

# Data Science Internship Test

## Task 2. Computer Vision — Sentinel-2 Image Matching

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### 1. Introduction

To develop a reproducible algorithm for matching Sentinel-2 satellite images captured in different seasons. The goal is to identify common keypoints between images of the same area taken under varying lighting, texture, and seasonal conditions, and to compare the performance of classical and deep-learning approaches to feature matching.

### Key Insights

The classical ORB + RANSAC approach showed poor performance under seasonal variations — the number of consistent matches did not exceed 2%. In contrast, the LoFTR model demonstrated stable results even for winter–summer pairs (0.98–0.99 inlier ratio) and was more robust to color and texture changes. Its runtime of up to 2 seconds per image pair (1024×1024 px) makes it suitable for practical applications. The interactive structure of the notebook allows users to test any image pair without modifying the code.

### 2. Dataset

The analysis was conducted using four Sentinel-2 images (Tile T36UYA) representing the same area in different seasons:

- 2016-02-12 — Winter scene
- 2019-03-13 — Spring scene
- 2019-06-01 — Summer scene
- 2019-09-09 — Autumn scene

The data were obtained from the open dataset Deforestation in Ukraine from Sentinel-2 data on Kaggle:  
<https://www.kaggle.com/datasets/isaienkov/deforestation-in-ukraine>

Folder with .jp2 files (Google Drive):

[https://drive.google.com/drive/folders/1j7u9IsiKA4RF5gTftOiknp\\_pBX2NpiMk?usp=sharing](https://drive.google.com/drive/folders/1j7u9IsiKA4RF5gTftOiknp_pBX2NpiMk?usp=sharing)

To run the notebook, users should download .jp2 files from this dataset and place them in /content/drive/MyDrive/Sentinel (for Google Colab) or ./data/Sentinel (for local execution).

### 3. Methodology

The entire solution is implemented in a single interactive notebook — Sentinel.ipynb — which includes:

- Reading .jp2 files from a local directory or Google Drive
- A classical ORB + RANSAC pipeline for keypoint detection and geometric filtering
- A deep-learning LoFTR (Kornia) model for robust feature correspondence
- Computation of performance metrics (number of matches, inlier ratio, runtime, reprojection error)
- An interactive loop for selecting image pairs and re-running analysis without restarting the notebook

#### 4. Comparison Results

Image Pair	ORB: Inliers (%)	LoFTR: Inliers (%)	ORB Time (s)	LoFTR Time (s)
2016-02-12 – 2019-03-13	1.49	0.98	0.94	2.33
2019-03-13 – 2019-06-01	1.00	0.99	0.60	0.79
2019-06-01 – 2019-09-09	1.18	0.99	0.46	0.86
2016-02-12 – 2019-09-09	2.06	0.98	0.45	0.83

#### 5. Conclusions

1. The ORB + RANSAC algorithm performs adequately only for similar-season images but quickly degrades when the texture or lighting changes.
2. The LoFTR model provides much higher robustness to seasonal and structural variations.
3. Average runtime per image pair is under 3 seconds, which is acceptable for medium-scale regional analysis.
4. The implementation ensures full reproducibility — users can freely choose any image pair and obtain metrics without modifying the code.

## Appendix

Execution Log: Appendix A includes a fragment of the console log with outputs for all four image pairs, demonstrating reproducibility and runtime consistency.

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call  
drive.mount("/content/drive", force_remount=True).
```

