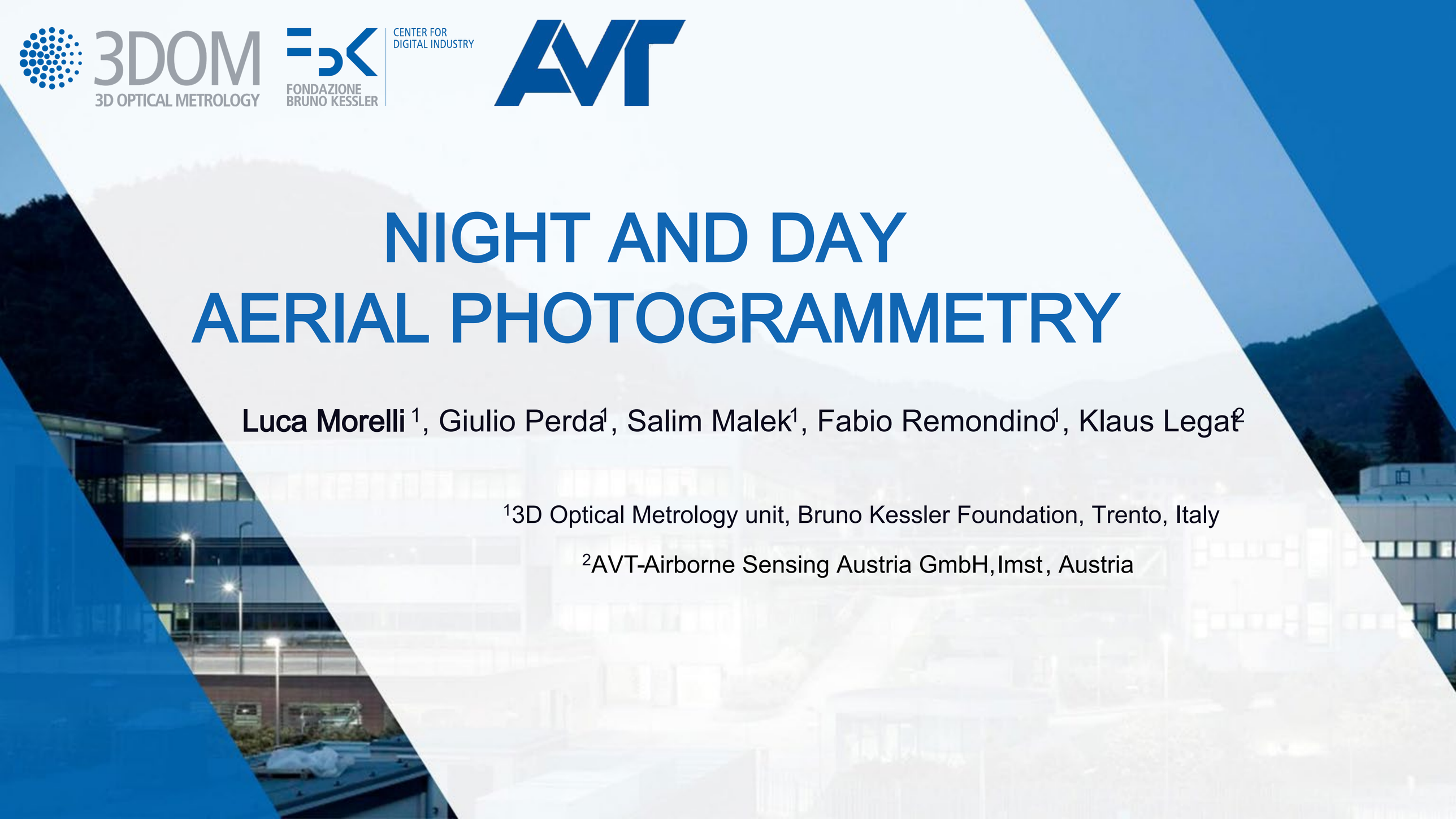


NIGHT AND DAY AERIAL PHOTOGRAMMETRY

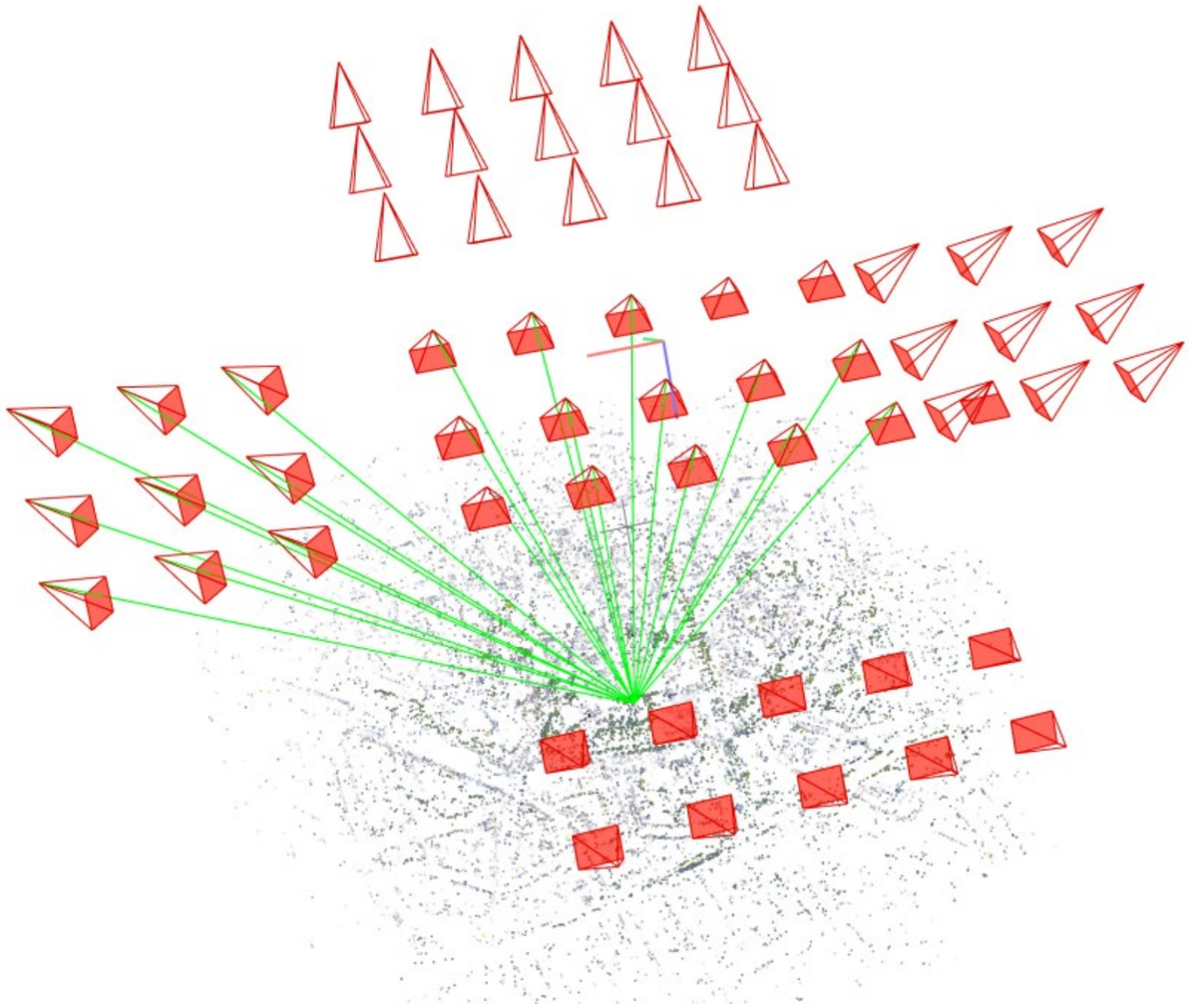
Luca Morelli [1], Giulio Perda[1], Salim Malek[1], Fabio Remondino[1], Klaus Legat[2]

