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Advantages of Photogrammetry for Radiological Mapping

Outline

- Introduction to Photogrammetry (Petr GABRLIK)
  - Basics, principles, methods, outputs

- Photogrammetry for Radiological Mapping (Tomas LAZNA)
  - Principles, applications, advantages, disadvantages, outputs

Introduction to Photogrammetry

Petr GABRLIK

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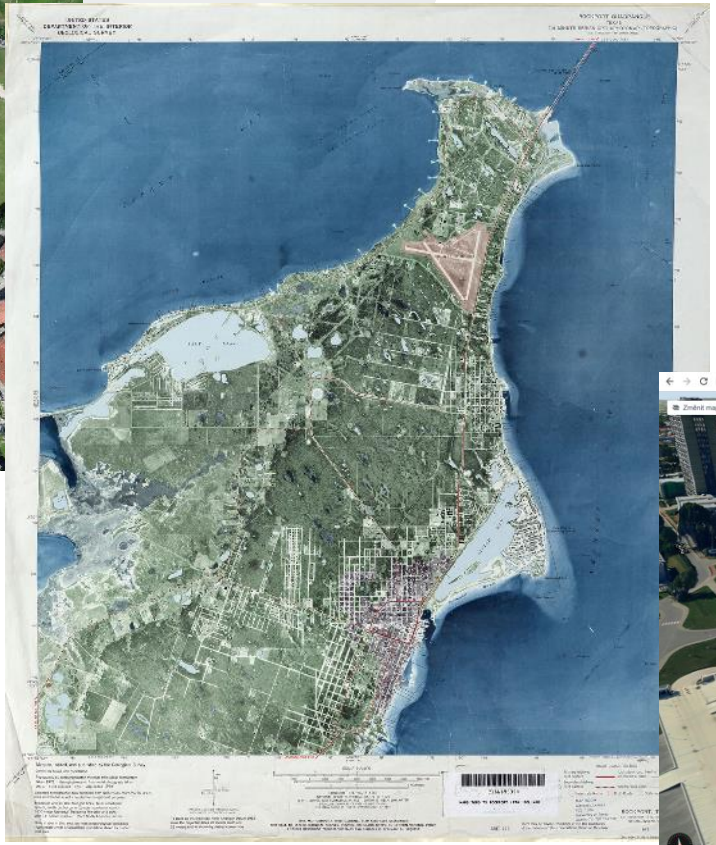
Photogrammetry

„Photogrammetry is a discipline dealing with extracting geometric and spatial information from photographs. “

Outputs and applications

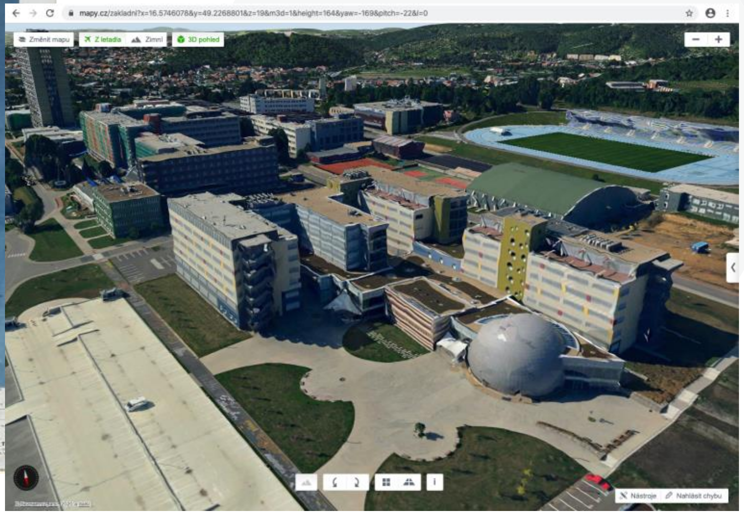
Orthophoto, orthomosaic

Source: https://en.wikipedia.org/wiki/Orthophoto



Orthophotomap

Source: https://en.wikipedia.org/wiki/Orthophoto



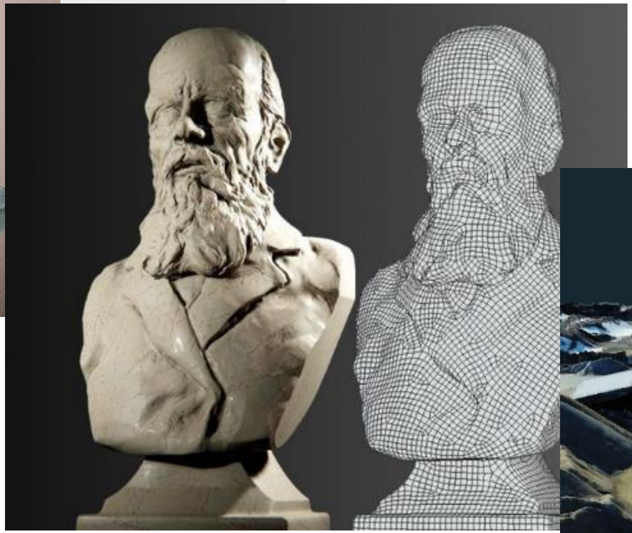
3D map

Source: https://mapy.cz

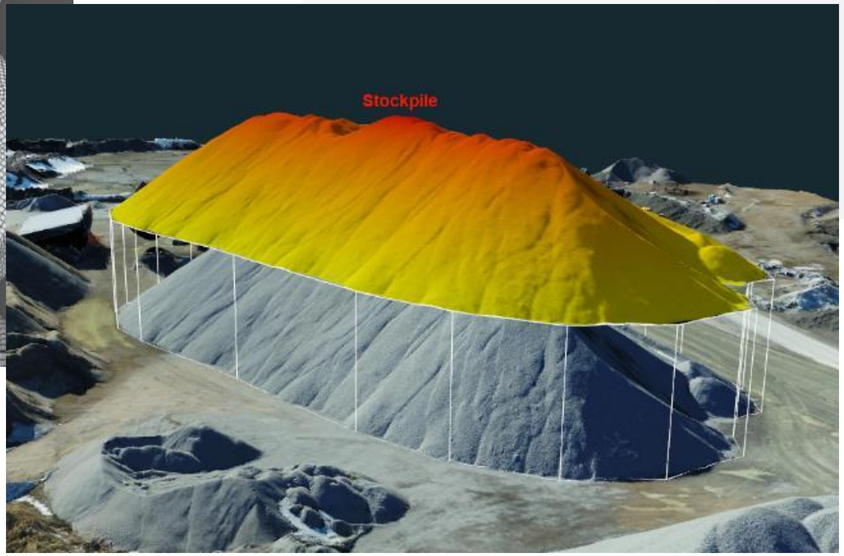
Outputs and applications

3D reconstruction of objects

Source: https://sketchfab.com/3d-models/utopia-building-raw-photogrammetry-scan-3d4d3527842044b8b8cb81ac578e81d4



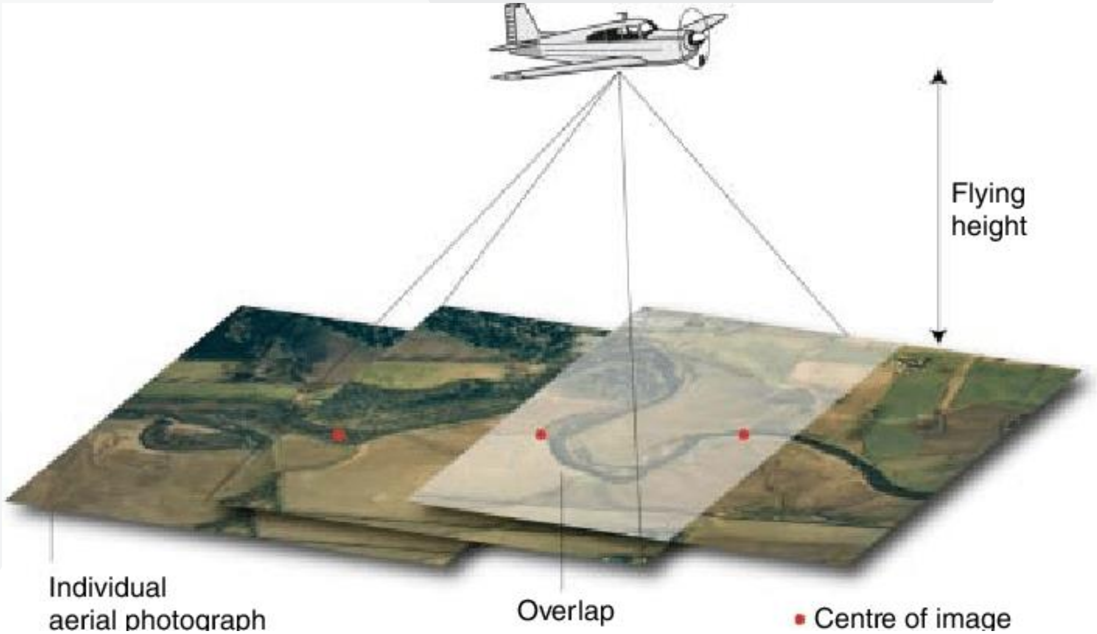
Source: https://modtechlabs.com/beginners-guide-photogrammetry/



Measurement of dimensions, distances, volumes

Source: https://www.3dsurvey.si/webinar/stockpile-volume-calculations-fast-easy-and-accurate

Aerial and UAS photogrammetry



Source: https://onlinelibrary.wiley.com/doi/10.1002/9781118648551.ch6

UAS = Unmanned Aircraft System

UAV = Unmanned Aerial Vehicle

RPAS = Remotely Piloted Aircraft Systems

Drone = UAV (slang)

