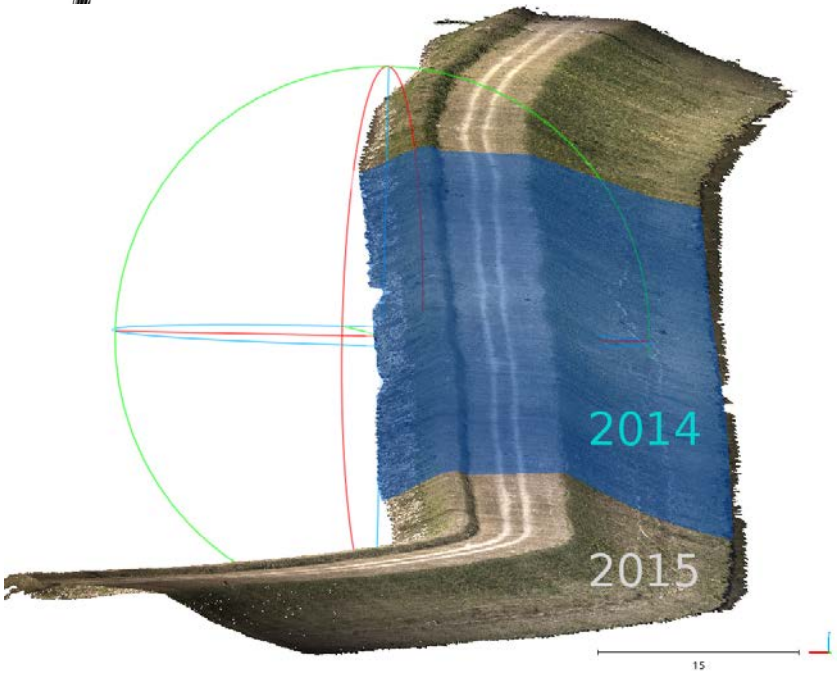


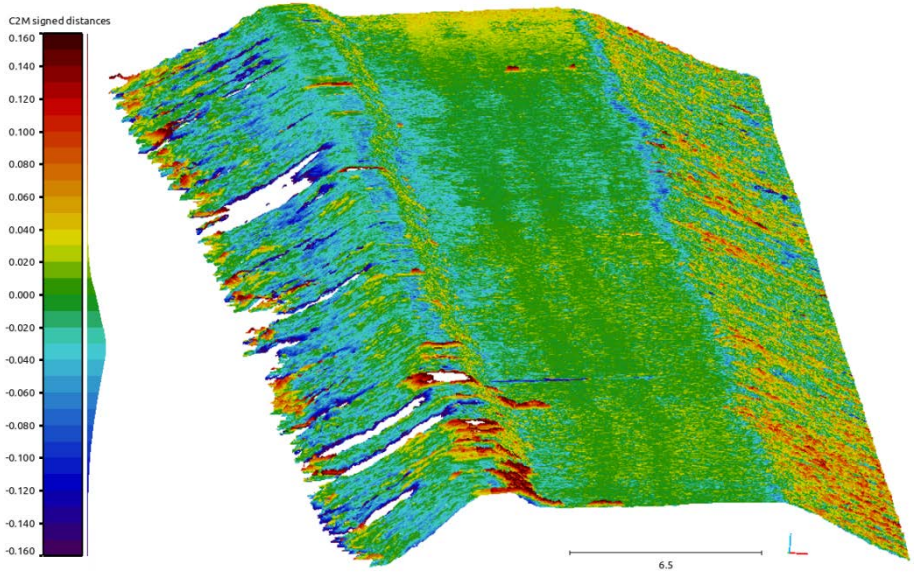


Monitoring applications - Dykes monitoring

- Accurate monitoring of surface changes every year



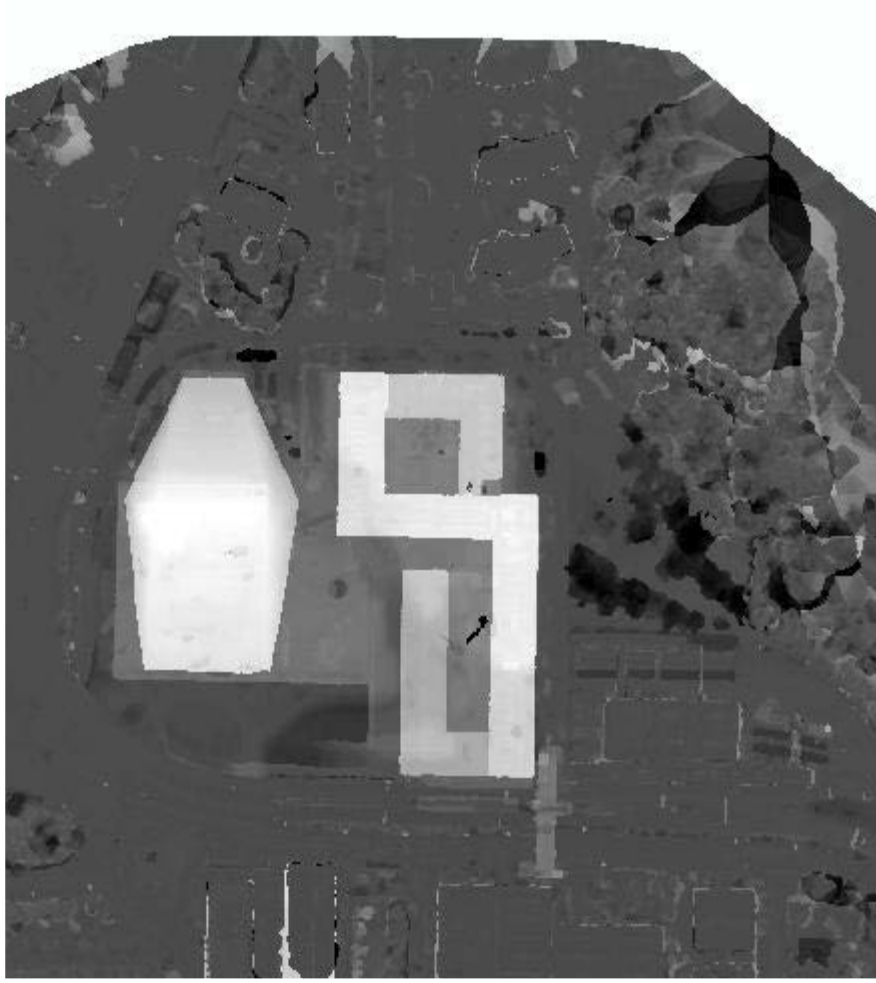




[Tournandre et al., 2015]

