Historical Aerial Image Orientation

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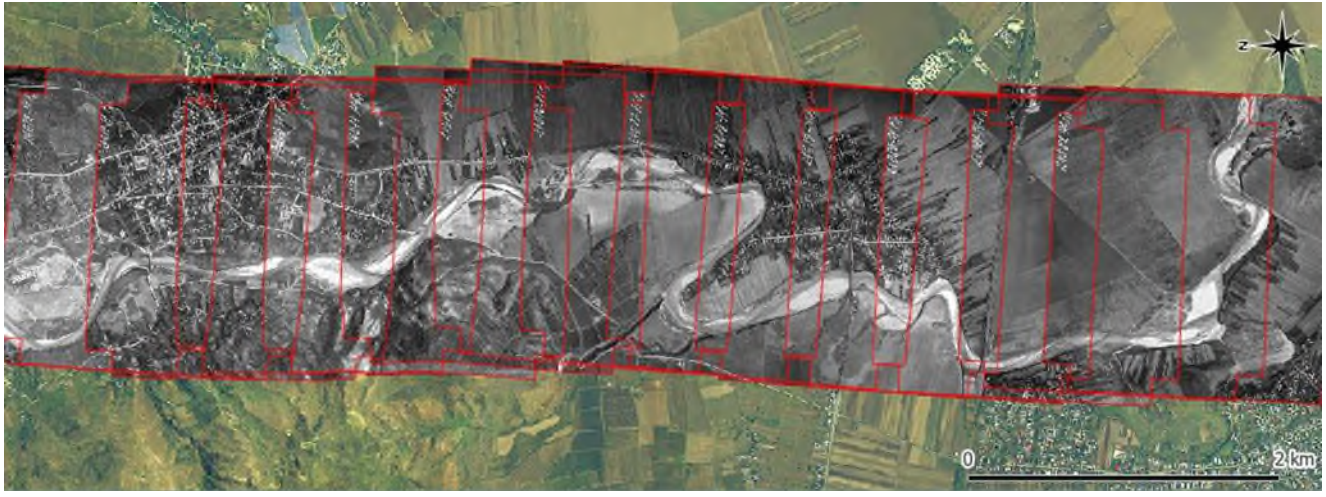
Why?

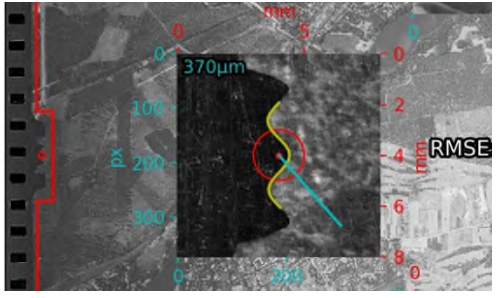
- Aerial imagery is **the** historical, wide-area data source:
- Dating back in time at least a few decades, unlike today‘s competing technologies.
- Not interpreted like maps, leaving interpretation to today‘s applications:
- Cadastral disputes, landscape dynamics, unexploded ordnance / bombs, …



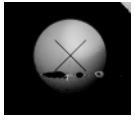
Ploiești, 1971

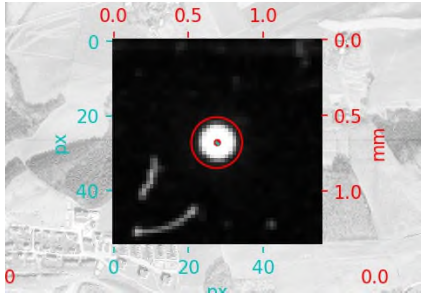
Challenges

- Labour intensive: (re-) organize image archives; scanning large volumes; manual search for reference data.
- Film degradation: scratches, dust, deformation, (taped) tears, hand labellings.
- Fiducial marks: various (bad) shapes, unlit.
- -> Detect image borders to search for fiducials. But that may fail, as well.
- Displays (image counter, clock, flying height, levelling) in various places inside image area.
- Calibration certificates:
  - Available? Interpretation may be unclear.
  - Missing? Use the average of measured fiducial marker positions, and estimate IOR.

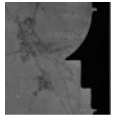


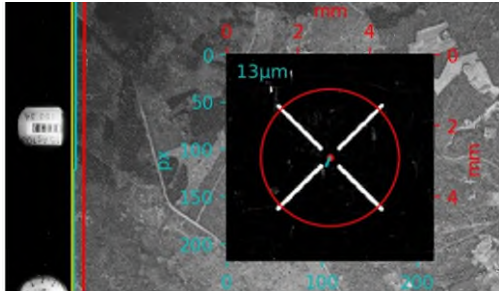
1953, Soviet?