[1]3D Optical Metrology unit, Bruno Kessler Foundation, Trento, Italy

[2]AVT-Airborne Sensing Austria GmbH, Imst, Austria

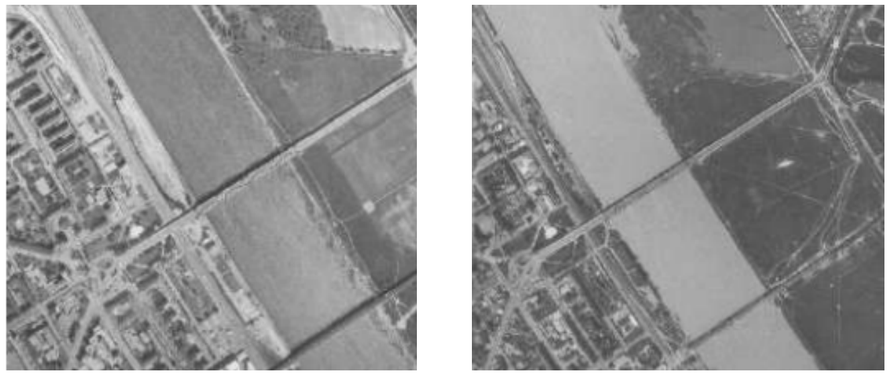
Image matching in photogrammetry

- Find **homologues points between images** is the initial step for many photogrammetric applications
- Tie points can be automatically extracted with traditional approaches (**hand-crafted**), e.g. SIFT
- Despite some invariance to rotation, illumination, perspective changes, and scale, traditional approaches fail in **challenging scenarios**



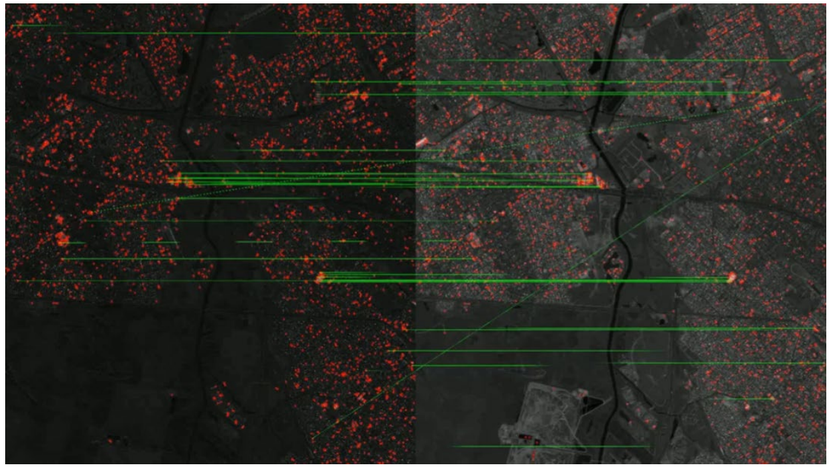
Example of SIFT matching in challenging scenarios

Multi-temporal datasets



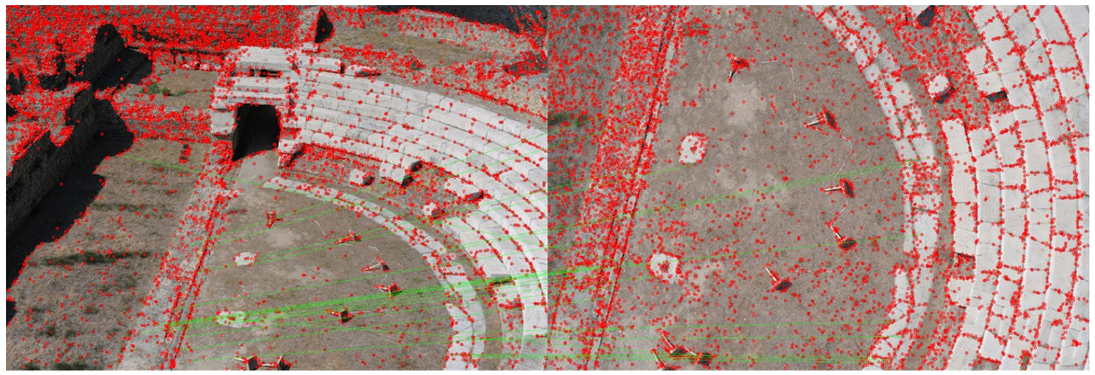
Farella, E.M., Morelli, L., Remondino, F., Mills, J.P., Haala, N. and Crompvoets, J., 2022. The EuroSDR TIME benchmark for historical aerial images. *International archives of the photogrammetry, remote sensing and spatial information sciences*, *43*, pp.1175-1182.