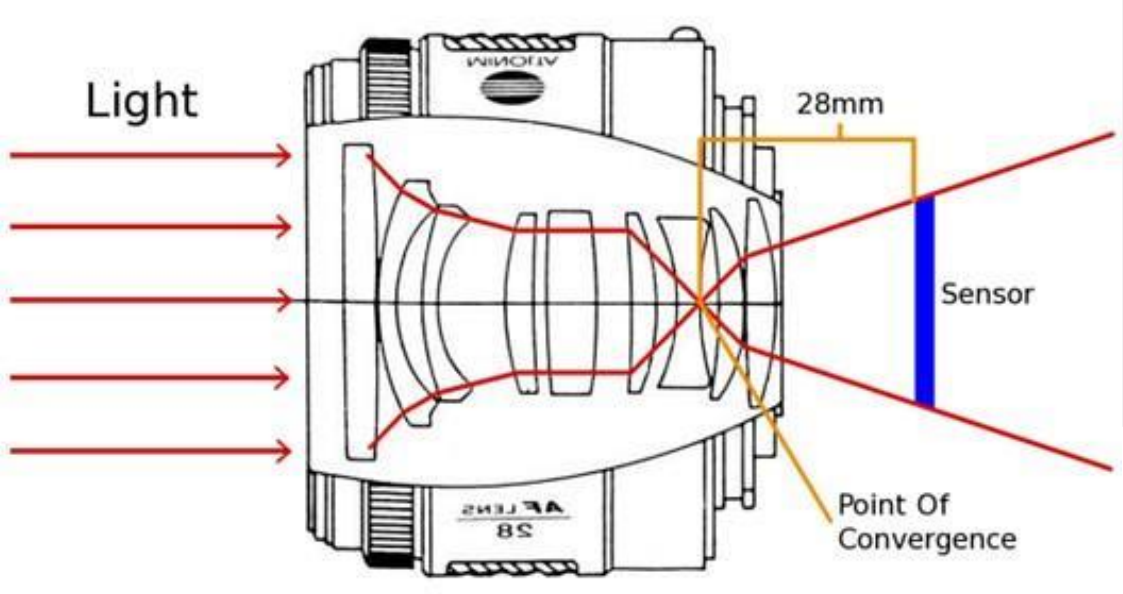
- **Aerial photogrammetry** – utilizes vertical images collected by an aircraft
- **UAS photogrammetry** – aerial photogrammetry employing UASs (Unmanned Aircraft Systems)

Aerial image

- By default, an aerial image **can't be utilized** for:
  - Distance measurement
  - Coordinate extraction
  - Combining with other map layers
  - Combining with measured radiation data etc.

Projection problem

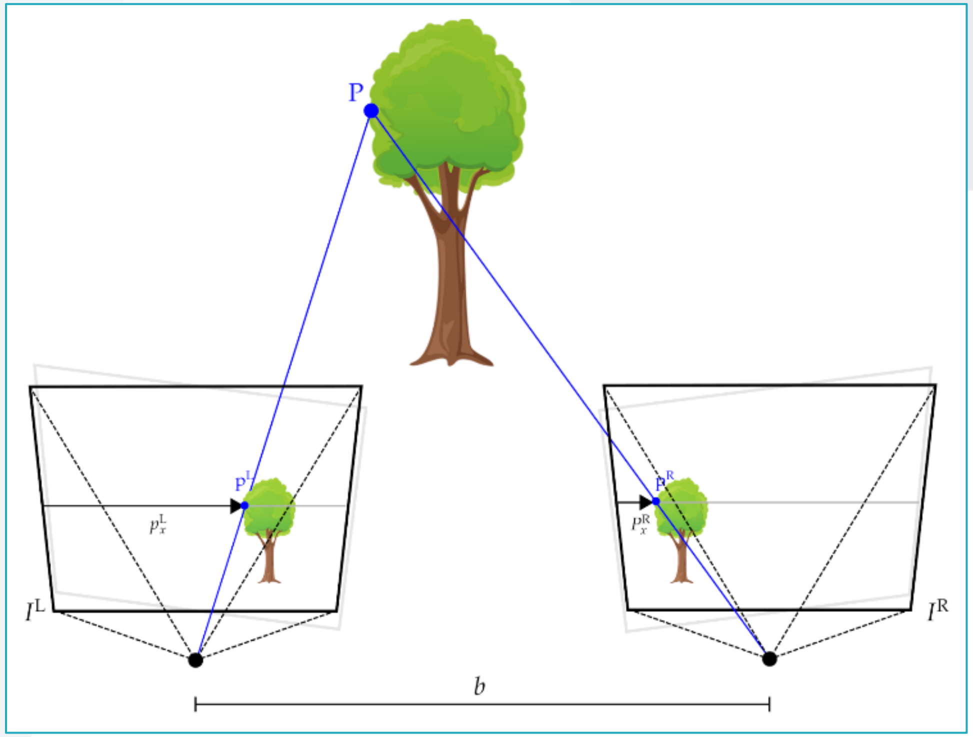
Source: https://www.fotoaparat.cz/fotogalerie/fotografie/378531



Source: https://www.dpreview.com/forums/post/60984654

Taking a photo → projecting 3D world into 2D space → **one dimension is lost**

Stereovision

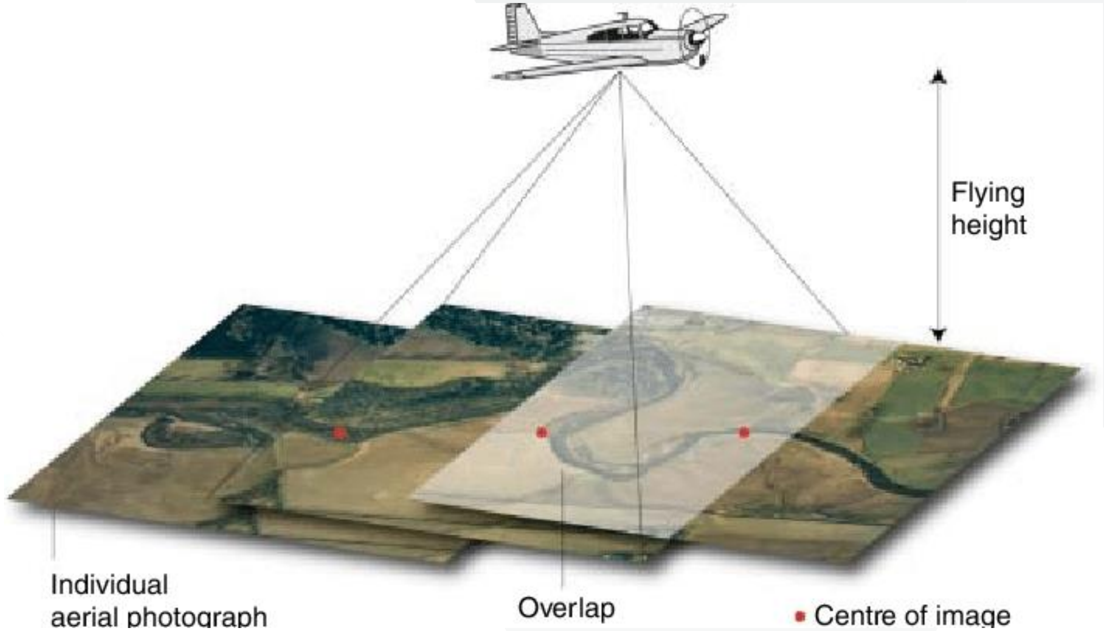


Source: https://www.mdpi.com/1424-8220/21/11/3938/htm

- **Two cameras** obtain two different views on a scene.
- In this case, 3D position of the object can be reconstructed.
- More images of the same object → higher accuracy.

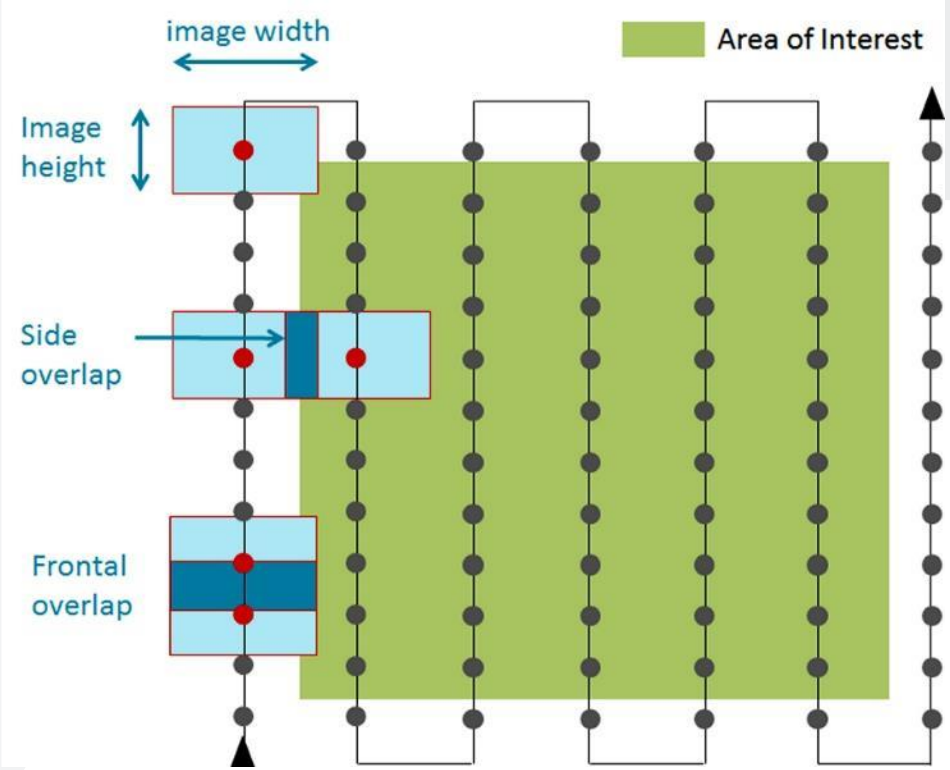
Aerial stereophotogrammetry

- Aircraft is equipped with **one** camera only (typically).
- Photographs are captured from different positions at different times.
- Photographs must overlap by 50 % at least (the stereovision condition).
- 3D position of each point on the scene can be reconstructed.



Source: https://onlinelibrary.wiley.com/doi/10.1002/9781118648551.ch6

Trajectory planning



Source: https://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/air-photos/about-aerial-photography/9687

- **Goal**: each point of the area of interest must be visible at two photographs at least.