1969, Zeiss RMK-A





1962, Wild RC8

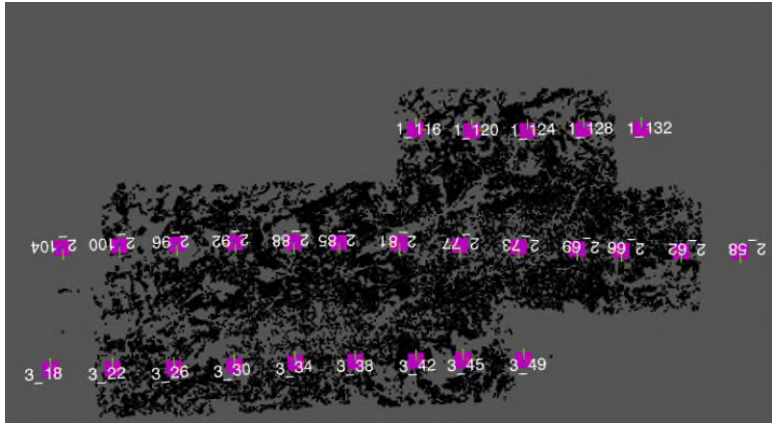
Country-Wide Historical Orthophoto Maps

- Archive with uncut film rolls + professional scanner + basic metadata make their production feasible.
- Each mapping agency typically used only a few different cameras during decades.
- Relative image orientation works well with classical image features **among** imagery from the same flight.
- A few manual ground control points may suffice to reach the wanted quality.
- Classical or true OP?
  - Historical DSMs typically unavailable, today's DSM is (locally) different.
  - Dense image matching suffers from limited image overlap.
- Study for the consortium of Germany's mapping agencies on various data sets:
  - Manual GCPs used.
- Next slide: 1969, Wuppertal, Western Germany.

Historical True Orthophoto Map: 1969, Wuppertal, W. Germany

Residual norms	Median		Max	
Fiducials [µm/px]	9	0,4	13	0,6
Tie image points [µm/px]	11	0,5	131	6,2
Control image points [µm/px]	40	1,9	109	5,2
Control object points [cm]	26		46	

Autom. Reconstr.
Ω →



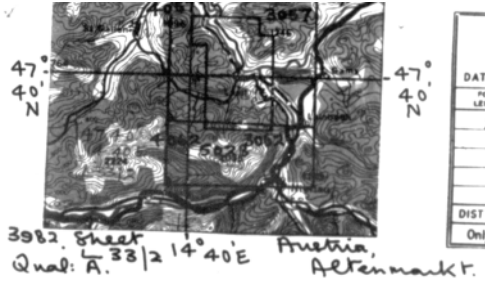
← True OP

DSM →

© nFrames

WWII Aerial Reconnaissance

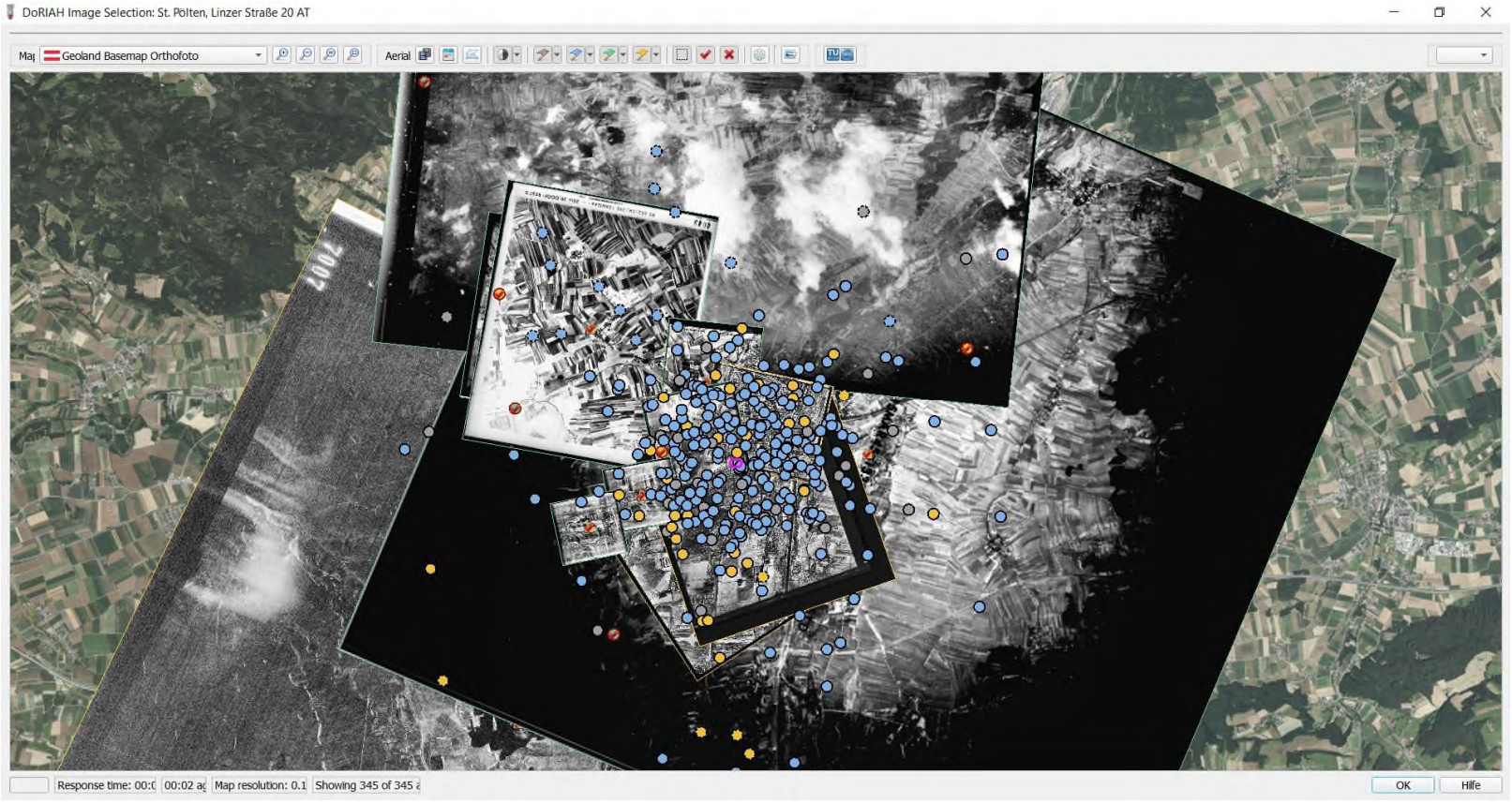
- Task: **risk assessment** of unexploded ordnance (UXO) / bombs before construction works.
- Starting with the most cost-effective method: aerial photogrammetry (then on-site magnetometry; digging).
- Data from (image) archives of the allies (USA, UK, ~~USSR~~):
  - Records of bomb attacks: dates, target areas, bomb counts, weights, and fuse types.
  - Aerial images, their coarse mappings, and plans of flights undertaken in between attacks.
- Flights were driven by war:
  - Various times of day/year: long shadows, cloud and snow cover.
  - Images of specific objects of interest, with arbitrary overlap (often none).
  - Wide range of image scales, many different cameras.
- To distinguish impact fuses (to be de-fused) from delay fuses (to be detonated on-site), UXO need to be associated with a certain attack (date): newly visible in a **time-series** of images.
- Images hardly resolve UXOs. UXOs may quickly be buried under vegetation or snow. Overlapping images of the same flight help to distinguish UXO from non-UXO.
- Hundreds of images from different flights may cover the project area, but images are **expensive**!
- → Minimal **sub-selection** of images to be purchased, based on cheap, low-resolution previews.