```
Available .jp2 files:
```

```
0: T36UYA_20160212T084052_TCI.jp2  
1: T36UYA_20190313T083739_TCI.jp2  
2: T36UYA_20190601T083609_TCI.jp2  
3: T36UYA_20190909T083559_TCI.jp2
```

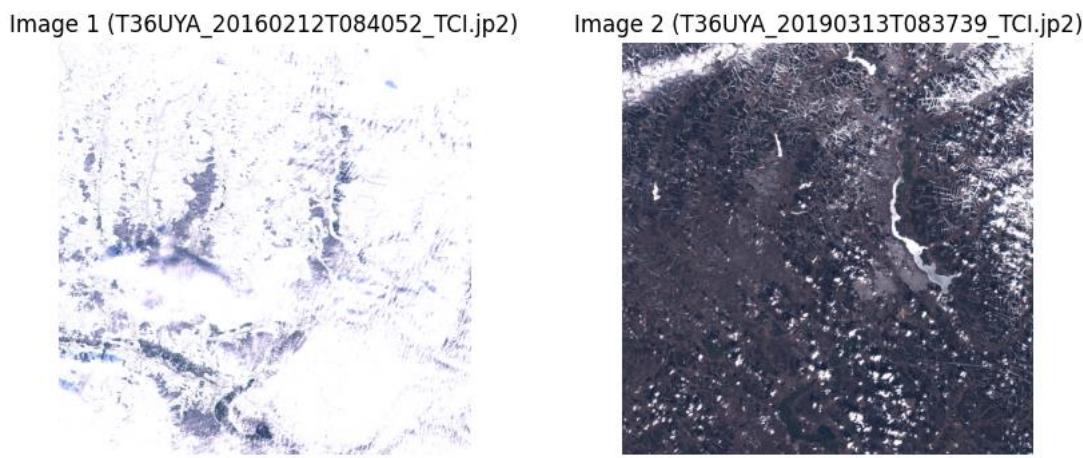
```
Enter index of FIRST image: 0
```

```
Enter index of SECOND image: 1
```

```
Selected images:
```

```
Image 1: T36UYA_20160212T084052_TCI.jp2
```

```
Image 2: T36UYA_20190313T083739_TCI.jp2
```



```
Running ORB + RANSAC...
```

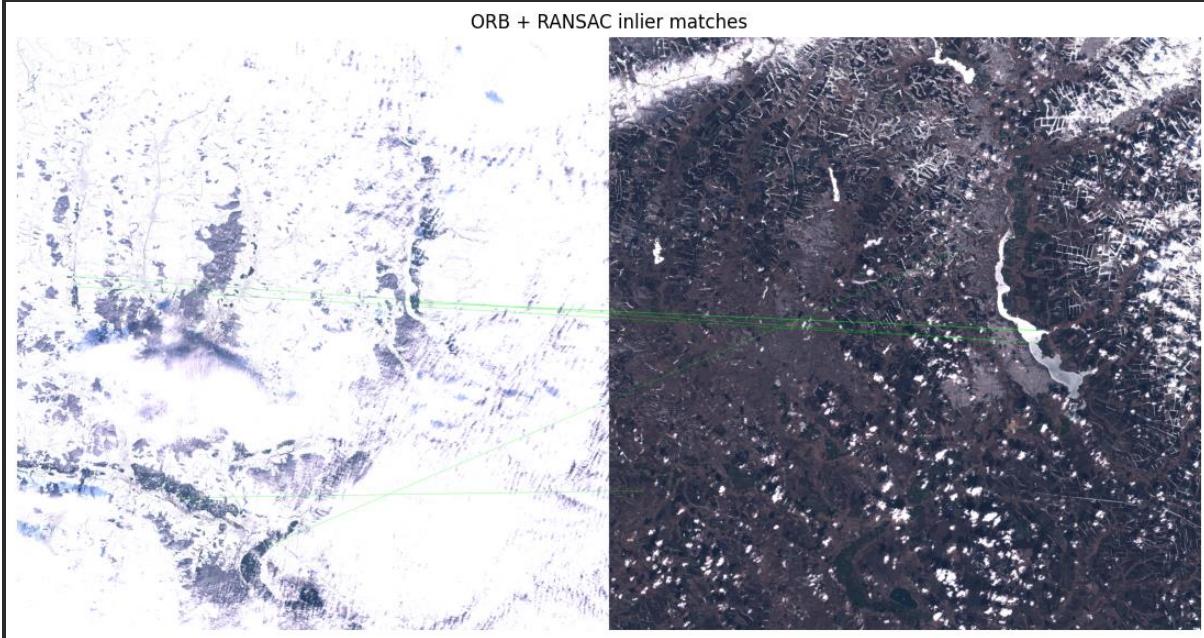
```
Raw ORB matches: 402
```