Monitoring applications - Construction sites

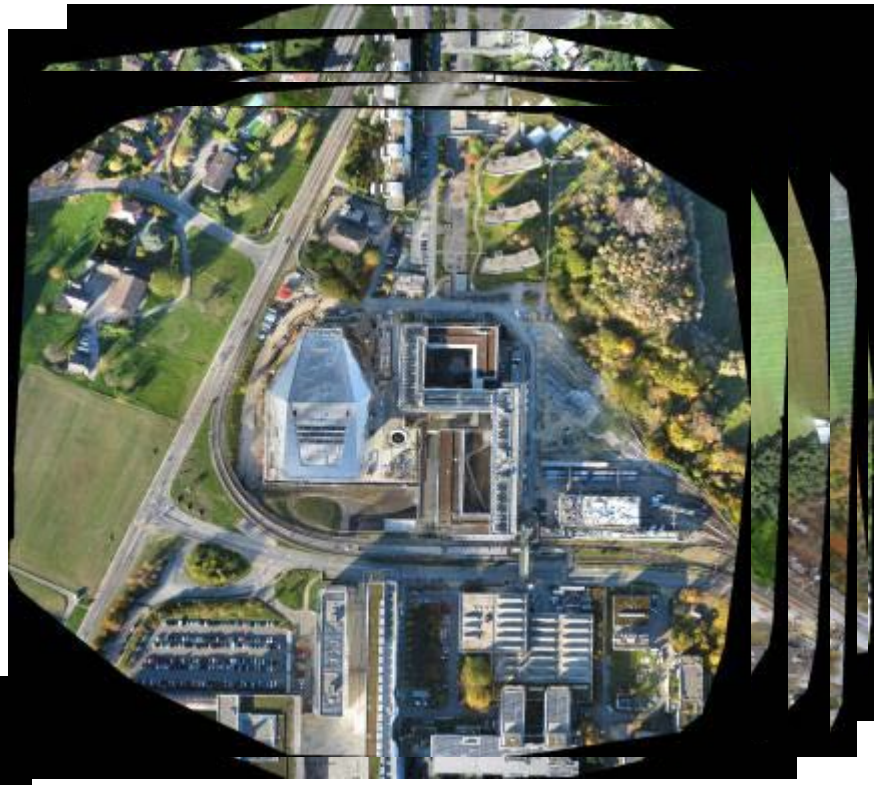
- Multi-temporal data acquisition to monitor the construction site progresses
- Acquired image blocks can be automatically co-registered together
- Very high dense DSM are generated for each flight