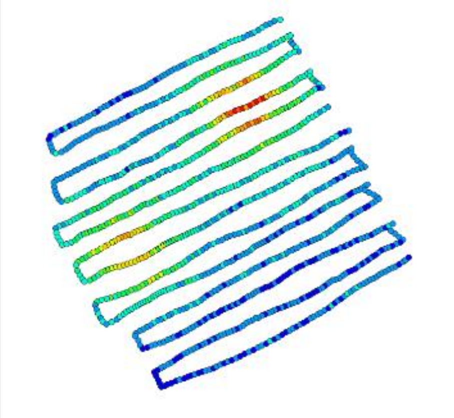
⬇

- Parallel flight lines covering entire area.
- Photographs are overlapped in both directions – frontal and side **overlaps** (typically 70-80 %).
- Flight speed, altitude, triggering interval and line spacing are computed accordingly.
- Legal and technical constraints must be considered.

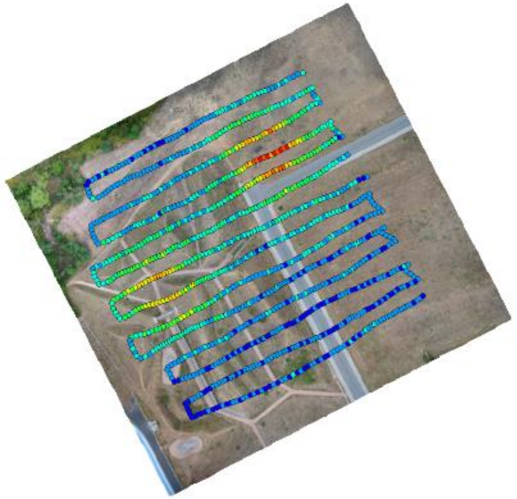
Trajectory planning software for photogrammetry (UgCS).

Georeferencing

- Georeferenging – transforming local/relative coordinates into global reference frame (e.g. WGS84).
- “*Obtaining position data.*”
- Required for combining different map layers together, extracting coordinates etc.
- Two types of georeferencing exist:
  - Direct
  - Indirect

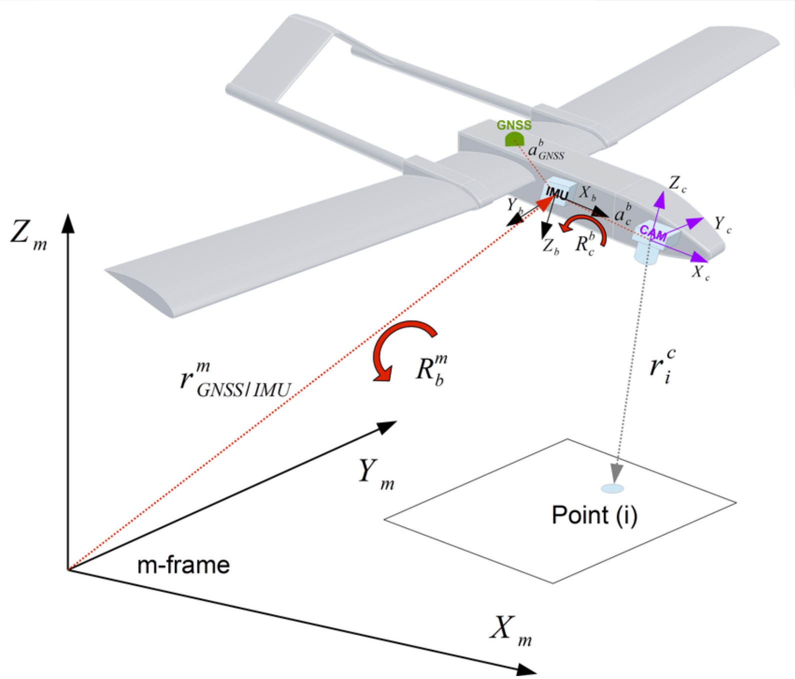


Georeferencing needed!



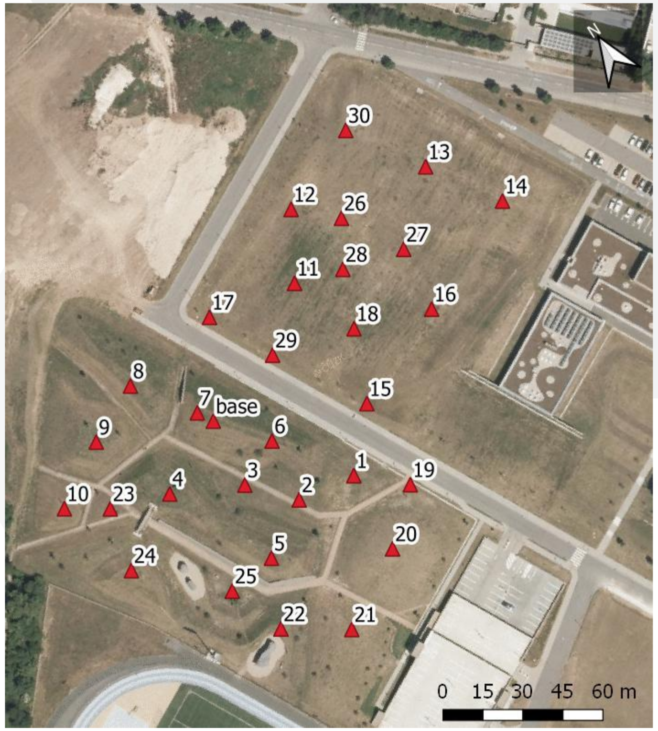
Georeferencing

Direct georeferencing



Source:
https://www.researchgate.net/publication/314259443_Integrated_Sensor_Orientation_on_Micro_Aerial_Vehicles

Indirect georeferencing



UAS equipment

- Camera
  - Every camera can be employed for photogrammetry
  - Image and lens quality is essential
  - Active stabilization - gimbal
  - Resolution is not the main parameter

Source: https://dji.com

DJI Phantom 3, 12 MP

Source: https://www.megapixel.cz/sony-a7-telo

Sony A7, 24 MP

Source: https://dji.com

DJI P1, 45 MP

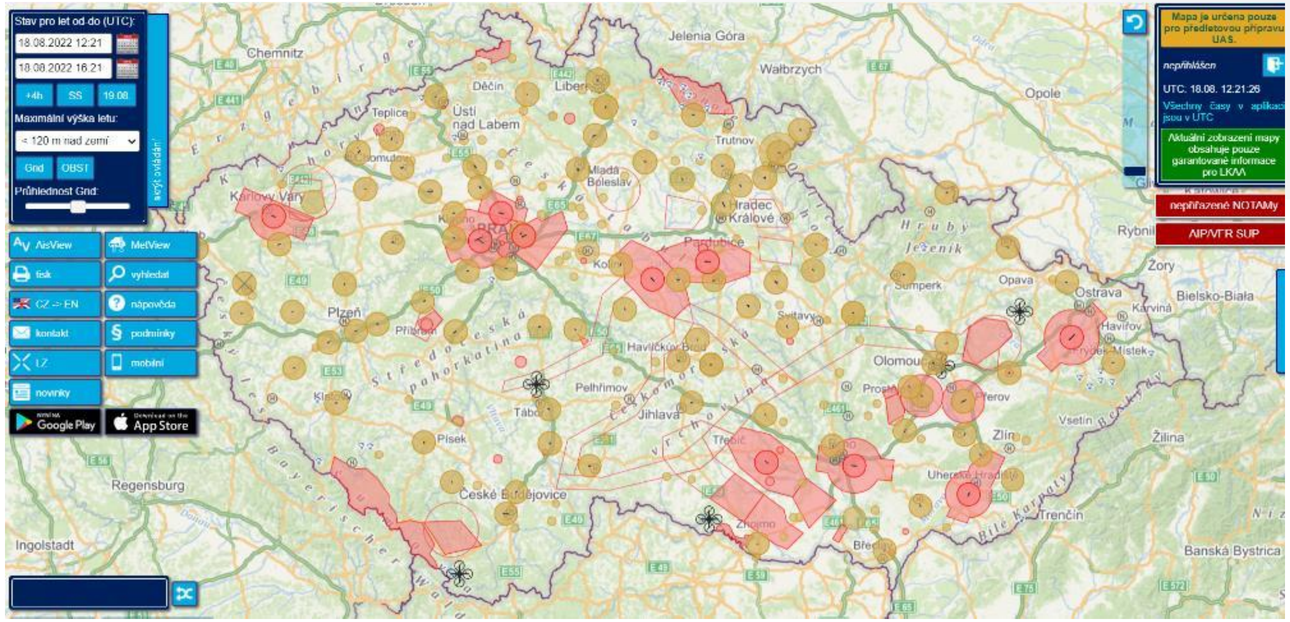
- GNSS
  - GNSS is required for the automatic operation.
  - Standard GNSS → low accuracy georeferencing (~meters)
  - RTK GNSS → accurate georeferencing (~cm)

Source: https://dji.com

DJI Phantom 4 RTK

UAS legislation

- Legal constraints in most of the countries
- European Union – EASA
- National rules
- EASA requirements
  - Operator registration
  - Pilot license
  - Insurance
- The most important:
  - **Airspace classes**