```
Inliers after RANSAC: 6 / 402 (1.49%)
```

```
Mean reprojection error: 0.83 px
```

```
Median reprojection error: 1.11 px
```

```
Runtime: 0.94 seconds
```



```
Running LoFTR matching...
```

```
Downloading: "http://cmp.felk.cvut.cz/~mishkdmy/models/loftr\_outdoor.ckpt" to  
/root/.cache/torch/hub/checkpoints/loftr_outdoor.ckpt
```

```
100%|██████████| 44.2M/44.2M [00:02<00:00, 15.6MB/s]
```

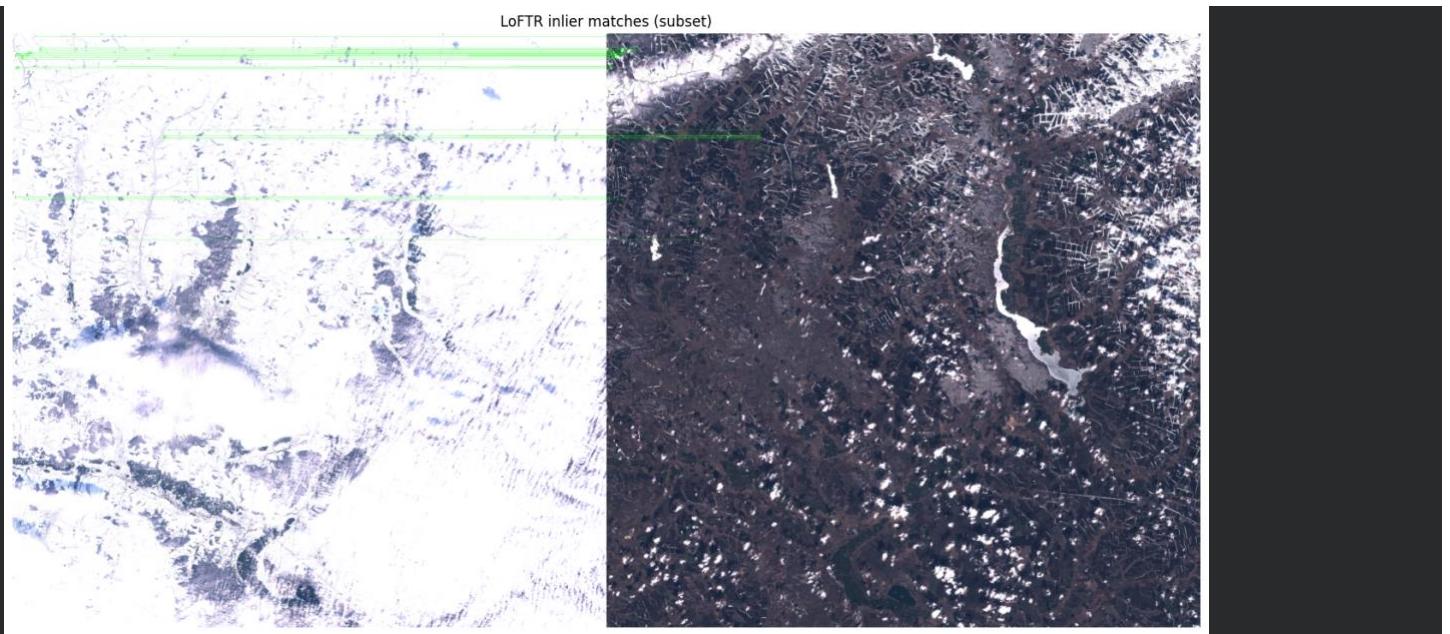
```
LoFTR stats:
```