Implicit Geo-Referencing during Image Selection

- Images need to be:
  - inspected by hand to check image quality;
  - coarsely oriented in 2D, to ensure coverage and overlap.
- First step: keep this process manual, but record the enhanced image orientations for re-use.
- Dedicated software needed. Must not feel like a measurement tool, to not slow down the process.
- Provide various web maps as background reference that can be zoomed and shifted (orthophotos: current and historic, topographic maps, cadastre, etc.).
- Aerial images come with a very coarse scale and planar position (post-flight mapping). Overlay the map with one or more of them accordingly.
- To orient an image:
  - set an image transparent to look through onto the background map, or another image below;
  - shift, rotate, and scale images to check spatial coverage and overlap.
- Rotation and scaling take place at the mouse cursor position. Thus, an image may be shifted to coincide with the map in one area first, and then rotated and scaled to coincide in a second area.
- This similarity transform is recorded, to be re-used for fine orientation after image delivery.

QGIS Image Selection PlugIn



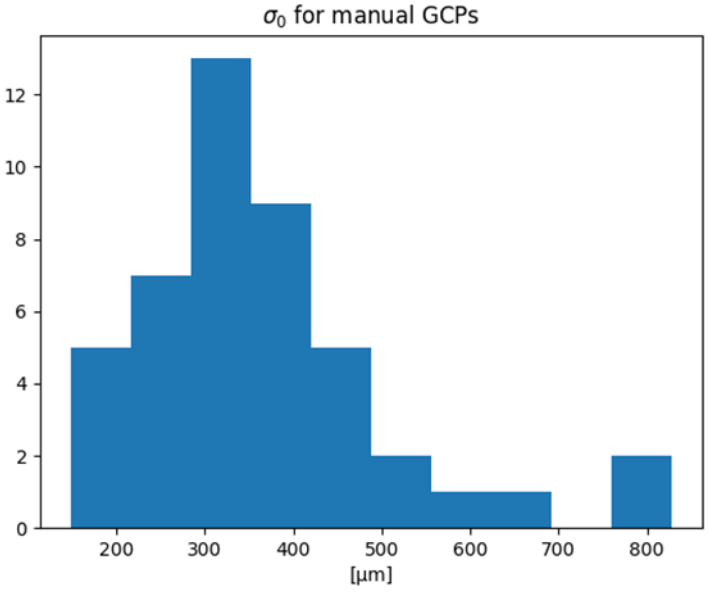
https://github.com/TUW-GEO/selorecon

Automatic Geo-Referencing

- Auto-geo-referencing further reduces the work-load. But is challenging:
  - Image quality: long shadows, clouds, snow cover.
  - Hardly any overlapping images from the same flight -> single-image geo-referencing.
  - Images taken decades before the reference (OP) map: newly built-up settlements, agricultural field borders moved, roads, railways, rivers straightened, …
  - -> Geometry is stable only in selected areas.
  - -> Appearance is completely different, and classical image point features fail.
- -> Use deep learning to extract homologous points in the aerial image and the reference OP. Interpolate the heights of OP points in a DSM.
- Because kappa is unknown a priori, features must be rotation-invariant. For ease of training, they should work end-to-end (detection and matching).
- Eliminate outlier matches with a robust similarity transform with large threshold to cope with terrain undulation, off-nadir images, etc..