[Nyapwere, 2015 – UT, ITC Master thesis]

Monitoring applications - Construction site

- Multi-temporal data acquisition to monitor the construction site progresses
- Generated DSMs can be automatically aligned together
- Very high dense DSM can be generated from each flight



- An orthophoto and a 3D mesh can be automatically generated using the same dataset

[Nyapwere, 2015 – UT, ITC Master thesis]

Cultural heritage applications

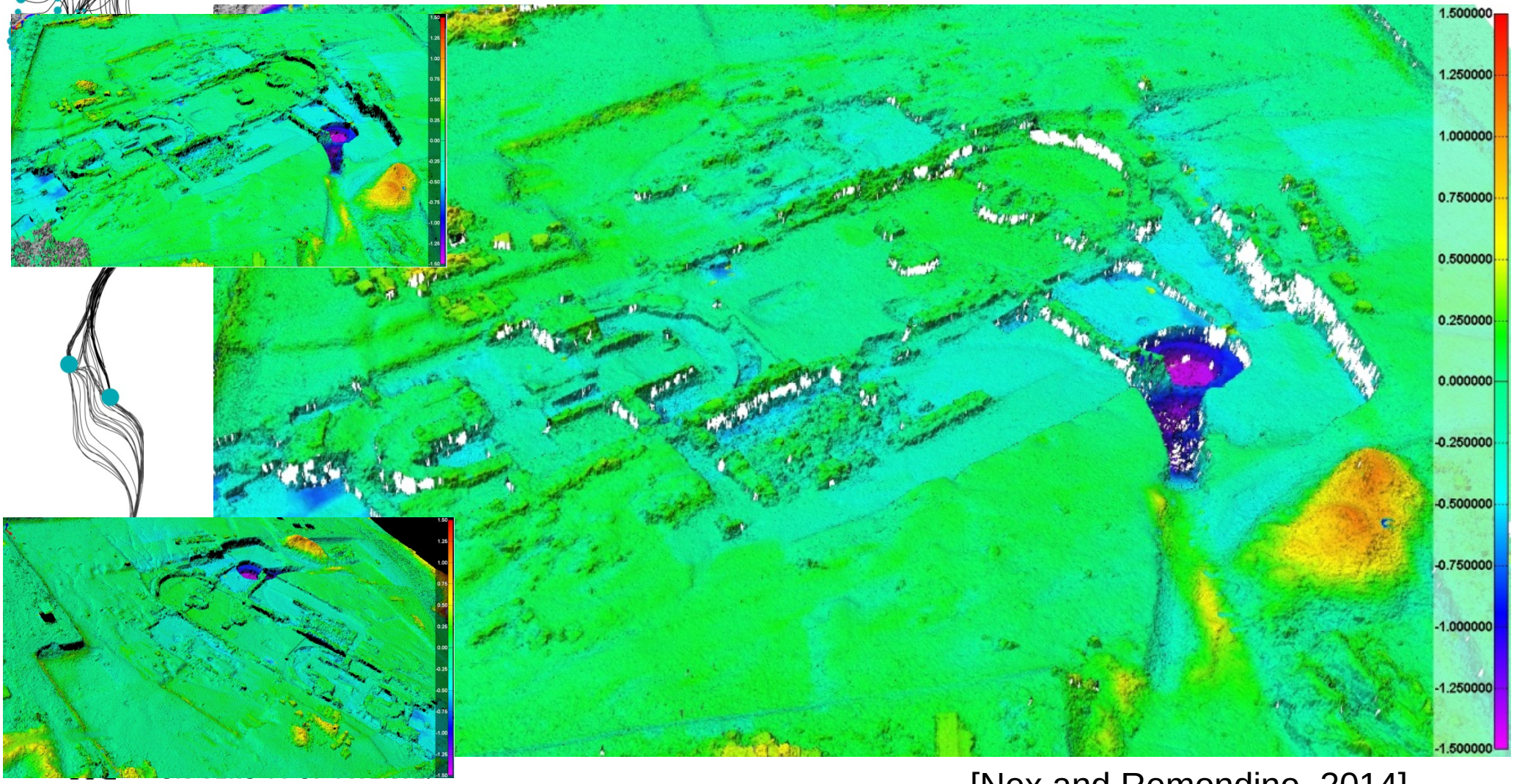
- Archaeological area of Pava (Siena, Italy), 40 images, ca 40x50 m
- Microdrone MD4-200, Pentax Optio A40 (8 mm lens, 12 Mpx, pixel size 1.9 mm)
- Flying height ca 35 m, GSD ca 2 cm
- DSM @ 5 cm resolution
- 11 ground points (5 as GCPs and 6 as CK)