```
Total matched keypoints: 47
```

```
Inliers (MAGSAC): 46
```

```
Inlier ratio: 0.98
```

```
Runtime: 2.33 seconds
```



Do you want to process another pair of images? (y/n): y

Available .jp2 files:

- 0: T36UYA\_20160212T084052\_TCI.jp2
- 1: T36UYA\_20190313T083739\_TCI.jp2
- 2: T36UYA\_20190601T083609\_TCI.jp2
- 3: T36UYA\_20190909T083559\_TCI.jp2

Enter index of FIRST image: 1

Enter index of SECOND image: 2

Selected images:

- Image 1: T36UYA\_20190313T083739\_TCI.jp2
- Image 2: T36UYA\_20190601T083609\_TCI.jp2

Image 1 (T36UYA\_20190313T083739\_TCI.jp2)

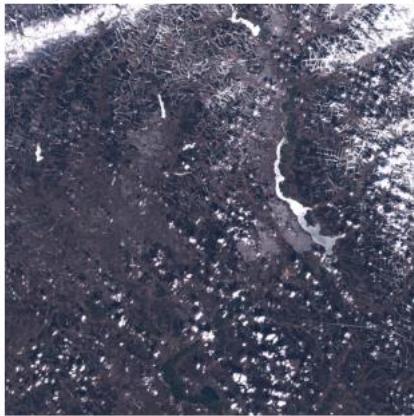
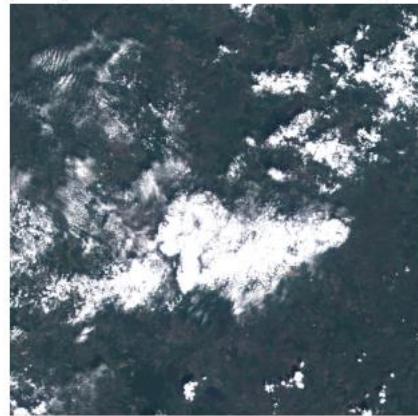


Image 2 (T36UYA\_20190601T083609\_TCI.jp2)



Running ORB + RANSAC...

Raw ORB matches: 501

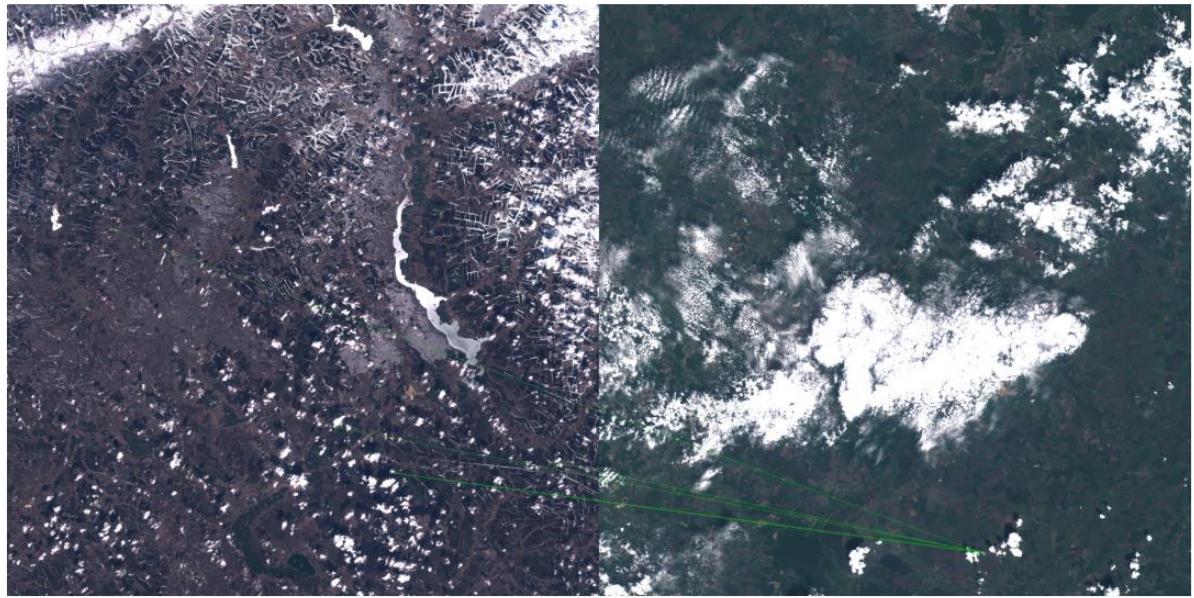
Inliers after RANSAC: 5 / 501 (1.00%)

Mean reprojection error: 2.26 px

Median reprojection error: 2.58 px

Runtime: 0.60 seconds

ORB + RANSAC inlier matches

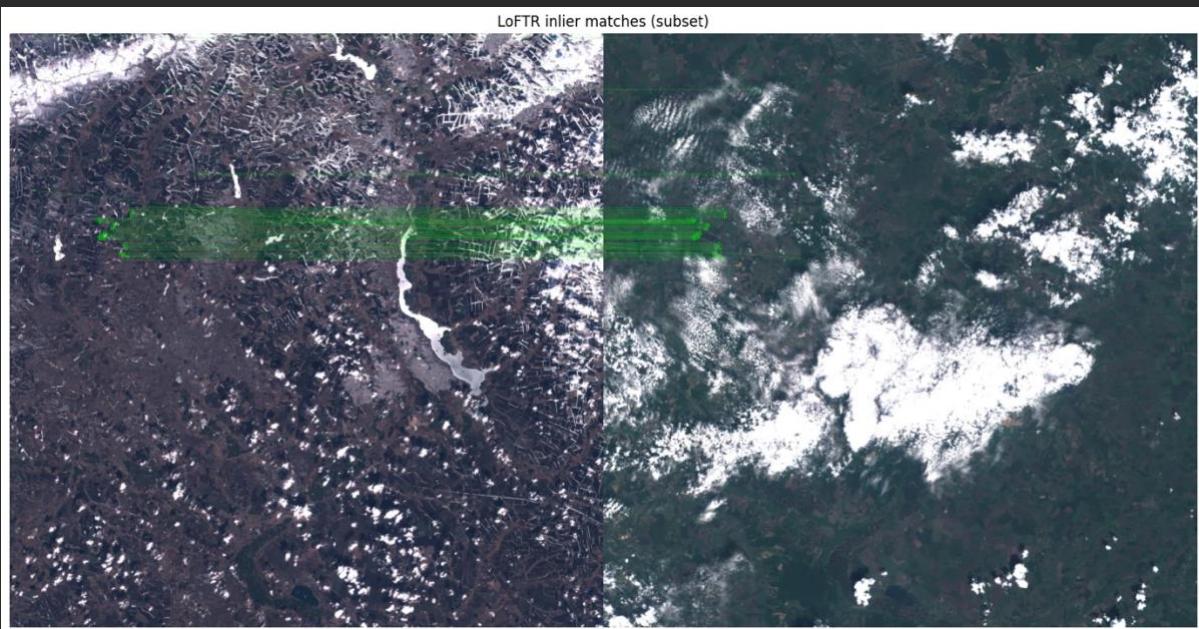


Running LoFTR matching...

LoFTR stats:

Total matched keypoints: 112