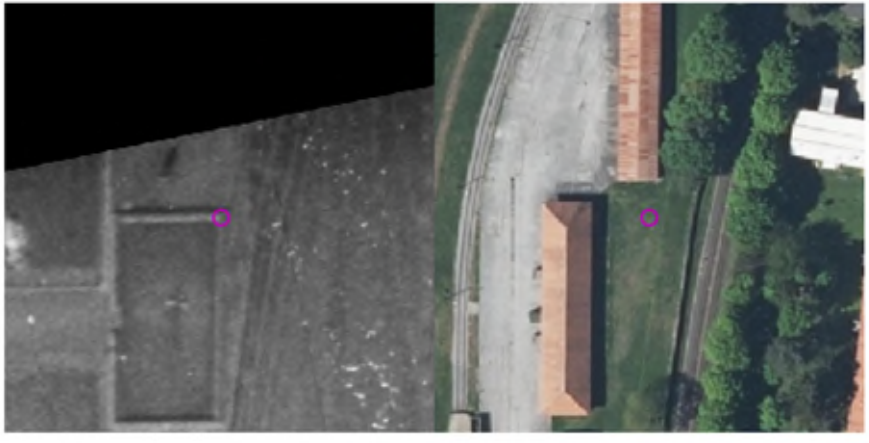
Auto-Georef.: Example Data Set

- 45 aerial images taken with Fairchild K-17:
  - 9" x 9" image area
  - 24" focal length
  - Geometrical scan resolution: 22µm
  - Image scales: 1:7500 to 1:14250
  - Snow cover, clouds, etc.
  - Scans „enhanced“:
    aligned and cut to image contents,
    fiducials partly cut off.