Different illumination



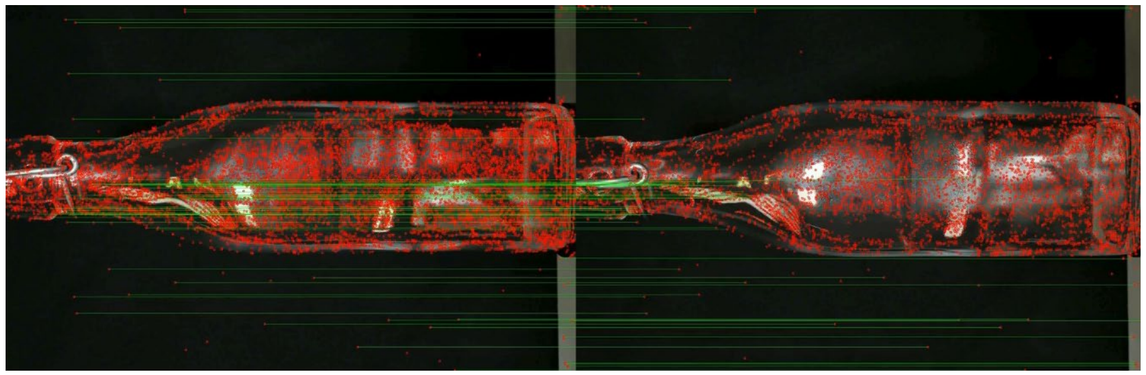
Song, S., Morelli, L., Wu, X., Qin, R., Albanwan, H. and Remondino, F., 2024. Evaluating Learning-based Tie Point Matching for Geometric Processing of Off-Track Satellite Stereo. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *48*, pp.393-400.

Different viewing angles



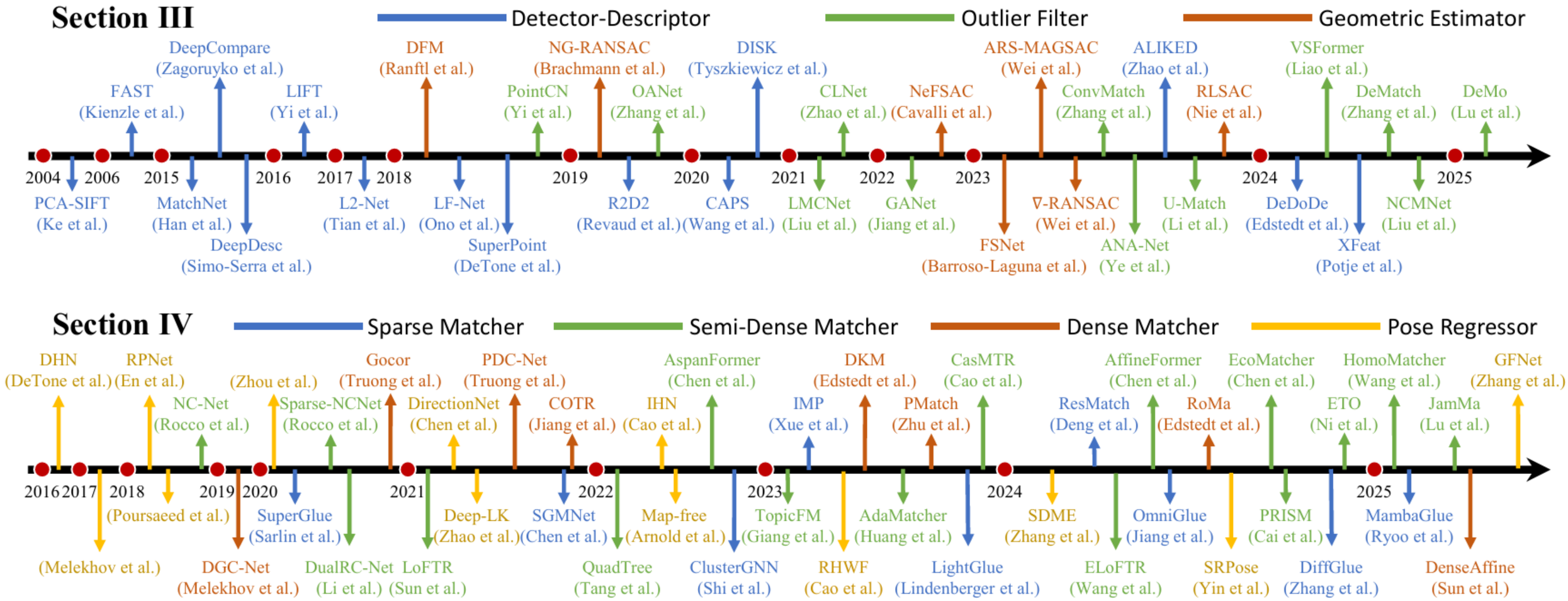
Bellavia, F., Morelli, L., Menna, F. and Remondino, F., 2022. Image orientation with a hybrid pipeline robust to rotations and wide-baselines. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *46*, pp.73-80.

Poor texture



Morelli, L., Karami, A., Menna, F. and Remondino, F., 2022. Orientation of images with low contrast textures and transparent objects. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *48*, pp.77-84.