```
Inliers (MAGSAC) :      111
Inlier ratio:          0.99
Runtime:              0.79 seconds
```



```
Do you want to process another pair of images? (y/n): y
```

```
Available .jp2 files:
```

```
0: T36UYA_20160212T084052_TCI.jp2
1: T36UYA_20190313T083739_TCI.jp2
2: T36UYA_20190601T083609_TCI.jp2
3: T36UYA_20190909T083559_TCI.jp2
```

```
Enter index of FIRST image: 2
```

```
Enter index of SECOND image: 3
```

```
Selected images:
```

```
Image 1: T36UYA_20190601T083609_TCI.jp2
Image 2: T36UYA_20190909T083559_TCI.jp2
```

Image 1 (T36UYA\_20190601T083609\_TCI.jp2)

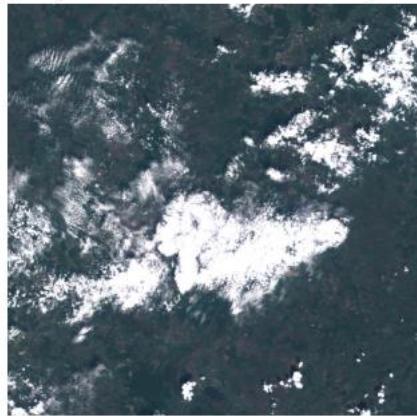


Image 2 (T36UYA\_20190909T083559\_TCI.jp2)



Running ORB + RANSAC...

Raw ORB matches: 508