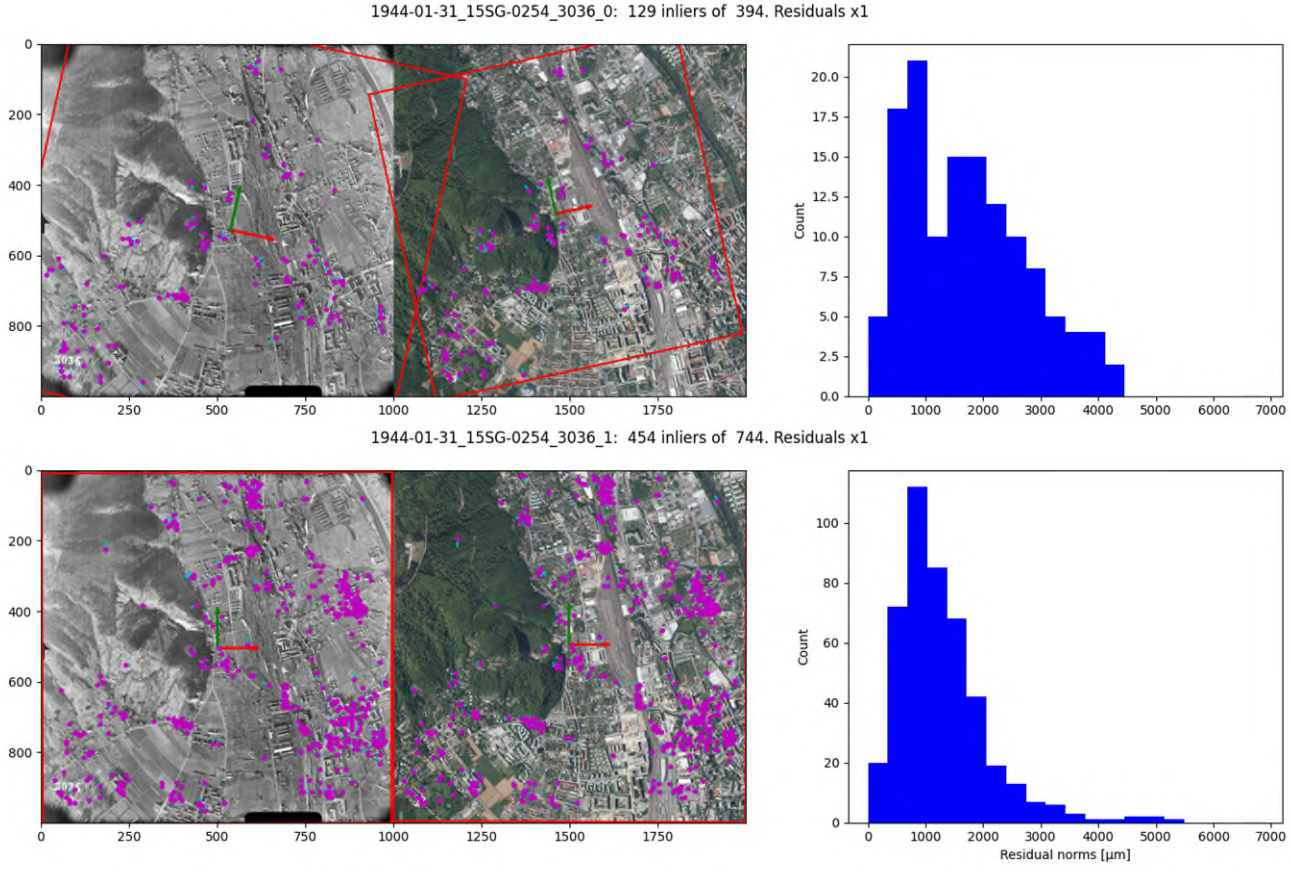


- Manually measured GCPs available for evaluation:
  - 2D in image and object space, 10 to >50 GCPs per image.
  - Used for **2D-rubber sheeting** i.e. unfiltered 2D spline transform, uncontrolled!
  - Use perspective model instead: nominal IOR, GCP heights interpolated in DTM.
  - Sigma naught as benchmark: 200 to 800 µm.