Mosaic of the area

An image of the dataset

Cultural Heritage applications – multi-temporal

- Multi-temporal flights over the area – DSM comparisons to map / compute excavation volumes



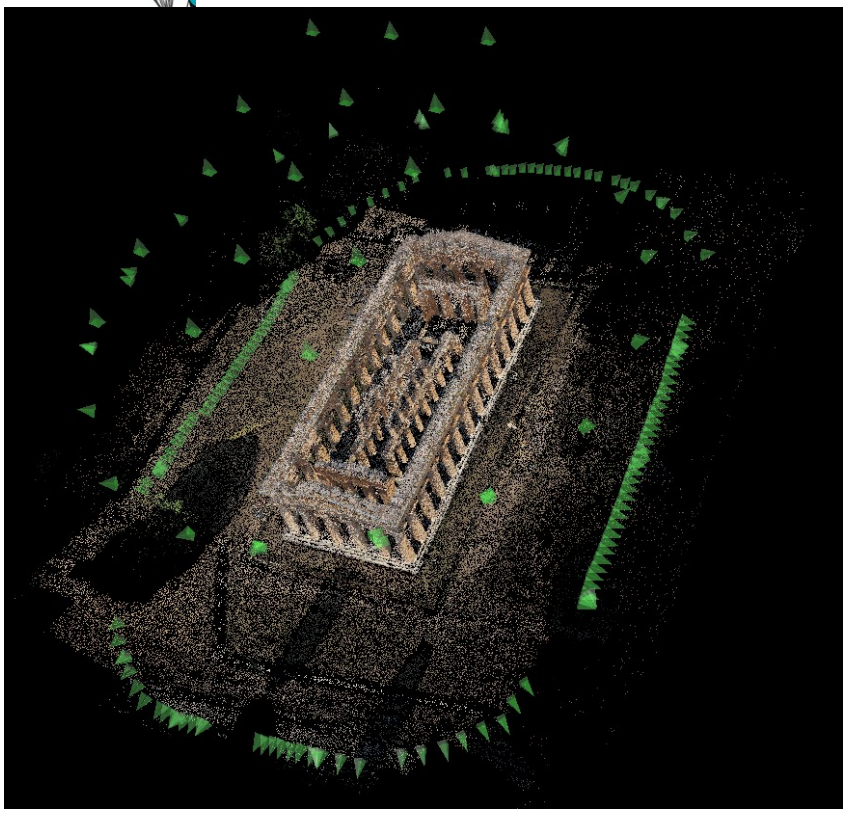
[Nex and Remondino, 2014]