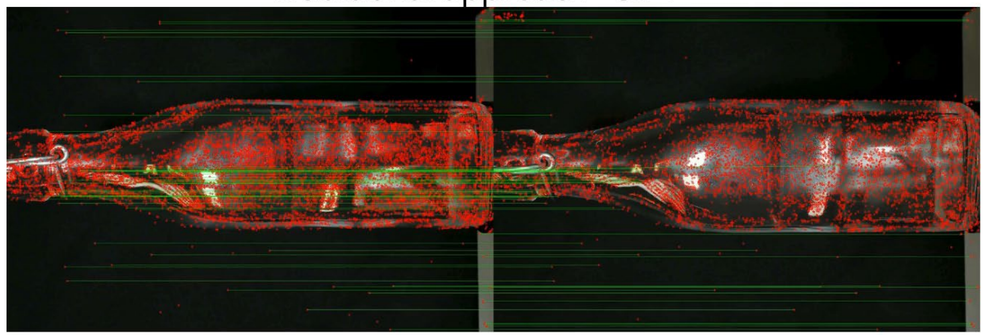
Deep learning local features



Zhang, S., Li, Z., Zhang, K., Lu, Y., Deng, Y., Tang, L., Jiang, X. and Ma, J., 2025.
Deep Learning Reforms Image Matching: A Survey and Outlook. *arXiv preprint arXiv:2506.04619*.

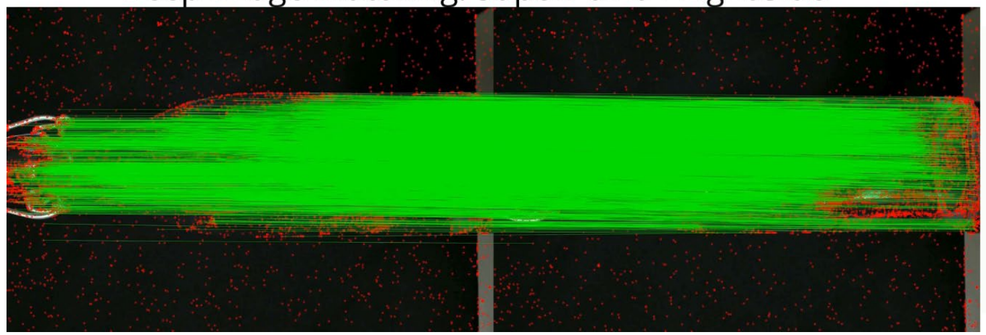
DL local features -> open to new applications

Traditional approach - SIFT



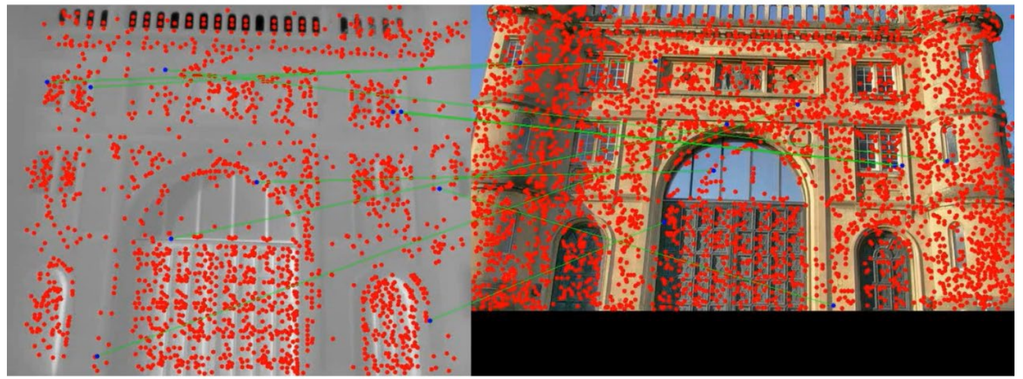
Not oriented

Deep-image-matching: SuperPoint + LightGlue

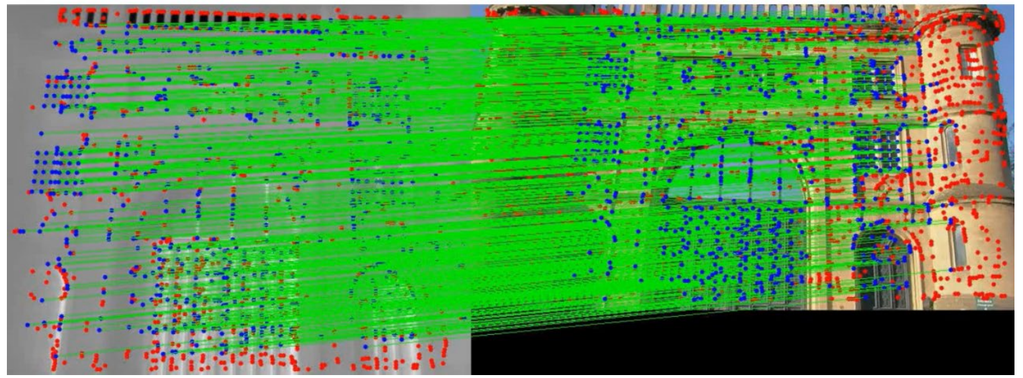


Morelli, L., Karami, A., Menna, F. and Remondino, F., 2022. Orientation of images with low contrast textures and transparent objects. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *48*, pp.77-84.

Traditional approach - SIFT



Deep-image-matching: SuperPoint + LightGlue



Morelli, L., Sutherland, N., Ioli, F., Vitti, A., Marsh, S., Mills, J., Bryan, P. and Remondino, F. Deep Learning Multi-Modal Image Matching for the Automatic Co-registration of Infrared and Visible Images. Under review.

Motivation and objective

Motivation

Nighttime imagery is increasingly used in diverse applications, such as:

- Earthquake damage assessment
- Urban functional zone classification

Accurate analysis requires co-registration with corresponding daytime imagery




Objective

Leverage deep learning-based features to achieve accurate automatic co-registration of day-night image blocks without GCPs

Data description

Two datasets over the city of **Graz, Austria** are employed:

- **Daytime RGB imagery** - 50 images acquired using the *Vexcel UltraCam Dragon 4.1* system
- **Nighttime RGB imagery** - 191 images captured with an *IGI DigiCAM* camera

For both datasets, **sensor position and orientation parameters** —derived from their respective onboard navigation systems —are available and used as **initial approximations in the aerial triangulation process** .