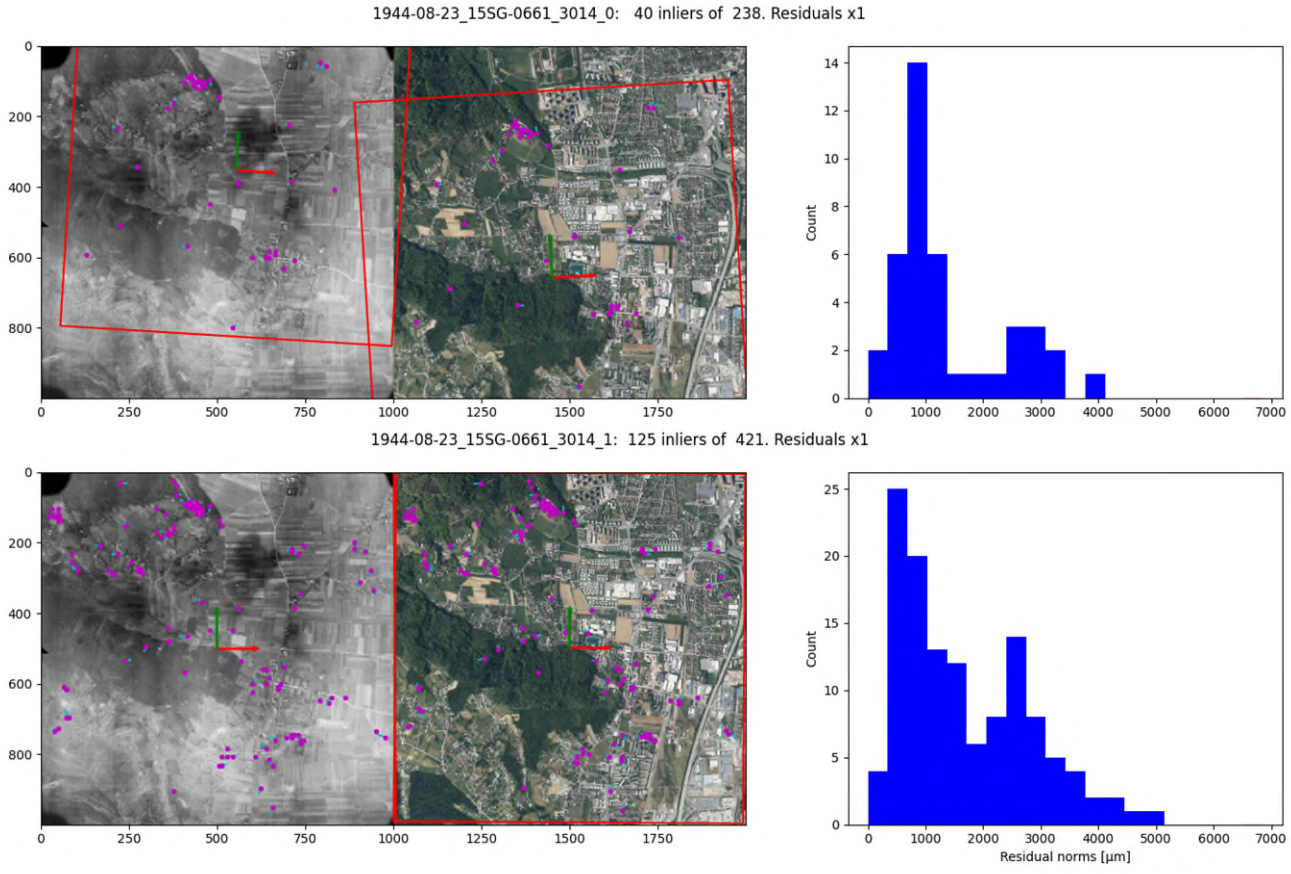
Manual GCP locations



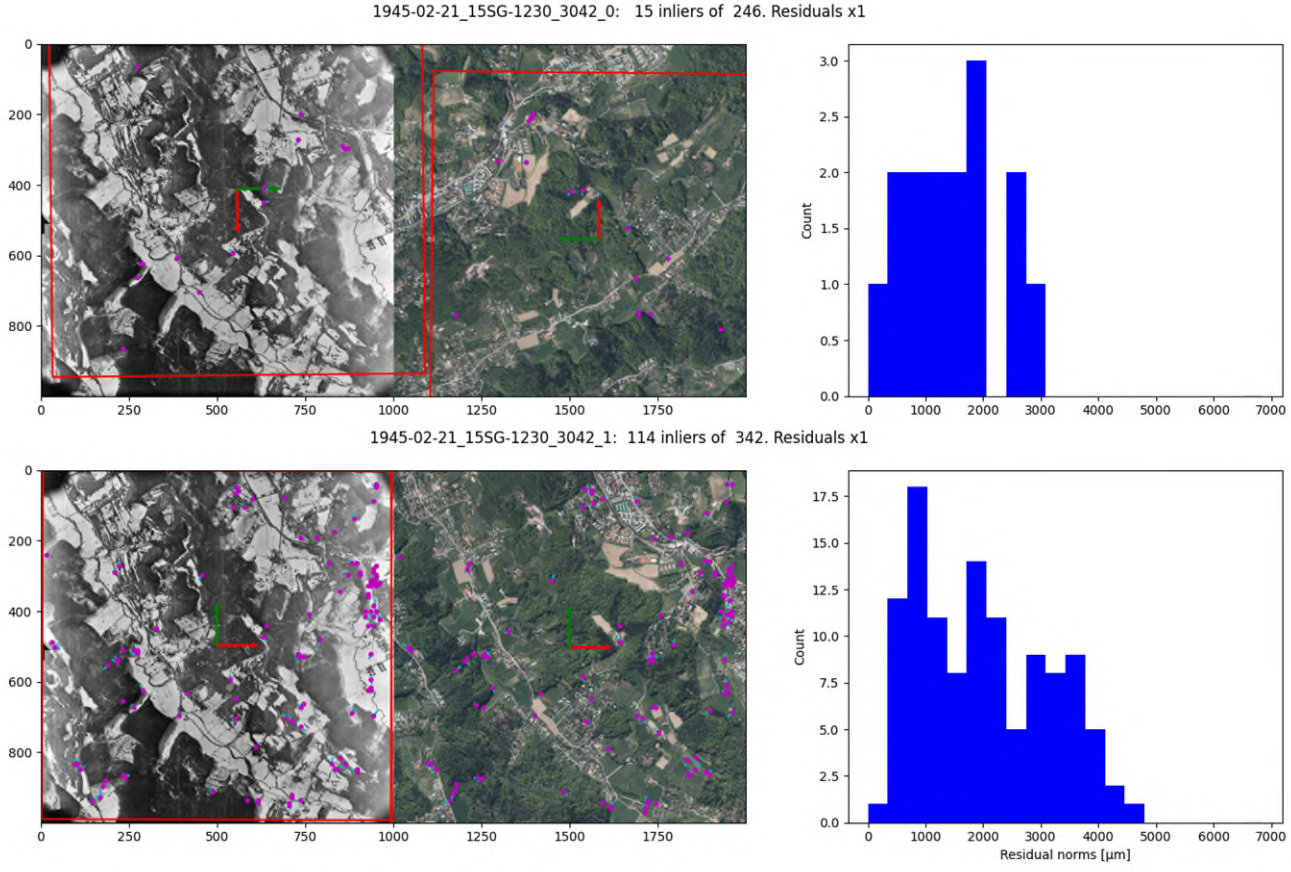
Deep Features May Work Well



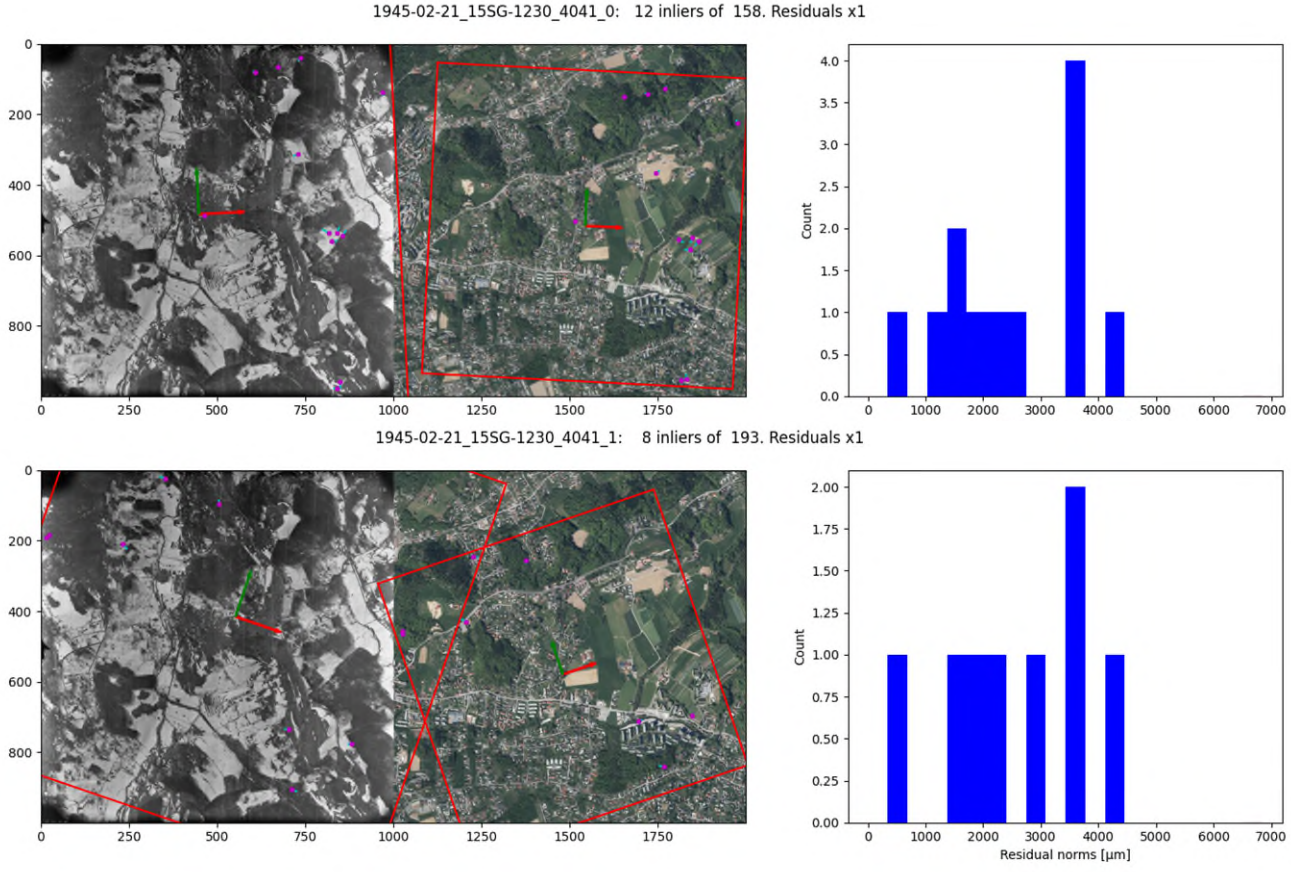
Deep Features May Work Well through Fog



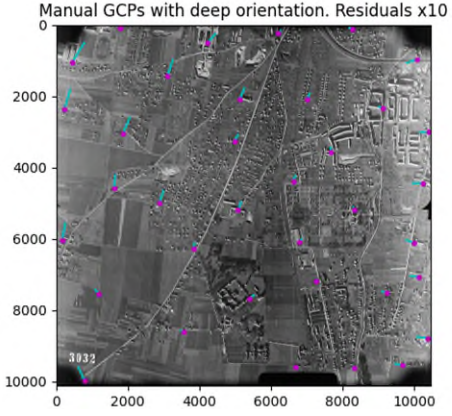