Source: https://dronview.rlp.cz/

Photogrammetric processing

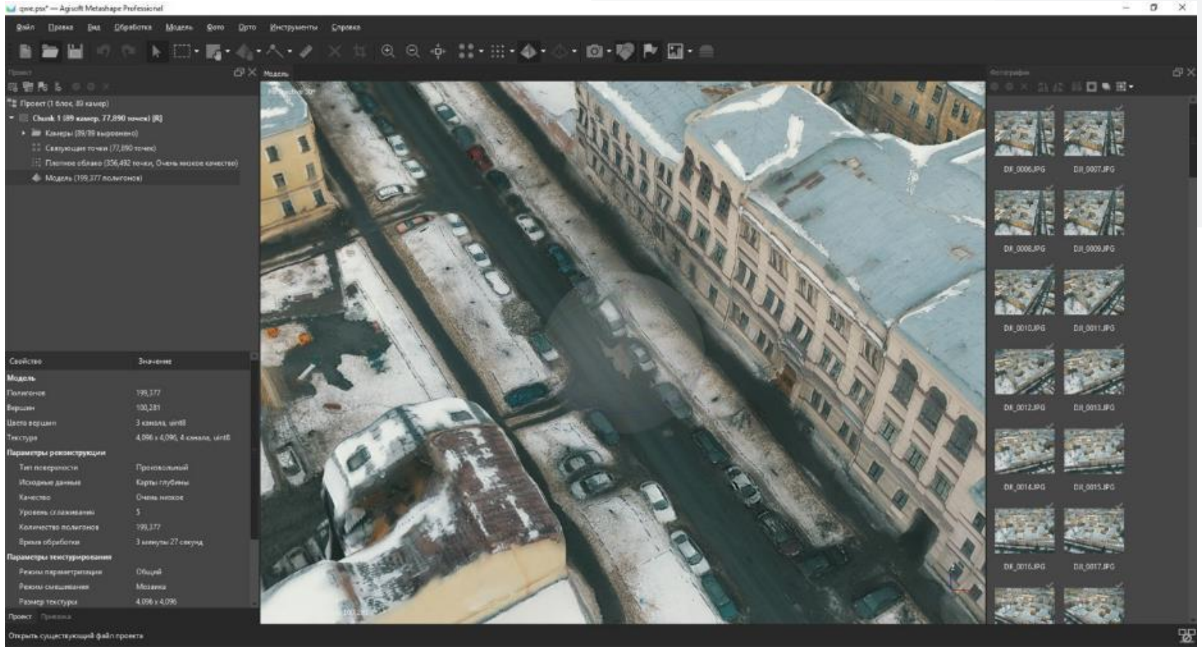
- The processing consists of numerous stages and methods – workflow.
- Todays photogrammetric SWs integrates all processing steps with user-friendly interface.
- The processing can last minutes/**hours**/days depending on quality and size.

Pix4Dmapper

DJI TERRA

Metashape

1. Importing photos and georeferencing data
2. Processing stages
3. Exporting products



Source: https://www.geoscan.aero/en/software/agisoft/metashape_standard

Photogrammetry outputs

- Photogrammetry may produce various outpus/products, the most common are:

- **Orthophoto / orthomosaic** – geometrically corrected aerial image composed of the individual photographs.

Source: https://en.wikipedia.org/wiki/Orthophoto

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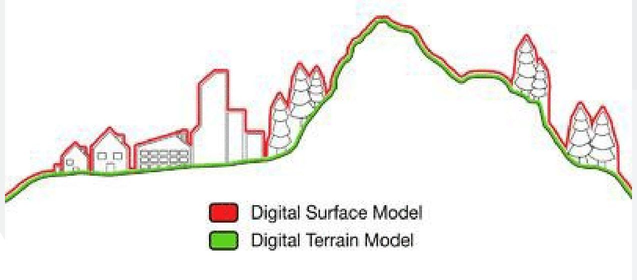
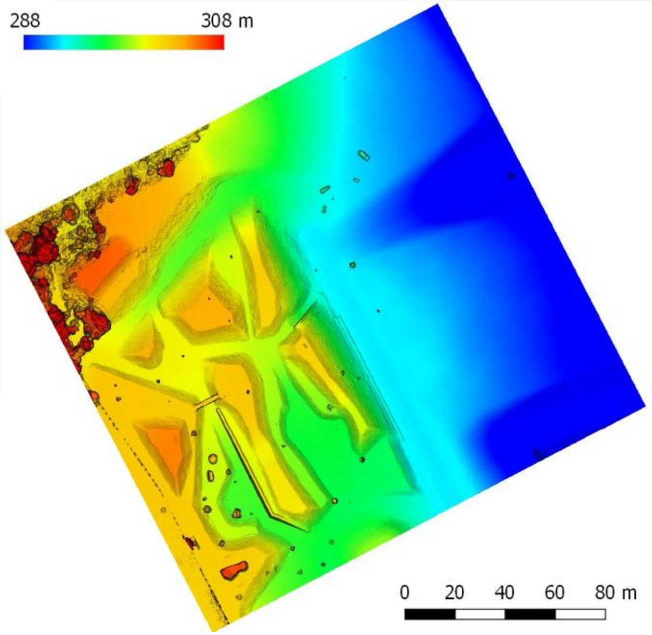


Source:
https://www.researchgate.net/publication/308063830_THREE_DIMENSIONAL_CITY_BUILDING_MODELLING_WITH_LIDAR_DATA_CASE_STUDY_CIWARUGA_BANDUNG



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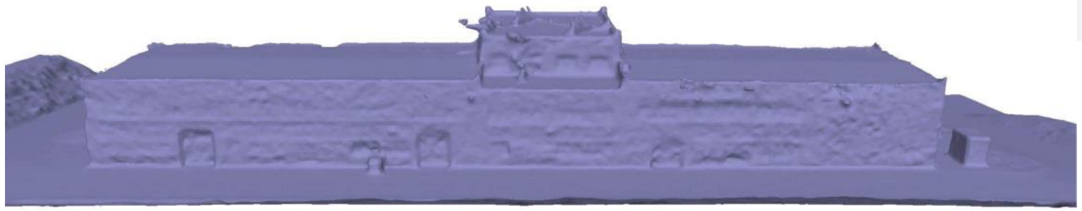
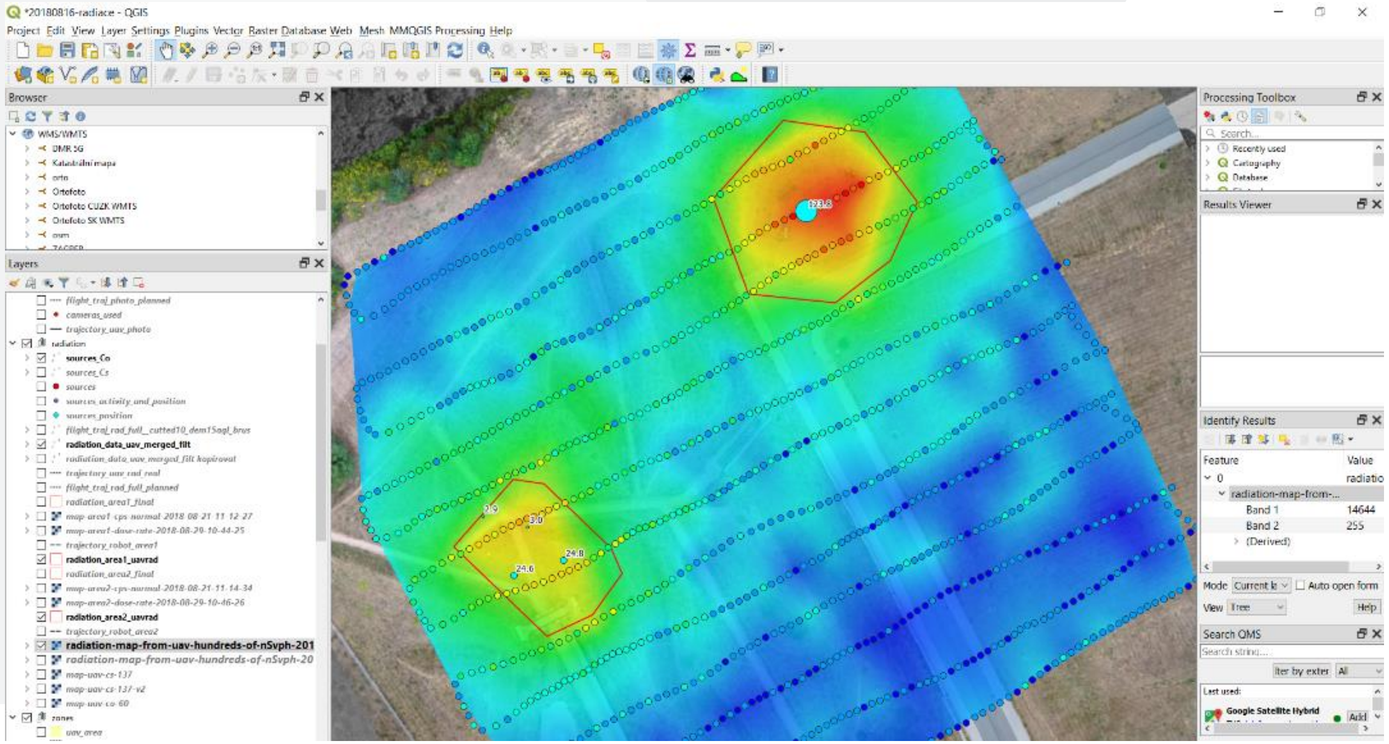


- **Mesh** – continuous 3D representation of the scene composed of triangles (covered with textrue).

GIS – Geographic Information System

- Standard SW tool for visualizing and combinig geographic data (raster/vector/spatil data)



- Enables to visualize georeferenced photogrammetry-based orthophoto and DEM
- Combining with radiation data
- Bult-in tools for raster analysis, data interpolation etc.
- Creating reports, exporting maps

Photogrammetry – problems

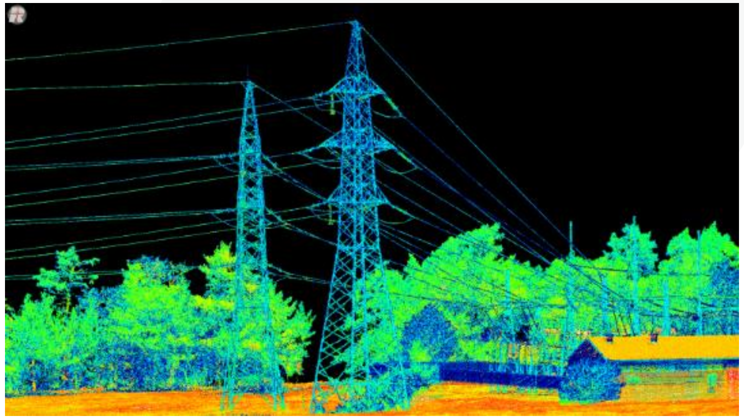
- Photogrammetry requires
  - Good lightning conditions
  - Rich texture
  - Static scene
  - Oblique images for vertical structures

- Other aspects
  - Computationally demanding
  - Any raster data can be utilized:
    - RGB, thermal, multispectral..