Preliminary study

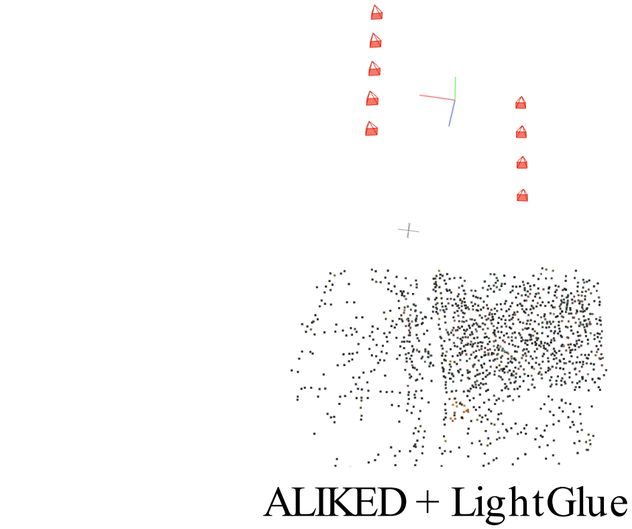
3DOM-FBK / deep-image-matching

Experimental Setup

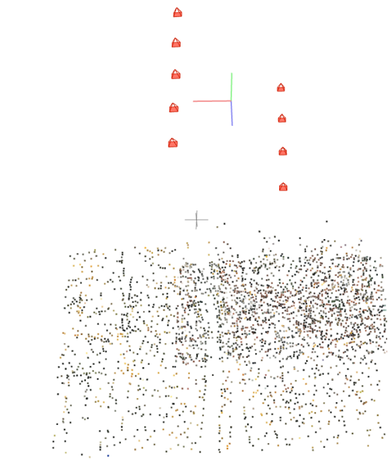
- Subset: **9 day/night images**
- Tools: **DIM library with tiling** to handle high-res images
- **DL features tested**: ALIKED + LightGlue, DISK + LightGlue, DeDoDe, SuperPoint + (SuperGlue / LightGlue), Key.Net + HardNet, LoFTR, RoMa

Key Findings

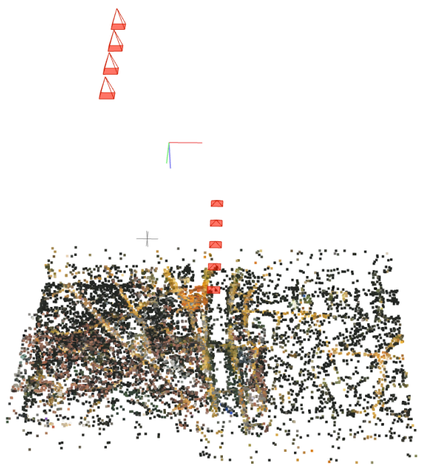
- **No method** succeeded at full resolution
- **Downsampling** was necessary to obtain reliable matches
- **Only few DL methods** produced valid tie points (ALIKED, SuperPoint + SuperGlue, RoMa)
- High **outlier ratio** persisted even among successful methods