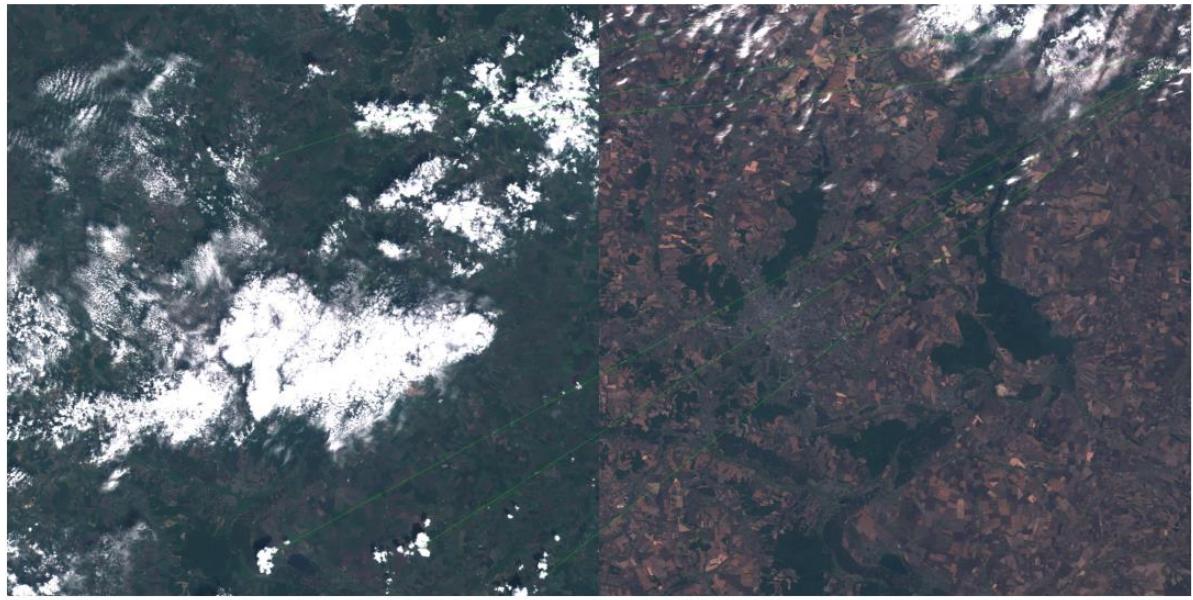
Inliers after RANSAC: 6 / 508 (1.18%)

Mean reprojection error: 2.78 px

Median reprojection error: 3.06 px

Runtime: 0.46 seconds

ORB + RANSAC inlier matches



Running LoFTR matching...

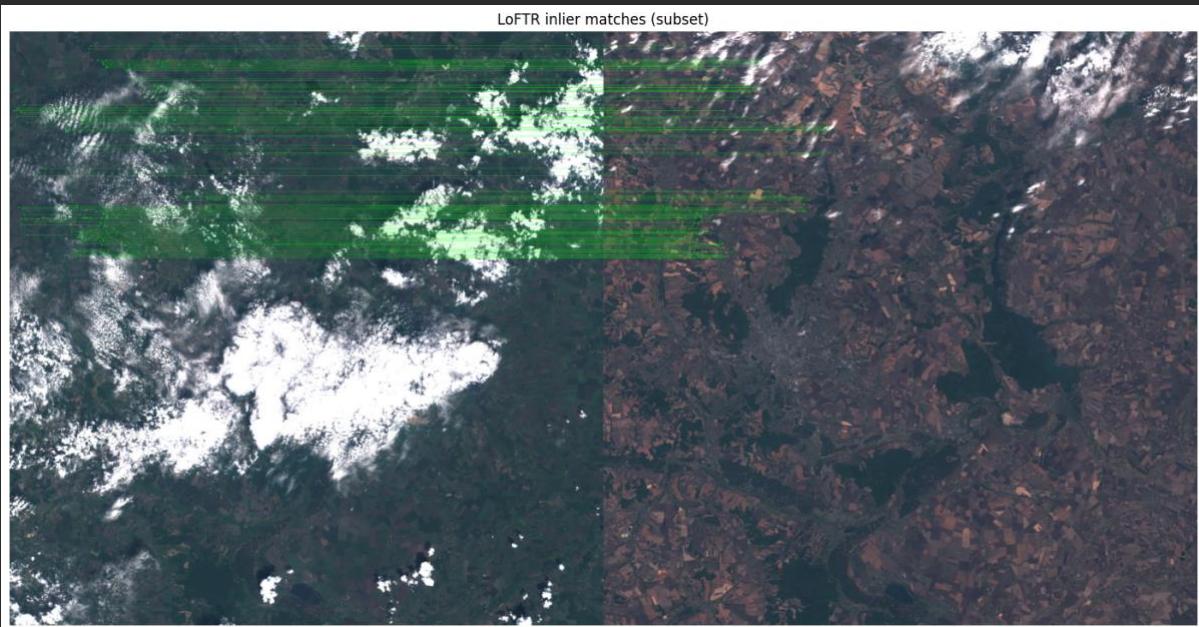
LoFTR stats:

Total matched keypoints: 2018

Inliers (MAGSAC) : 1993

Inlier ratio: 0.99

Runtime: 0.86 seconds



Do you want to process another pair of images? (y/n): y

Available .jp2 files:

0: T36UYA\_20160212T084052\_TCI.jp2

1: T36UYA\_20190313T083739\_TCI.jp2

2: T36UYA\_20190601T083609\_TCI.jp2

3: T36UYA\_20190909T083559\_TCI.jp2

Enter index of FIRST image: 0

Enter index of SECOND image: 3

Selected images:

Image 1: T36UYA\_20160212T084052\_TCI.jp2

Image 2: T36UYA\_20190909T083559\_TCI.jp2

Image 1 (T36UYA\_20160212T084052\_TCI.jp2)

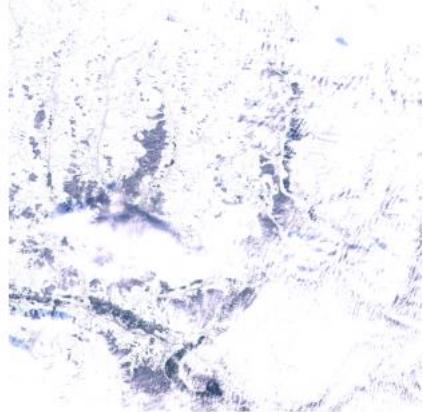


Image 2 (T36UYA\_20190909T083559\_TCI.jp2)



Running ORB + RANSAC...

Raw ORB matches: 535

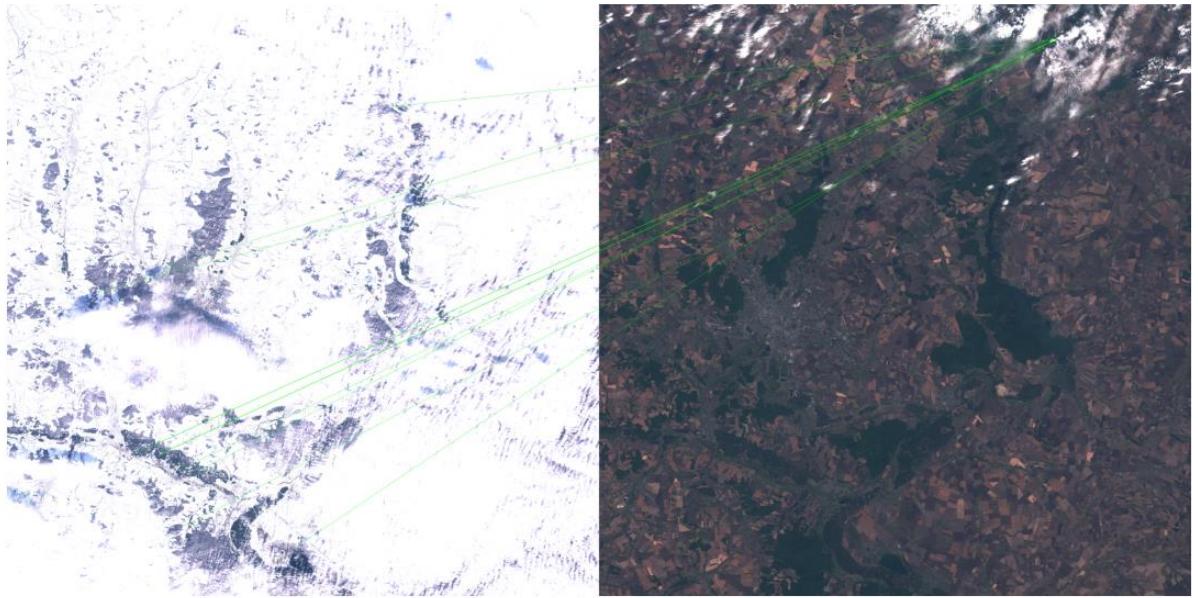
Inliers after RANSAC: 11 / 535 (2.06%)

Mean reprojection error: 2.31 px

Median reprojection error: 2.91 px

Runtime: 0.45 seconds

ORB + RANSAC inlier matches



Running LoFTR matching...

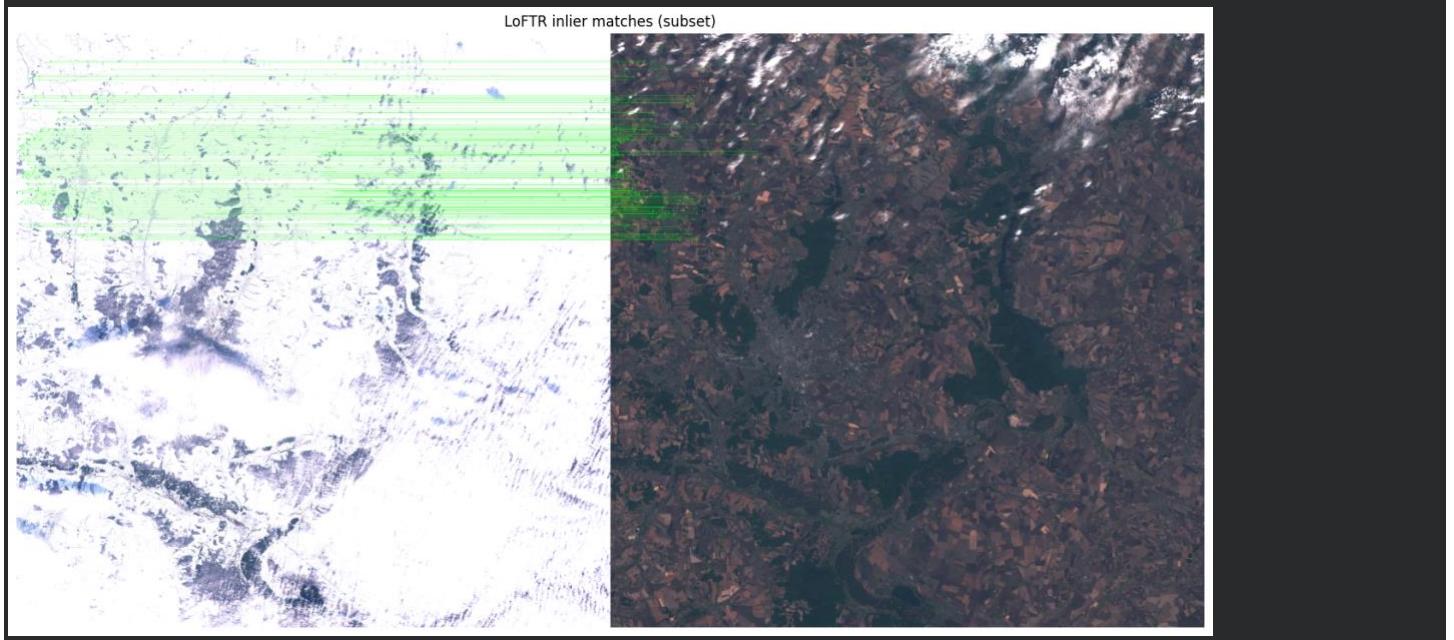
LoFTR stats:

Total matched keypoints: 1055

Inliers (MAGSAC) : 1035

Inlier ratio: 0.98

Runtime: 0.83 seconds



Do you want to process another pair of images? (y/n) :