Laser scanning

- „*Competitive*“ method of photogrammetry
- Uses **LIDAR** instead of camera
- Primarily produces point clouds; DEM/mesh/orthophoto can be generated as well (RGB camera needed for orthophoto)
- Typically more reliable data
- **Higher price**

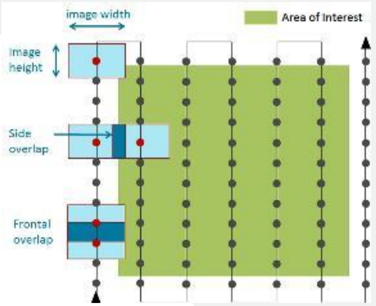
Source: https://www.logxon.com/en/uav-photogrammetry-uav-laser-scanning/



Source: https://www.rieglusa.com/press-releases.html

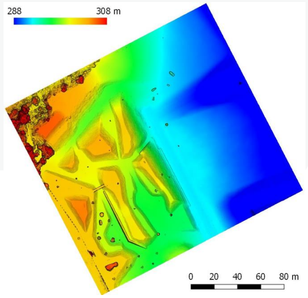
UAS photogrammetry workflow summary

1. Trajectory planning



2. Aerial data collection - UAS flight

3. Photogrammetry processing / data export



Photogrammetry for Radiological Mapping

Tomas LAZNA

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Radiological Mapping

- Means of presentation of radiation data:
  - Basic: Datapoints over an orthophoto map
  - Advanced: Interpolated radiation map, isodoses, hotspots, … in a context
- Sources of contextual data:
  - Publicly available (e.g., Google Maps)
  - Commercial
  - Own acquisition
- Useful tools:
  - Google Earth
  - MATLAB/Octave

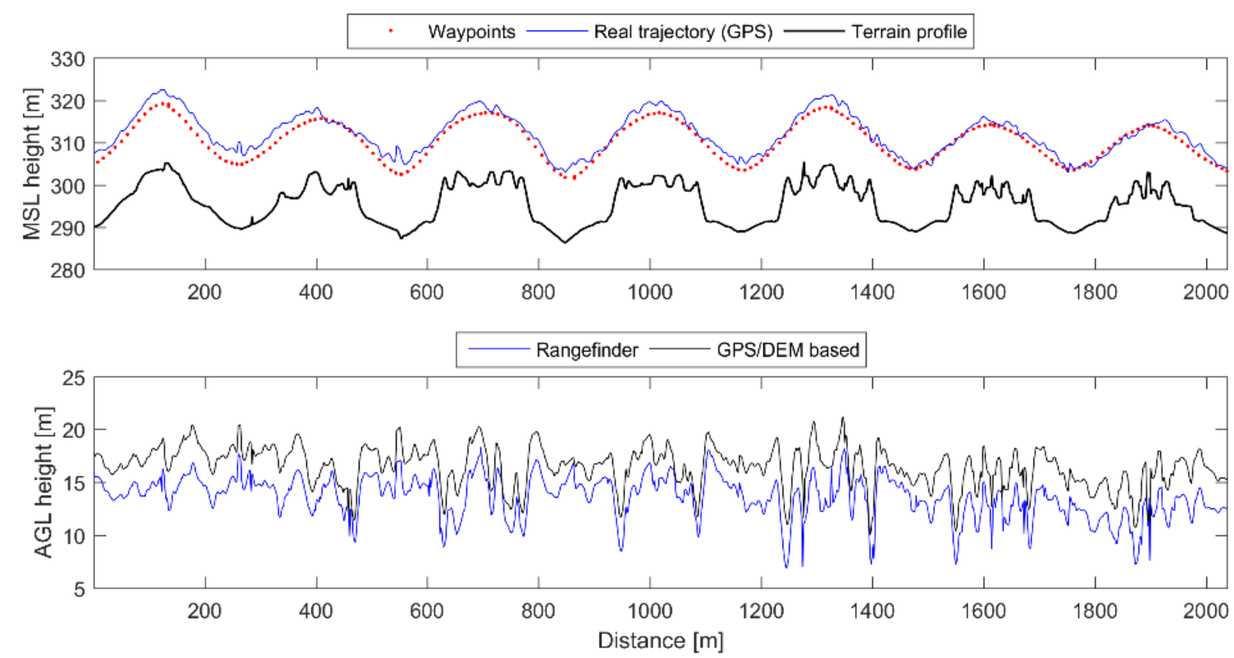
Comparison of orthophoto maps

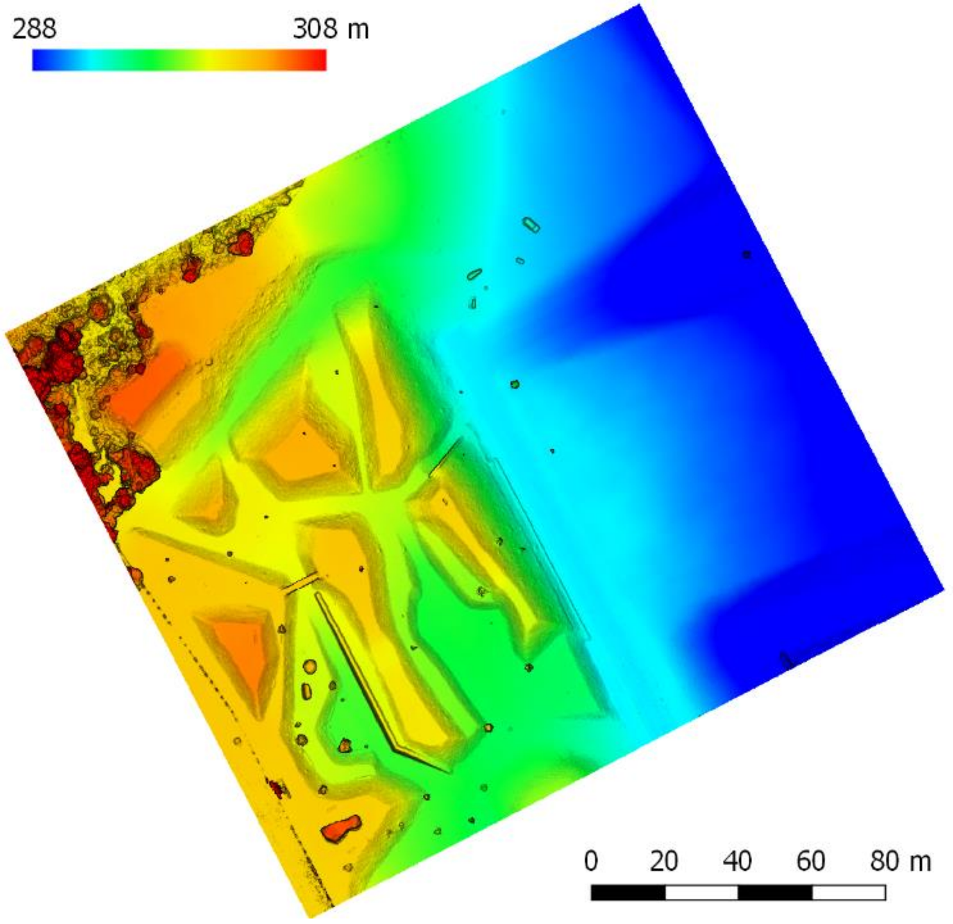
Publicly available

Created with a UAV

Terrain following

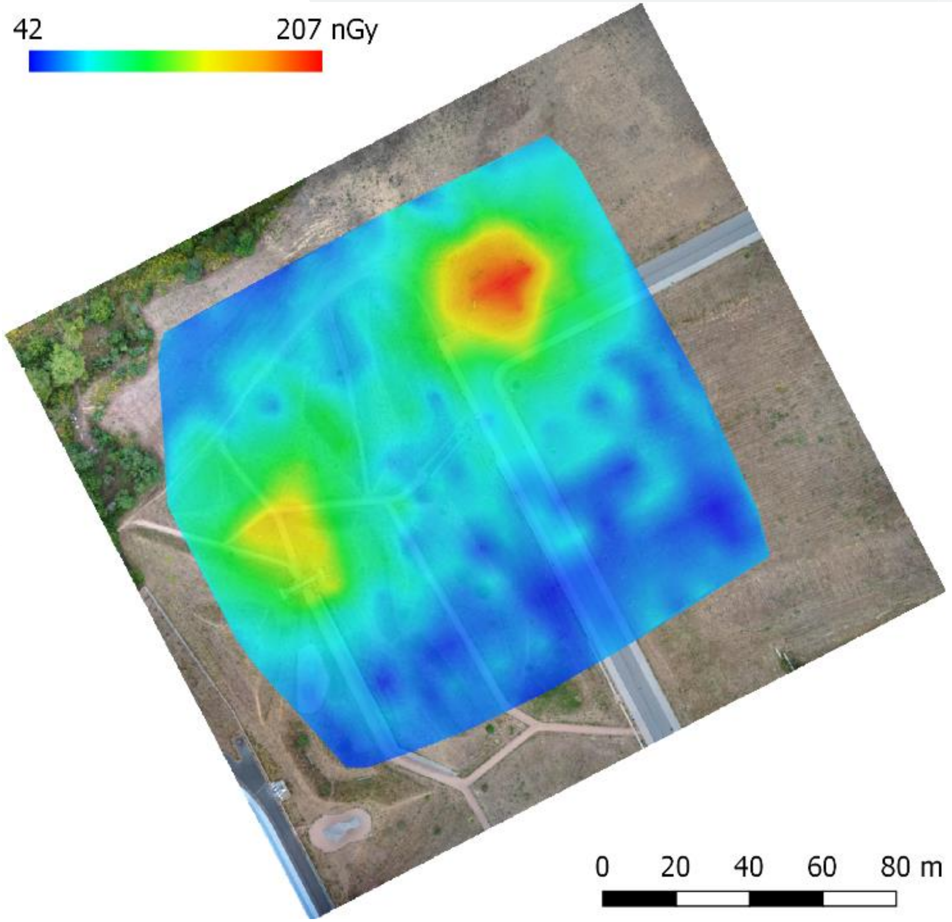
- A photogrammetry-based digital elevation model enables the UAV to maintain approximately constant altitude above the terrain during the radiation data acquisition