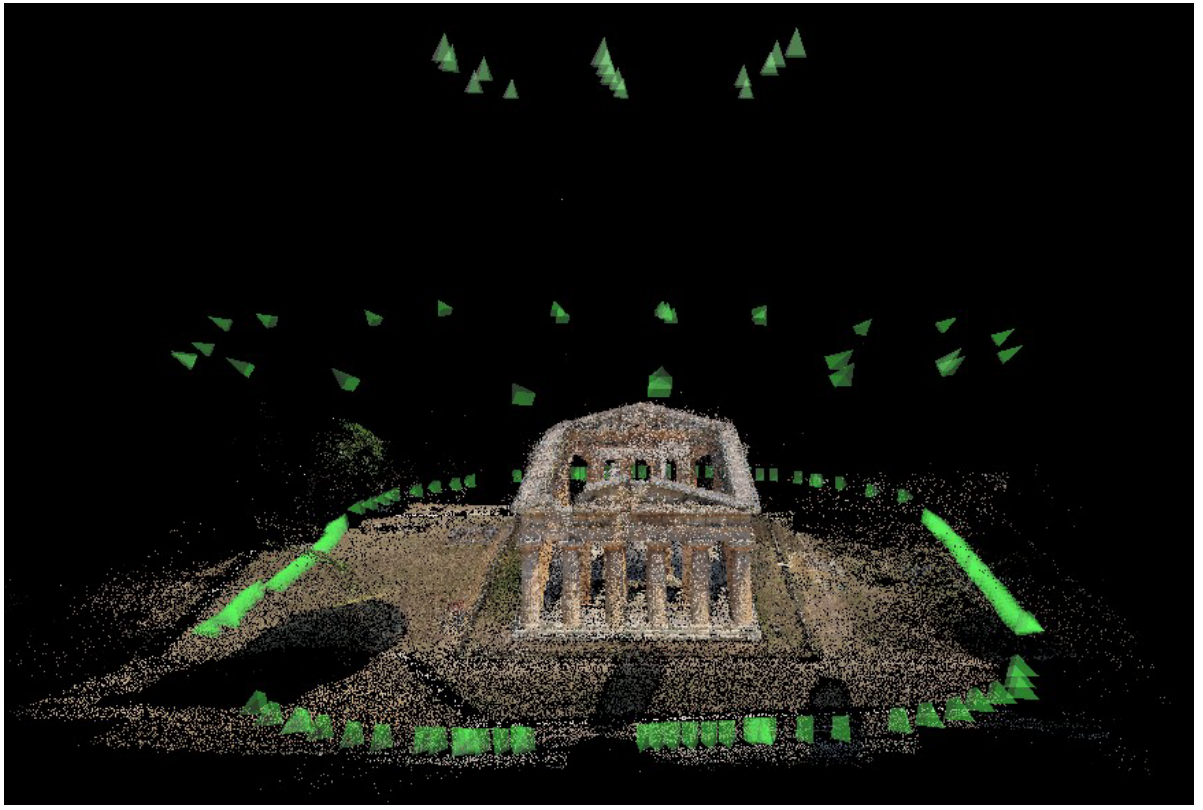
Cultural Heritage applications –– data integration

- 3D reconstruction of the **Neptune temple** integrating terrestrial and UAV (vertical and oblique) photogrammetry

Close the gap between terrestrial and aerial data

- 3D reconstruction of the **Neptune temple** integrating terrestrial and UAV (vertical and oblique) photogrammetry
- Image orientation (196 images)





Close the gap between terrestrial and aerial data

- 3D reconstruction of the **Neptune temple** integrating terrestrial terrestrial and UAV (vertical and oblique) photogrammetry
- Image orientation (196 images)
- 3D model generation

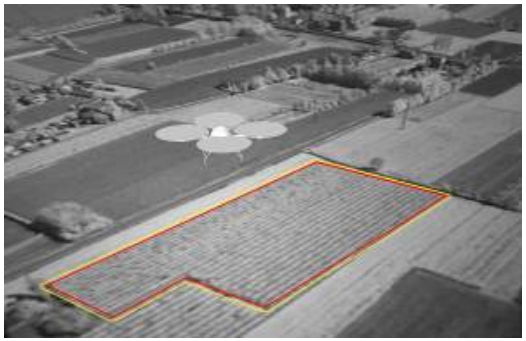
[Nex and Remondino, 2014]

Agriculture - Precision farming

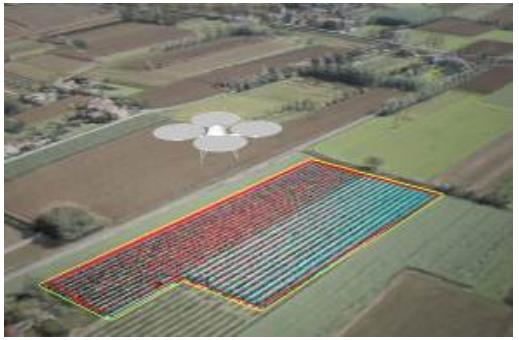
Precision Farming – Winery area

- Pentax Optio A40 for the images in the visible spectrum and a Sigma DP1 for the images in the NIR spectrum