Deep Features May Work Well on Snow

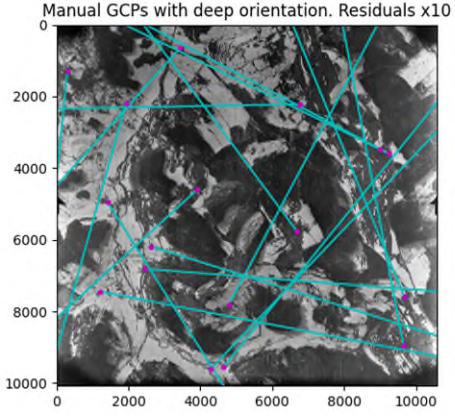


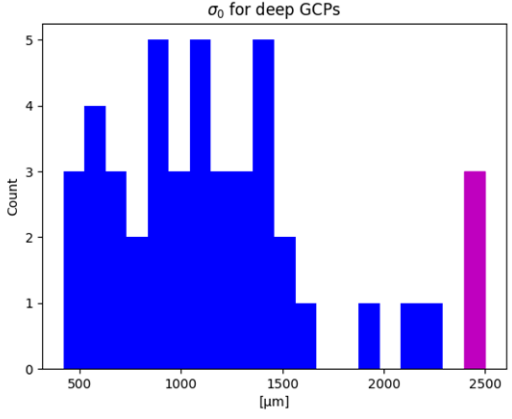
Deep Features May Work Well – or not



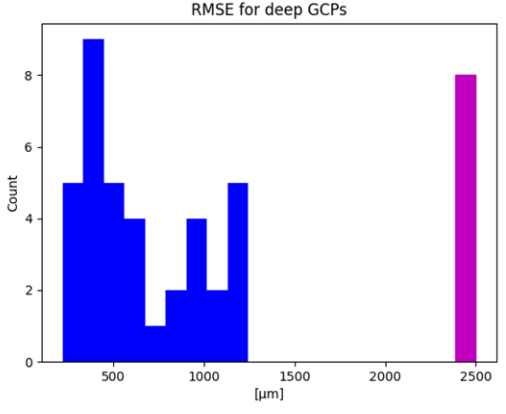
Evaluate Deep Orientations at Manual GCPs