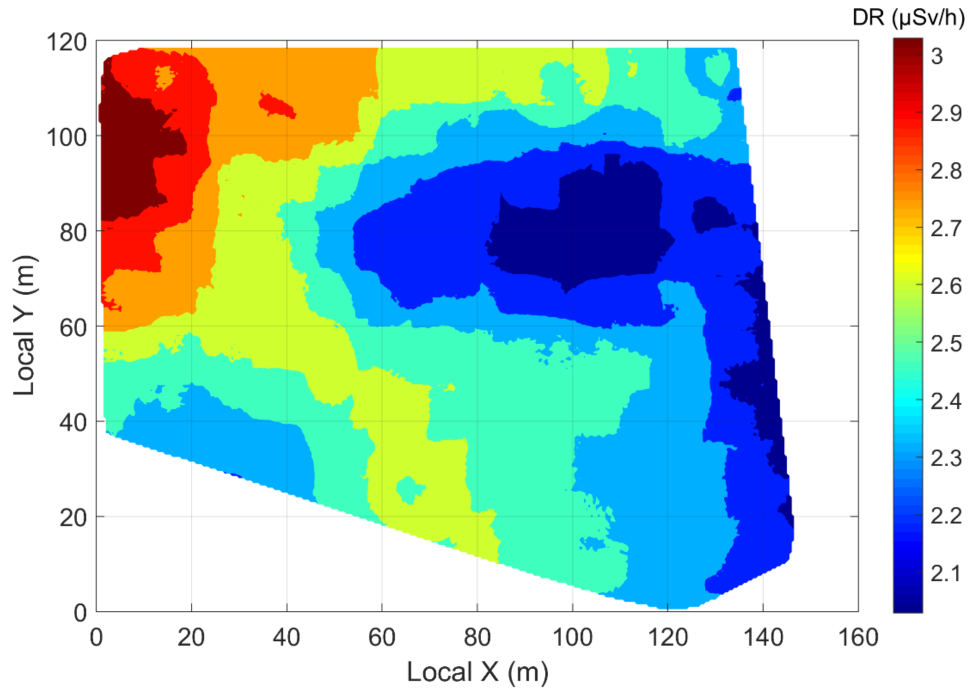


Interpolation

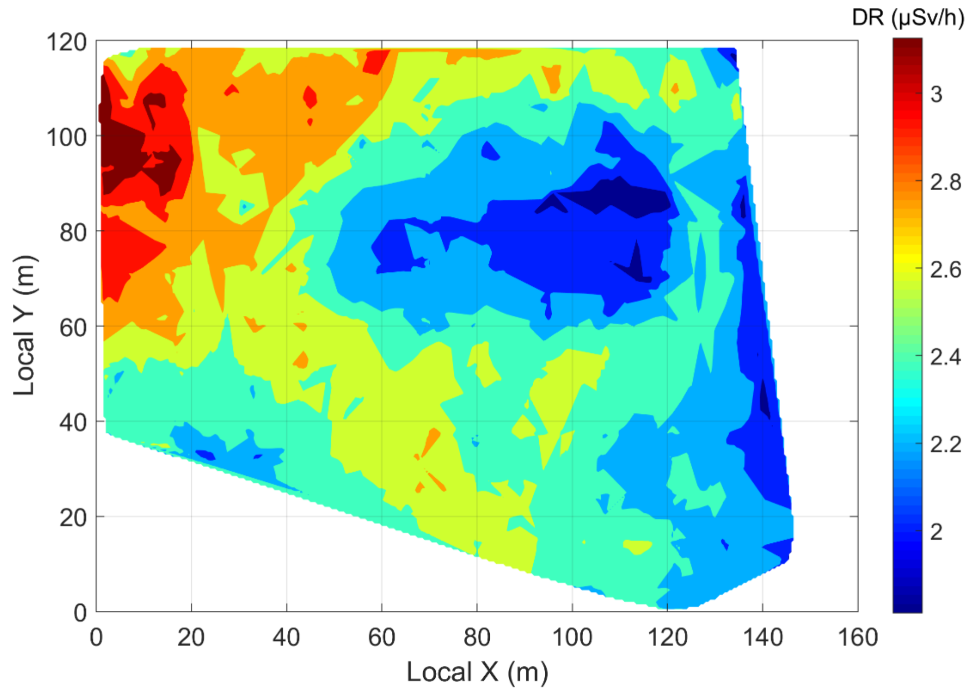
- Why do we interpolate scattered data?
  - Easier visual interpretation
  - Possibility to show isodoses
  - Useful for the hotspots separation
- Methods
  - Inverse distance weighting
  - Triangulation-based methods
  - Spline-based methods
  - Kriging
- Interpolation framework
  - Regular grid
  - Point cloud (photogrammetry)