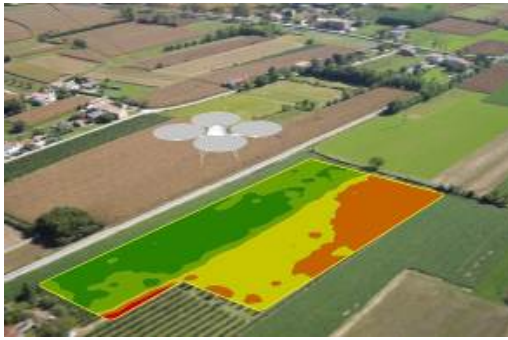
wine yard area



NIR



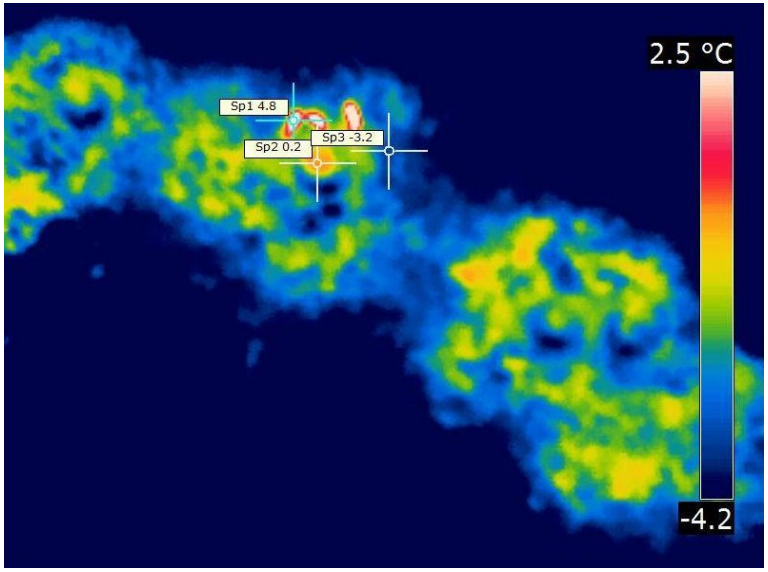
false colors



estimated NDVI index

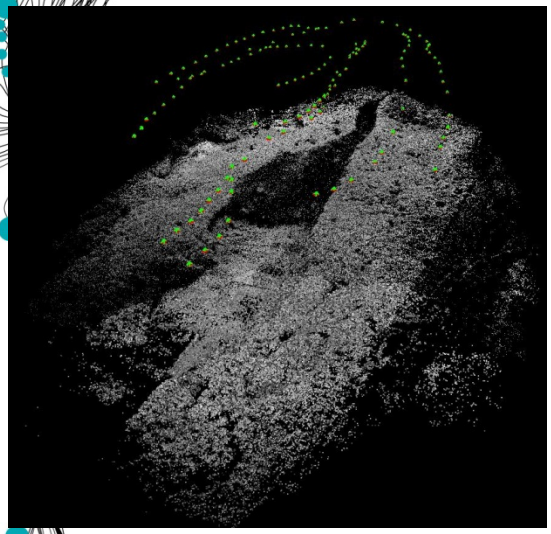
Thermal application

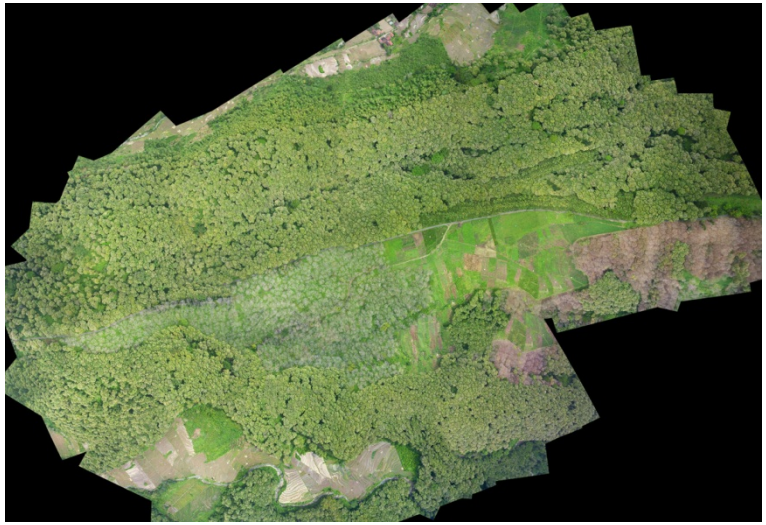
- MD4-100 with IR camera for real time tracking of animals