ALIKED + LightGlue

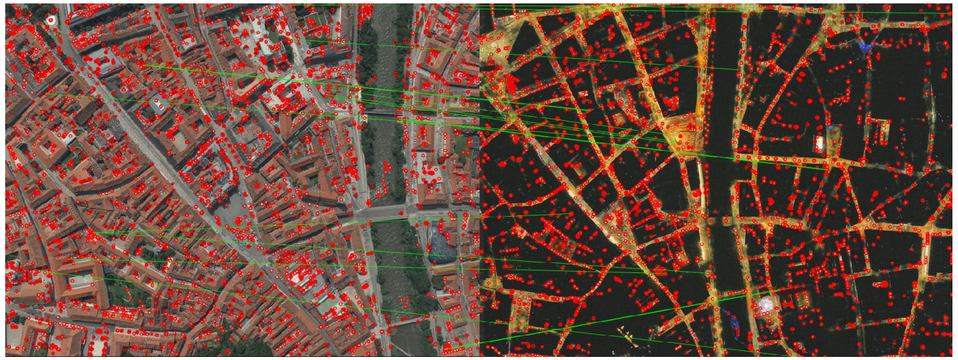


SuperPoint + SuperGlue

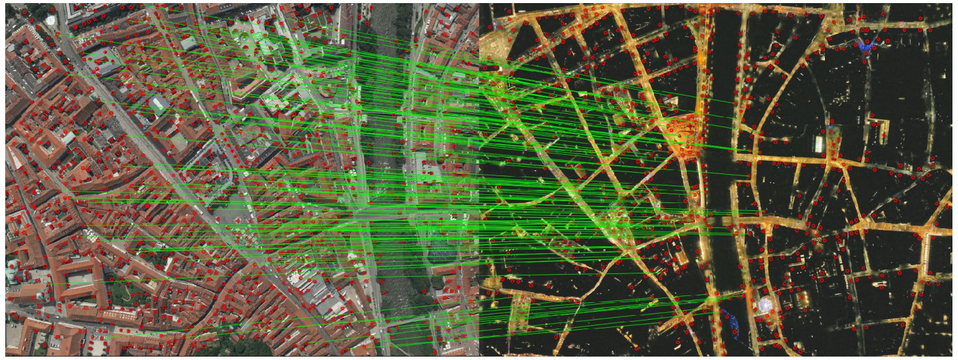


RoMa

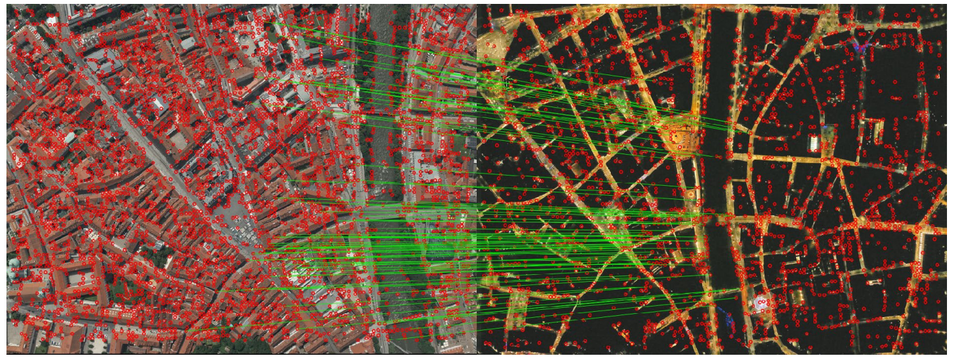
Preliminary study



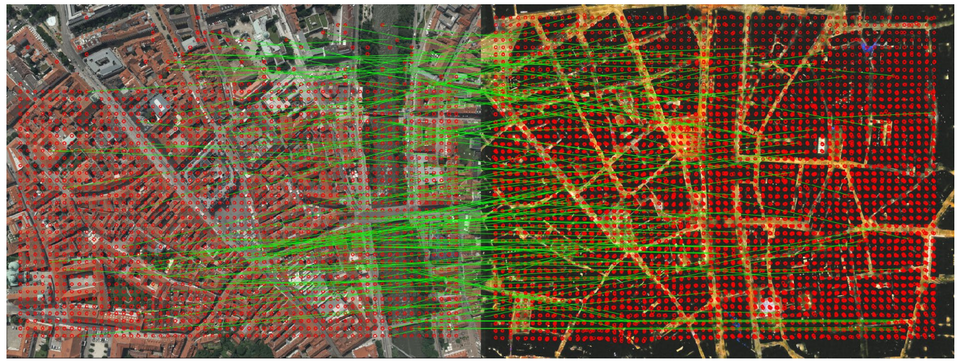
DeDoDe - 18 verified matches



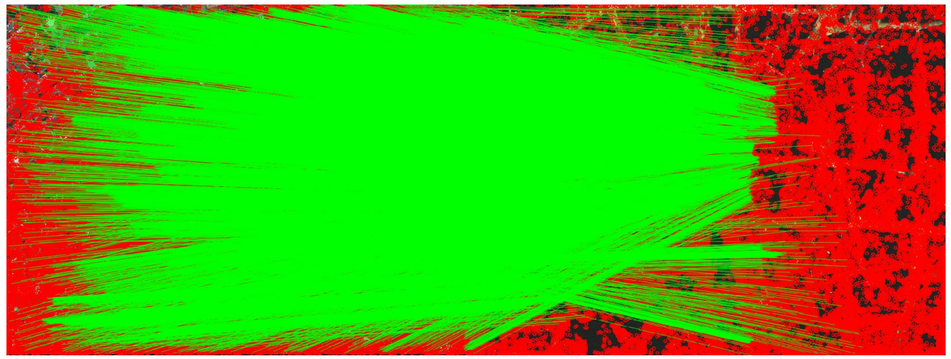
ALIKED + LightGlue - 149 verified matches



SuperPoint + SuperGlue - 80 verified matches



LoFTR - 124 verified matches



RoMa - 8625 verified matches

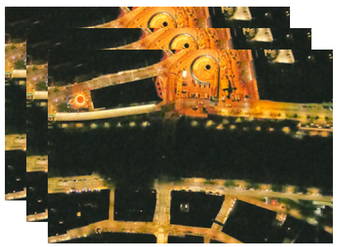
Preliminary study

Selected Method ✅
ALIKED + LightGlue

- Best balance of **accuracy** and **computational time**
- Successfully oriented the full image block
- Faster than SuperPoint + SuperGlue
- **RoMa** also worked but was too computationally expensive

Local features and matcher	Computation time [s]
SuperPoint + SuperGlue	33.96
SuperPoint + LightGlue	9.44
Disk + LightGlue	9.85
Aliked + LightGlue	8.18
DeDoDe+ LightGlue	35.30
KeyNet + HardNet8	10.44
LoFTR	16.32
RoMa	488.92