Comparison of interpolation methods

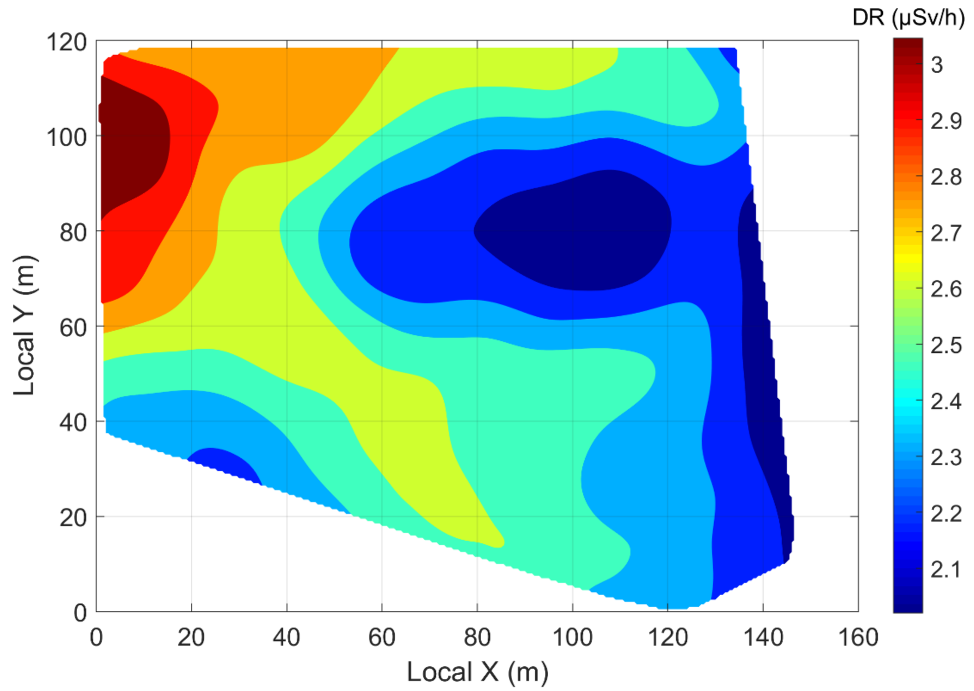


Inverse distance weighting

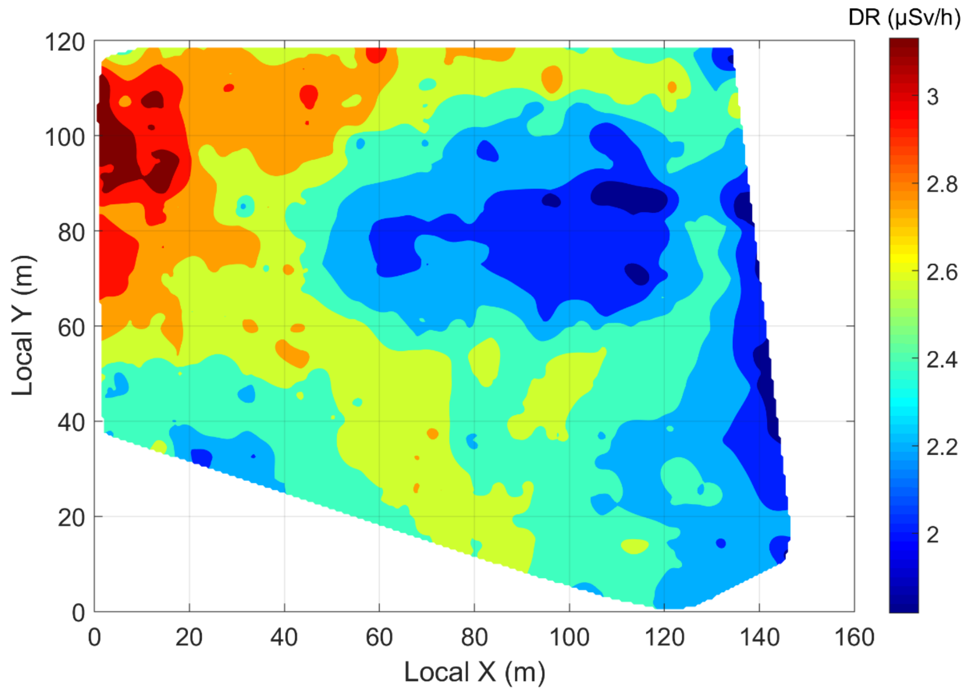


Linear interp. using Delaunay triangulation

Comparison of interpolation methods

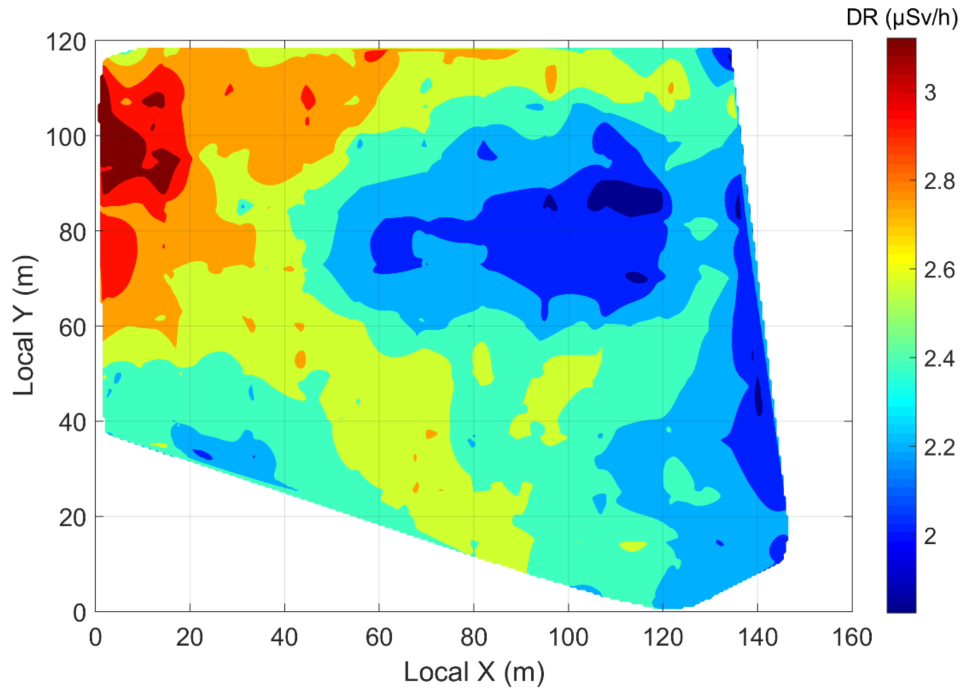


Thin-plate spline interp.

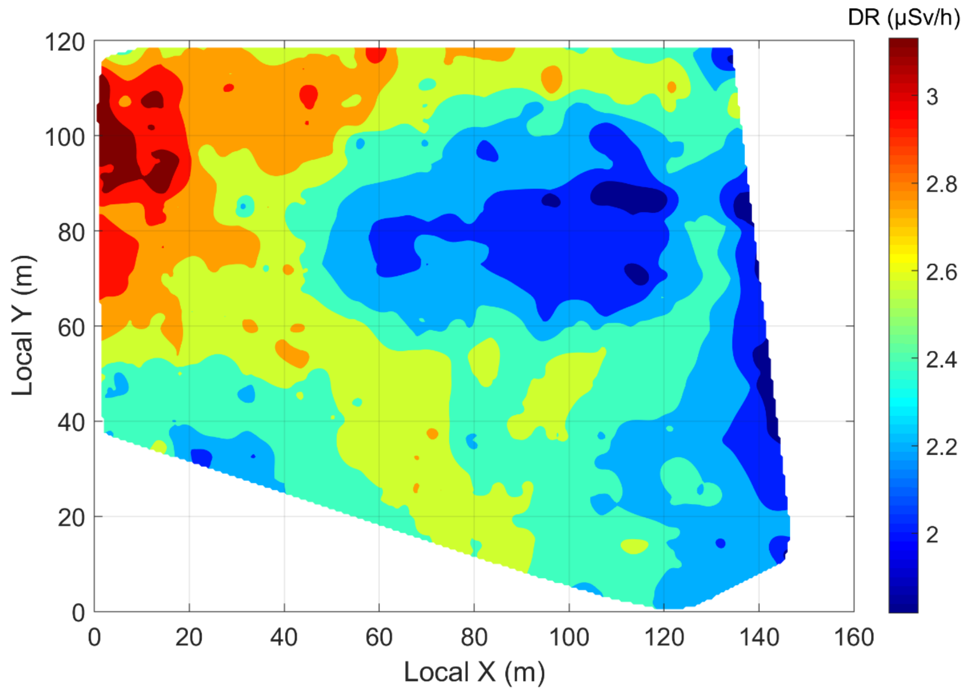


Kriging

Comparison of interpolation methods

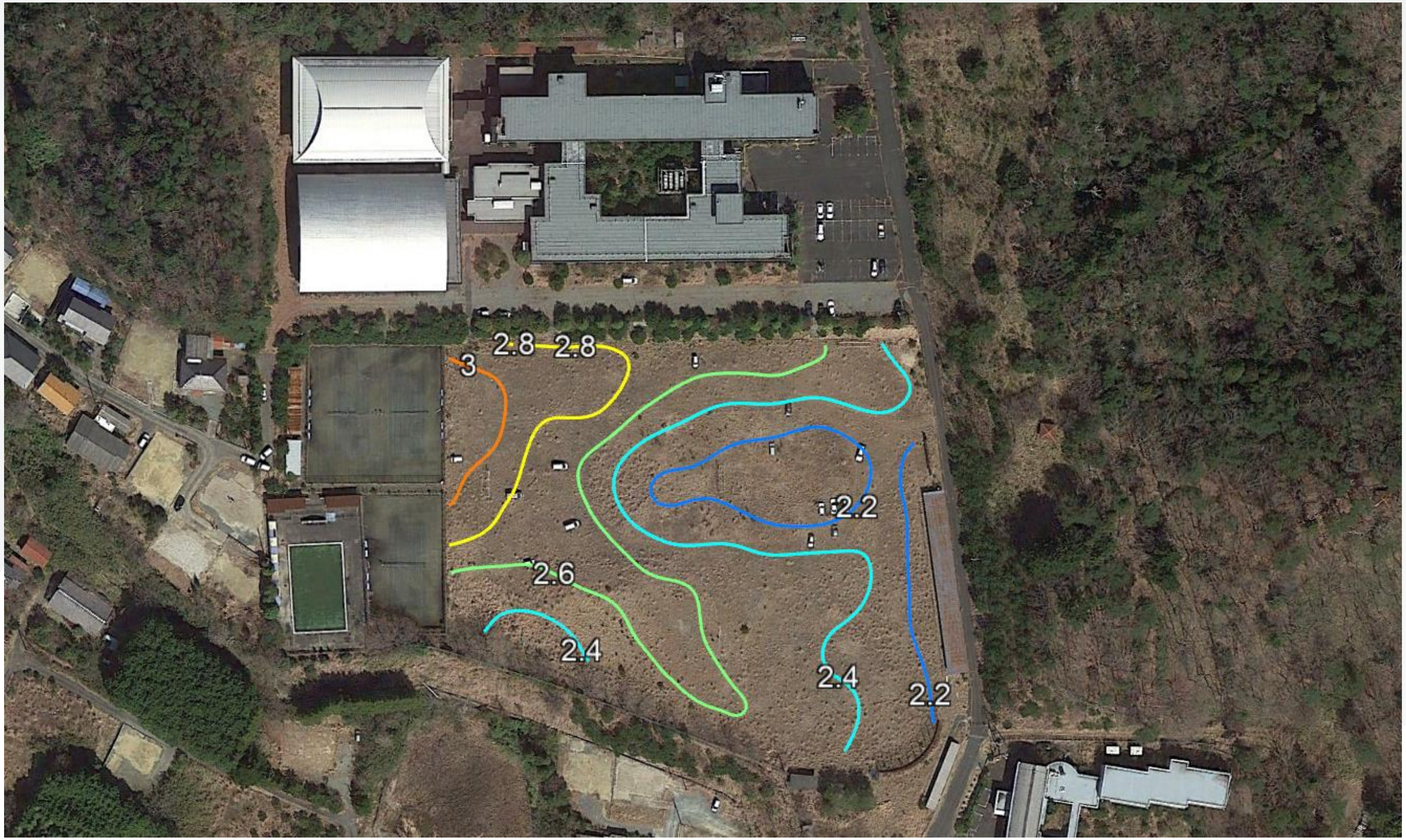


Natural neighbor interp. using Delaunay tr.