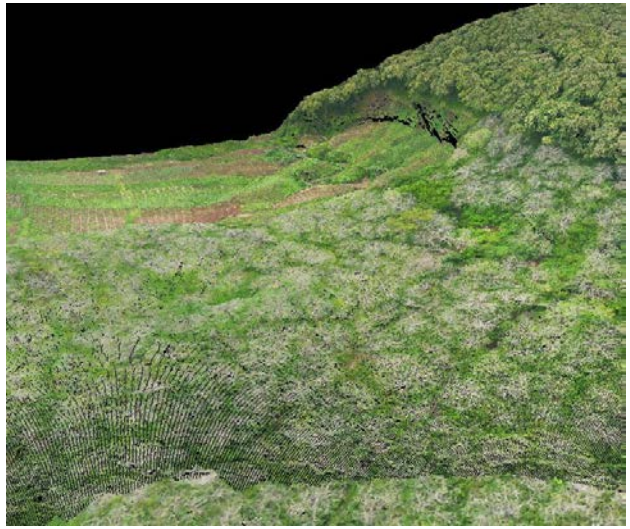


Forestry

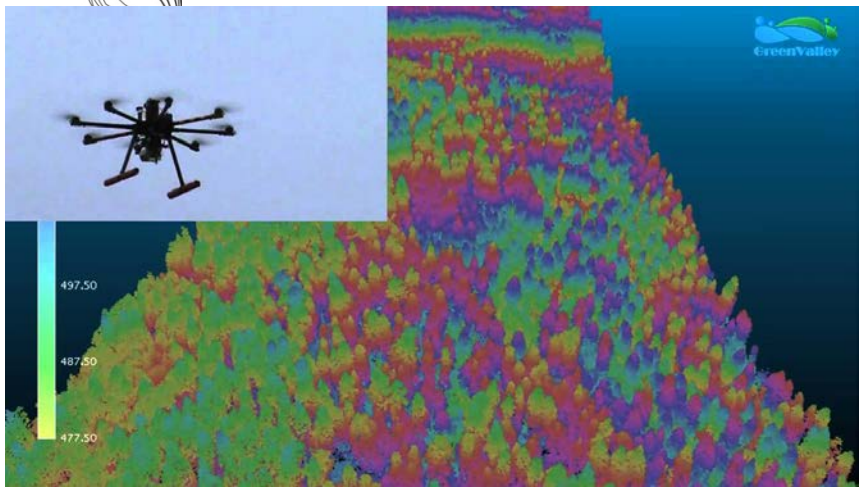
- Biomass estimation







- Forest inventory



[source GreenValley and Aibotix]

UAV regulations

- Regulations represent one of the biggest limitations to the use of UAVs.

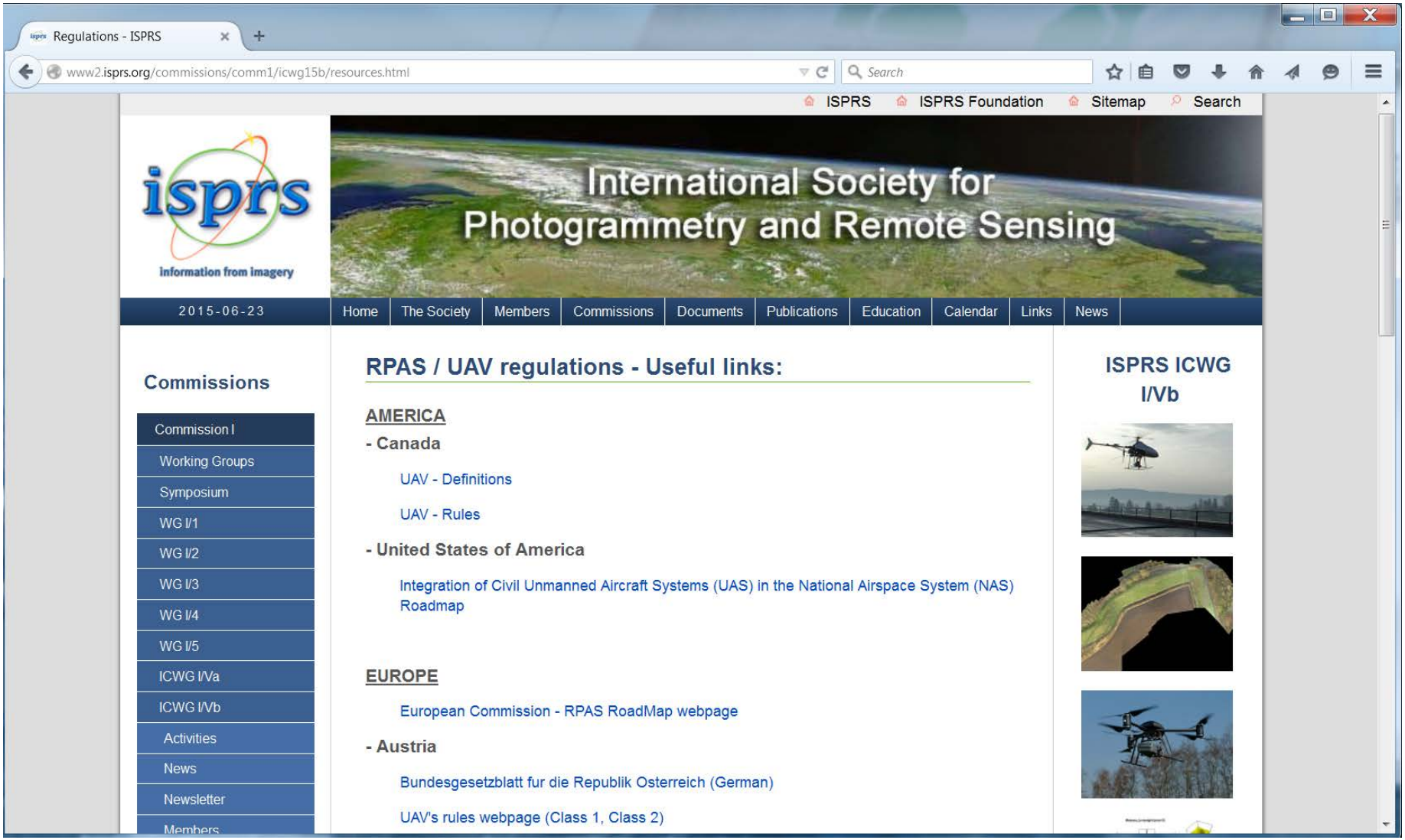
Every country is adopting a different rule, even if they have similar in some parts:

- Needed certifications:
  - Experienced pilot
  - Certified platform
  - Certified and insured company
- Permit to fly by the National Aviation Authority
- Limitations during the flight
  - Maximum flight height
  - Distance from Ground Control Station (line of sight)
  - Critical / not critical areas

Experimental test-field at the University of Twente under construction!

UAV regulations

- A not-exhaustive list of the UAV regulations on the ISPRS website



Conclusions and remarks

❑ UAV **Advantages**

- ➢ Use in risky and inaccessible areas
- ➢ Data acquisition with high temporal and spatial resolution
- ➢ Flexibility in terms of hosted sensors
- ➢ Possibility for autonomous flight
- ➢ Low-cost platforms / onboard sensors
- ➢ Easily controllable / transportable
- ➢ Overview of the area of interest in real-time
- ➢ Useful for teaching / HW & SW open-source solution

❑ UAV **Limitations**

- ➢ Limitations of the payload and endurance
- ➢ Instability of the platforms (wind, electromagnetic influences, etc.)
- ➢ Regulations and insurance
- ➢ Use of low-cost sensors denies high-end performances and accuracy

Conclusions and remarks

- Open **research issues** in Earth Observation with UAVs
  - Direct geo-referencing with d-GNSS (→ see e.g. Mavinci Sirius Pro)
  - New miniaturized (light) and efficient sensors
  - Sensor fusion (combination laser scanning and images)
  - Data fusion with different data source (satellite)
  - Automated and real time data processing (images, point clouds etc.)
  - Efficient (big) data processing
  - Reliability of the systems / platforms in every operative condition
  - Collaborative UAVs (fleet of UAVs)
  - Regulation for the flights
  - Longer flying time and more autonomy

Benchmark for multi-platform very photogrammetry

Foster research concerning:

1) Fully automatic and reliable co-registration of multi platform imagery

2) dense image matching within/across platforms

Data captured lately in Dortmund / Germany

➔IGI PentaCam-flight by AeroWest (80/80%), GSD 10cm

➔UAV flights in selected areas (oblique/nadir), GSD 1-2cm

➔Terrestrial images in selected areas, GSD < 1cm

➔Reference data: static GNSS, Totalstation, TLS, ALS

http://www2.isprs.org/commissions/comm1/icwg15b/benchmark_main.html

terrestrial image blocks

UAV (nadir/oblique)

airborne (nadir/oblique)

GEOBIA2016
SOLUTIONS & SYNERGIES

- 6th GEOBIA conference – 14-16 September 2016
- Hosted by ITC/ University Twente (Enschede, the Netherlands)
- Abstract deadline: 1 March 2016
- Full paper / extended abstracts: 1 July 2016
- www.geobia2016.com

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THE USE OF UAVS FOR EARTH OBSERVATION

FRANCESCO NEX

f.nex@utwente.nl