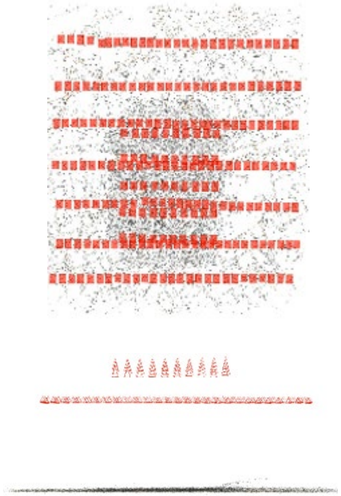
Methodology: workflow 1 - baseline



DIM python library

ALIKED + LightGlue bruteforce matching

Day-Night Image block orientation



Pycolmap

Pycolmap Optimization with pose constraints

Georeferenced sparse model

No GCPs required

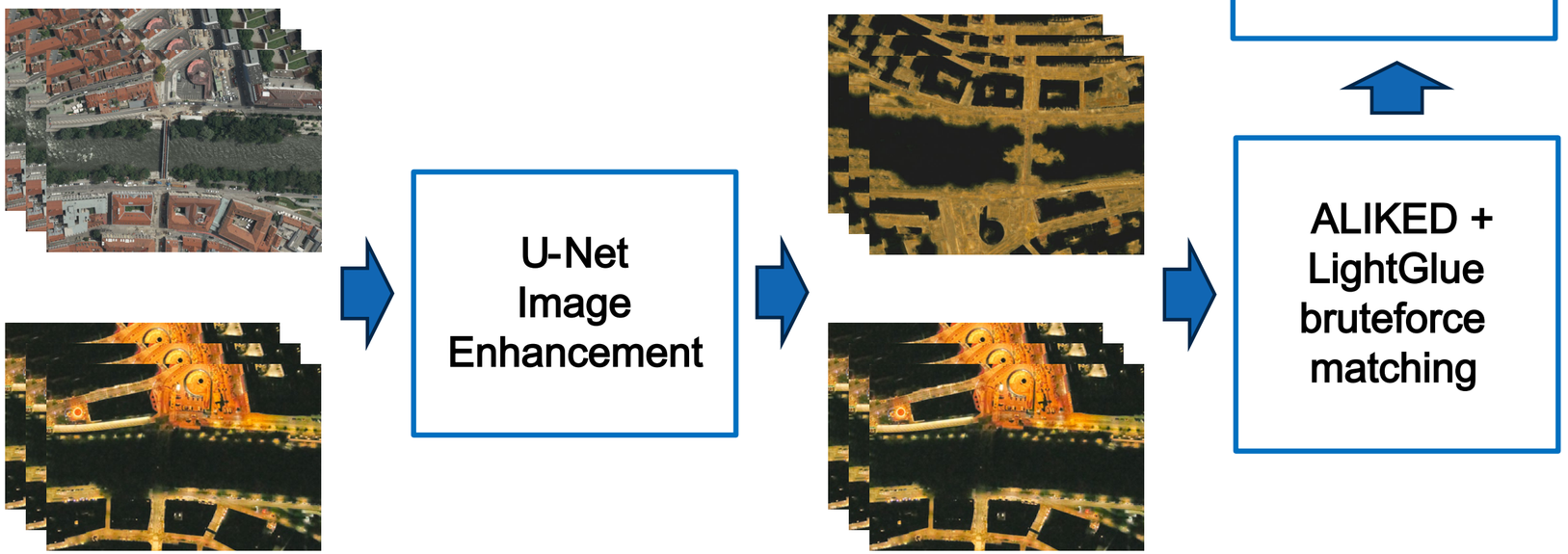
Agisoft Metashape

Two separate dense reconstructions for day and night blocks

C2C distance

Cloud Compare

Methodology: workflow 2 – U-Net enhancement

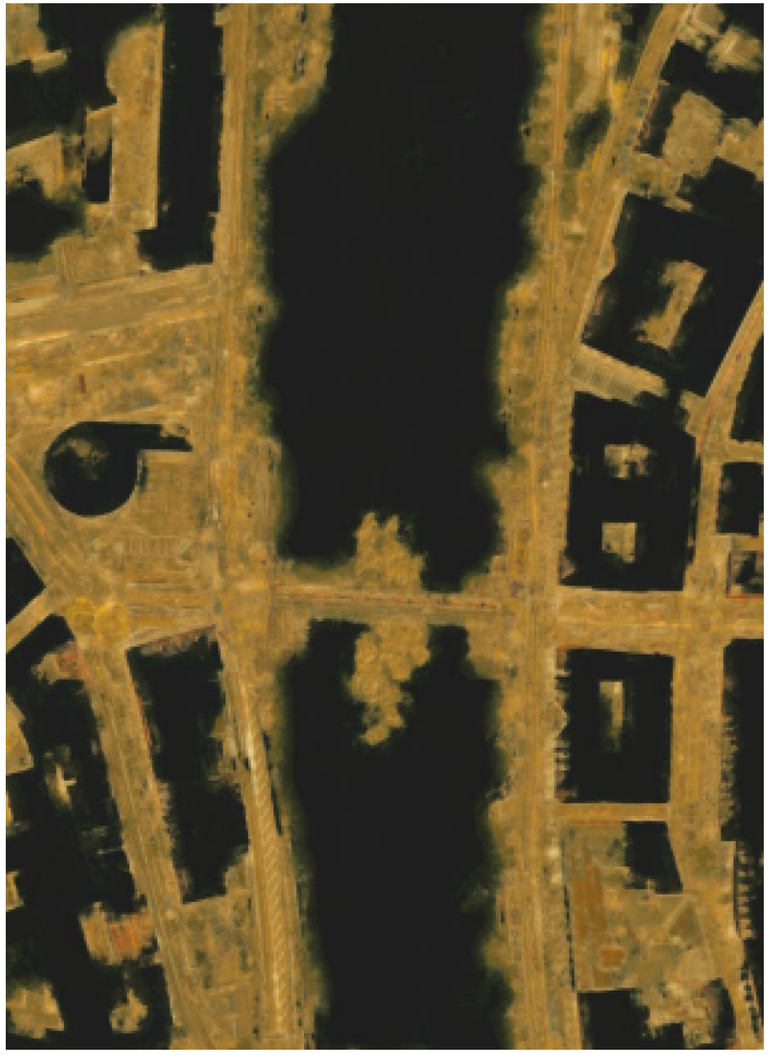


Optional augmentation process:

- U-Net network trained on day and night **orthophots**, predicts **night-like versions of daytime images**
- Applyed **before keypoint extraction** with ALIKED
- Aims to increase **robust tie point detection** across modalities