Kriging

Example of isodoses over orthophoto map

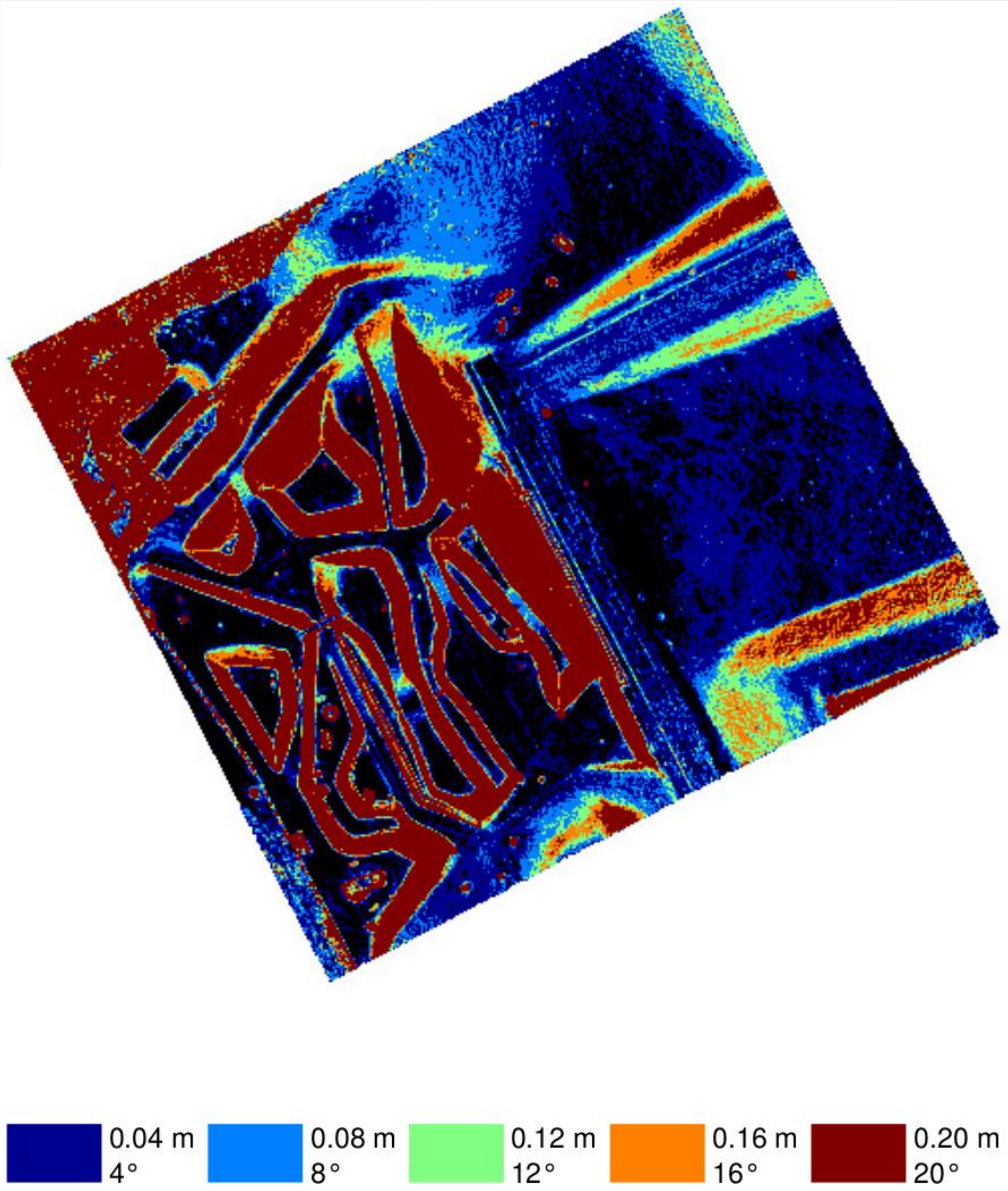


Utilization of a 3D model

- Data visualization
- Acquisition of the altitude without a laser altimeter
- Calculation of the dose rate in a certain height AGL (e.g., 1 m)
- Better situational awareness
- Projection & interpolation on a 3D profile

Obstacle map generation

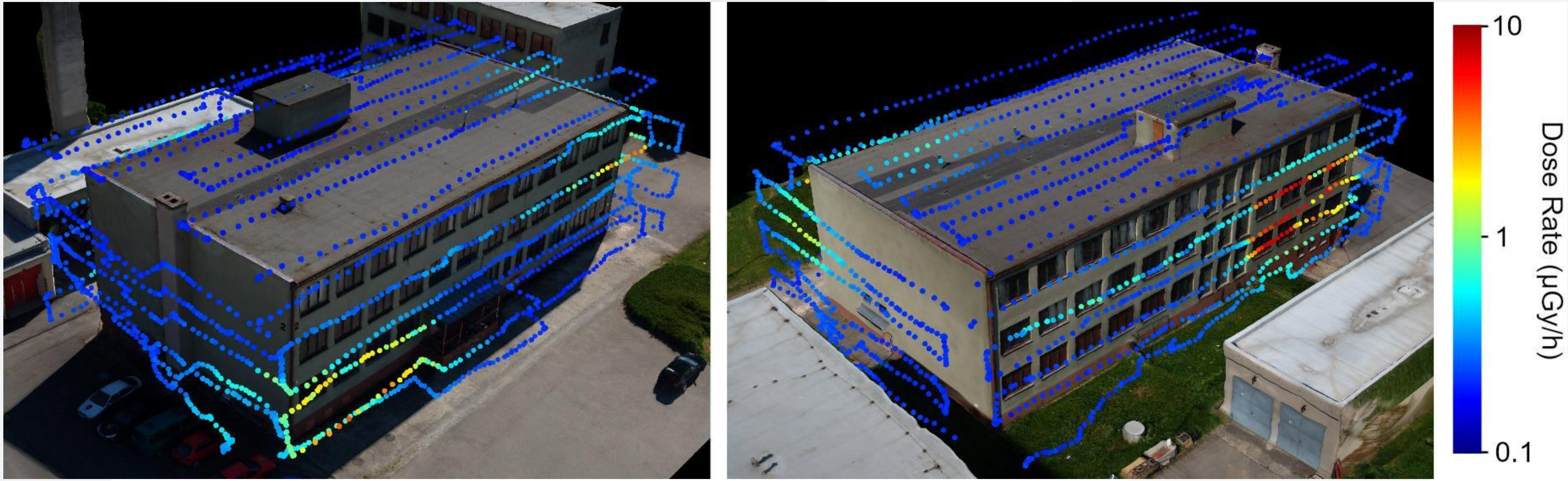
- Cooperation of a UAS and a UGV
- UAS provides:
  - Photogrammetry-based DEM → an obstacle map for the UGV
  - Boundaries of hotspots
- UGV provides:
  - Detailed measurements
  - Nuclide identification
- Obstacle map
  - Based on a terrain traversability
  - Maximal allowed slope/height difference
  - UGV type-dependent



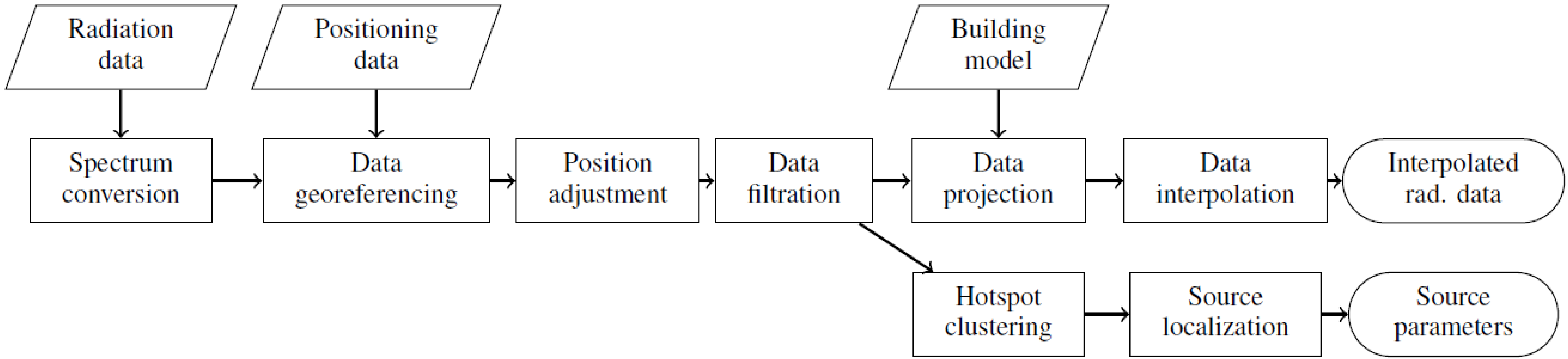
UAS-based radiological mapping of buildings

- Motivation: tracking illegal transportation and storage of radioactive nuclear material, searching for uncontrolled radioactive sources, securing detailed surveys of buildings and structures to detect possible contamination, monitoring nuclear facilities (e.g., nuclear repositories), etc.
- Two-phase survey
  - Acquisition of photogrammetry data
  - Acquisition of radiological data
- The 3D model is not required for the rad. data collection if the UAS is controlled manually
- The model is used to provide user friendly visualization for decision makers

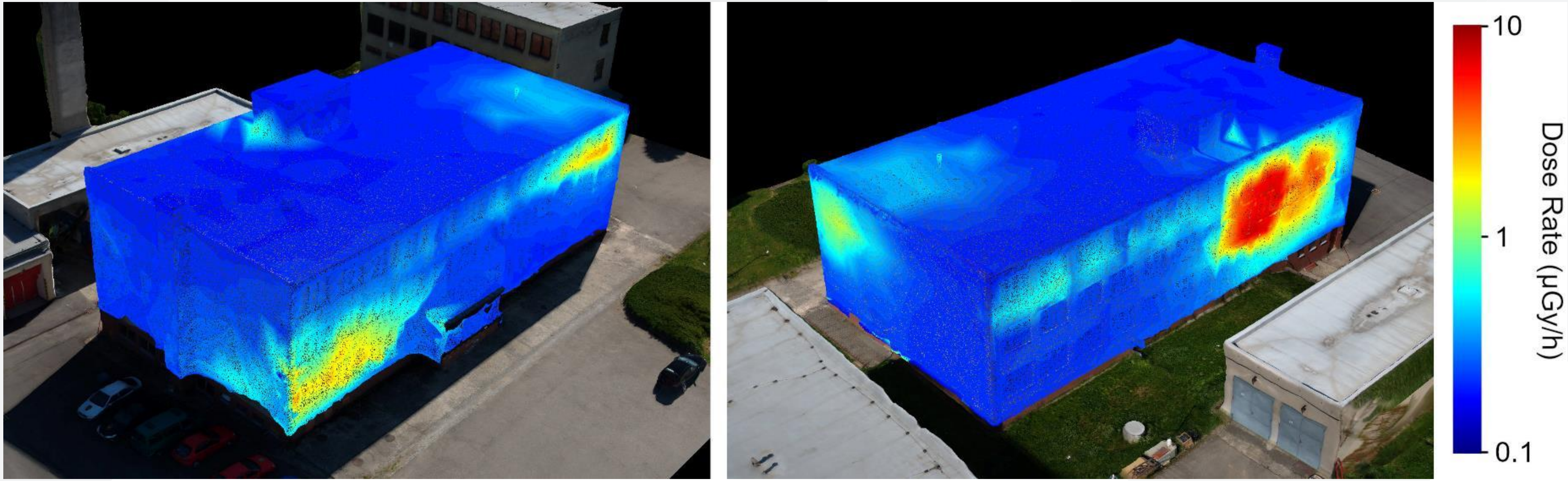
Mapping of buildings: Measured datapoints



Mapping of buildings: Processing pipeline



Mapping of buildings: Interpolation



Summary

- Photogrammetry-based models = contextual data
- Advantages:
  - Provides up-to-date data
  - Allows advanced path planning techniques (terrain following, obstacle maps, …)
  - Enables indirect altitude measurements
  - Useful framework for data interpolation in 3D
  - Off-the-shelf method
- Disadvantages:
  - It is not always available
  - Requires some time to process
  - Not suitable for all type of objects
  - Dependent on light conditions

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