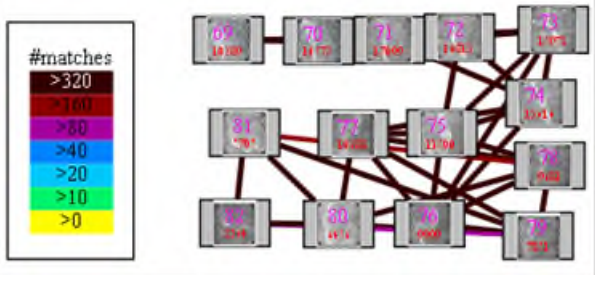


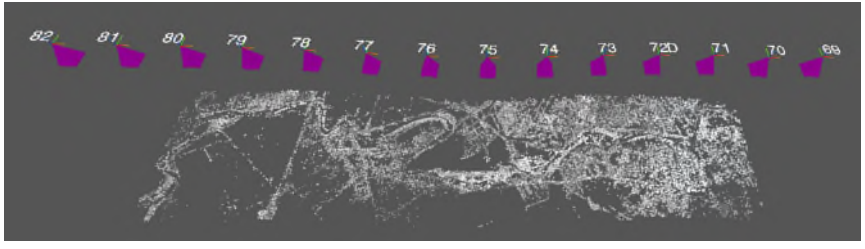
Results for 45 images



Landscape Dynamics: Albești-Paleologu, Prahova

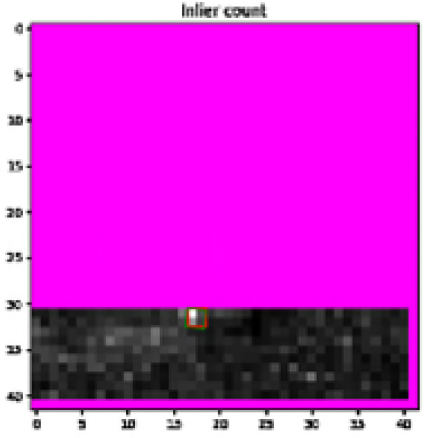
- 1971 imagery of Centrul Naţional de Cartografie, mapping the Cricovul Sărat river:
  - Single flight strip of 14 images, f=210mm, 1:10000, Wild RC8.
  - On 18 by 18cm² glass plates for analysis in analogue stereo plotters.
  - Scanned at 600dpi using a conventional flatbed scanner.
- Affine fiducial transformation needed despite only 4 marks.
- Use classical image features for tie points among images.

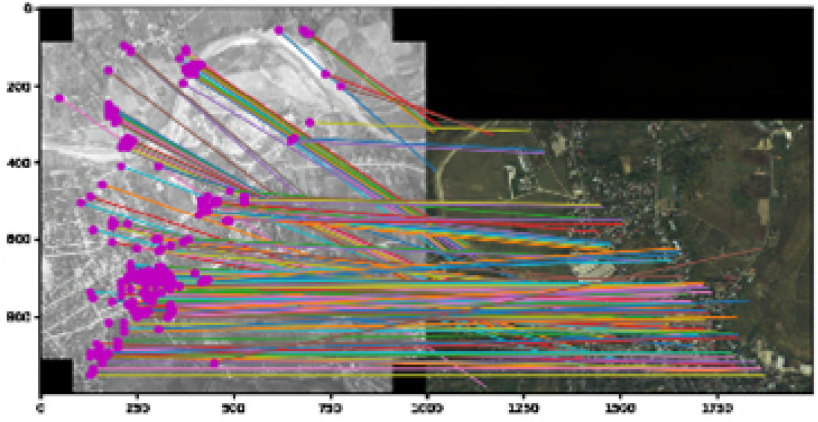




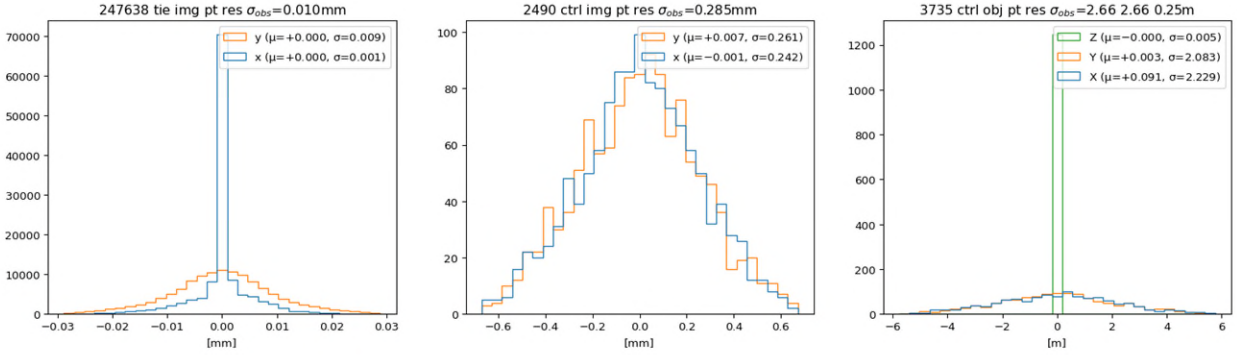
Albești-Paleologu, Prahova: Autom. Geo-Referencing

- For geo-referencing, only the municipality name and image scale were known a priori.
- Current-day, wide-area OP and DTM available.
- But deep matcher requires image pairs of same resolution (and scale).
- Brute-force search: work in OP tiles, and use the one with best results.





Mulțumesc!



wk @ CNC