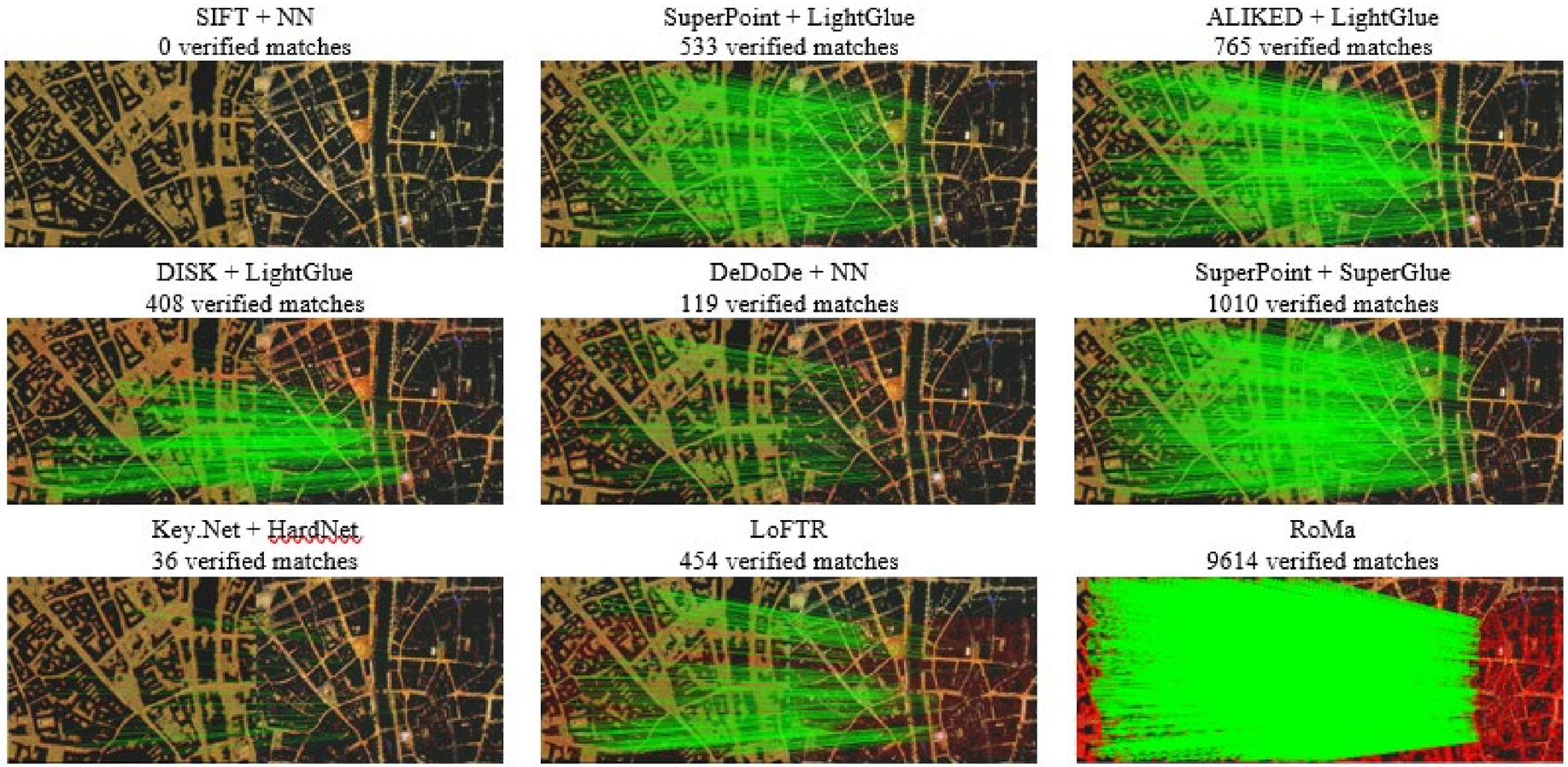
Example patches for training

Example of image enhancement with U-Net



Results: 2D tie points

- Many DL features were not able to extract tie points before augmentations
- All tested DL features significantly increase the number of matched features after augmentation and manage to orient the day-night image block

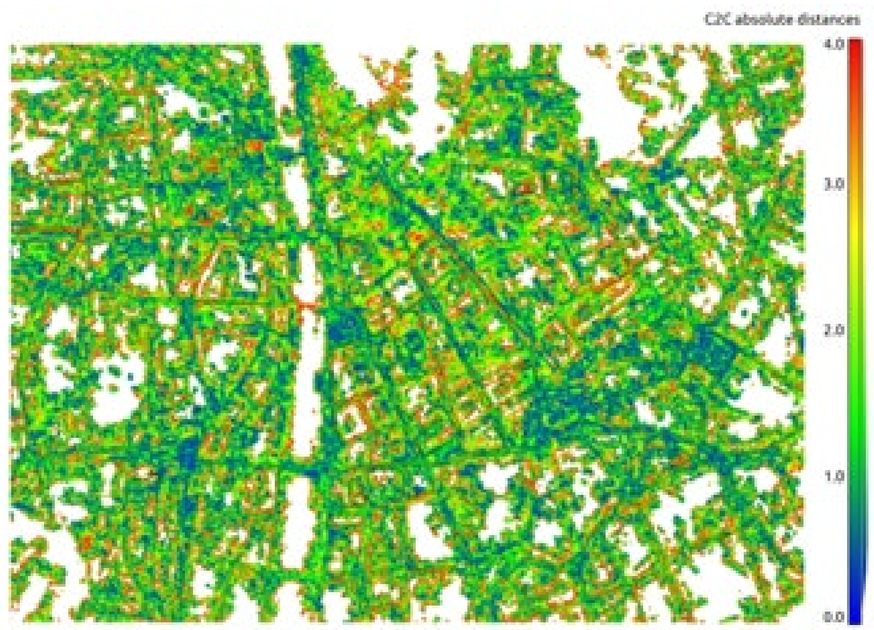


Results

- Automatic co-registration of day-night image blocks is possible with off-the-shelf pre-trained DL features
- U-Net image enhancement improves:
  - Camera pose accuracy (↓avg. C2C distance by 8 cm)
  - Tie point quantity & quality (↑inliers, ↓outliers)

C2C error	
Original images	1.80 m
U-net enhancement	1.72 m

Without U-Net enhancement



With U-Net enhancement

Conclusions

Key findings:

- Day-night matching is feasible with some off-the-shelf pretrained DL features, but a significant downsampling is needed
- Only **limited subset** of deep learning extractors proved effective without retraining or image enhancement
- **ALIKED + LightGlue**Best trade-off: matches vs. processing speed

Innovation & Impact:

- **U-Net pre-processing** enables radiometric normalization
- All 8 tested DL-features worked effectively **with U-net enhancement**
- Improvement in **co-registration accuracy**
- No GCPs needed

NIGHT AND DAY AERIAL PHOTOGRAMMETRY

Luca Morelli

lmorelli@fbk.eu

thank you!

https://3dom.fbk.eu/