ETH zürich

IGP
Institute of Geodesy and Photogrammetry

Landslide Monitoring through TLS and RGB Fusion with Coarse-to-Fine Dense 3D Displacement Estimation

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Background & Task Objective

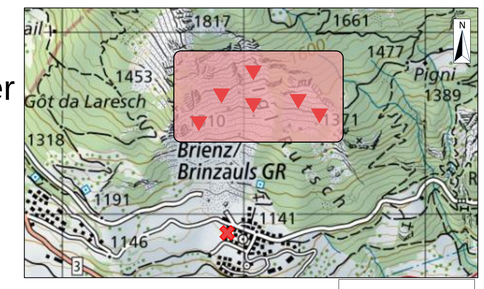
Background: In landslide monitoring, estimating 3D deformation can enhance our understanding of Earth's physical processes, potentially contributing to reducing risks associated with geological hazards such as landslides, rockfalls, and debris flows.

Task objective: Given two epoch point clouds, referred to hereinafter as the source and target point clouds, along with their associated source and target RGB images, our objective is to estimate point-to-point 3D displacement vector fields (DVFs) between these two epochs.

Test Dataset

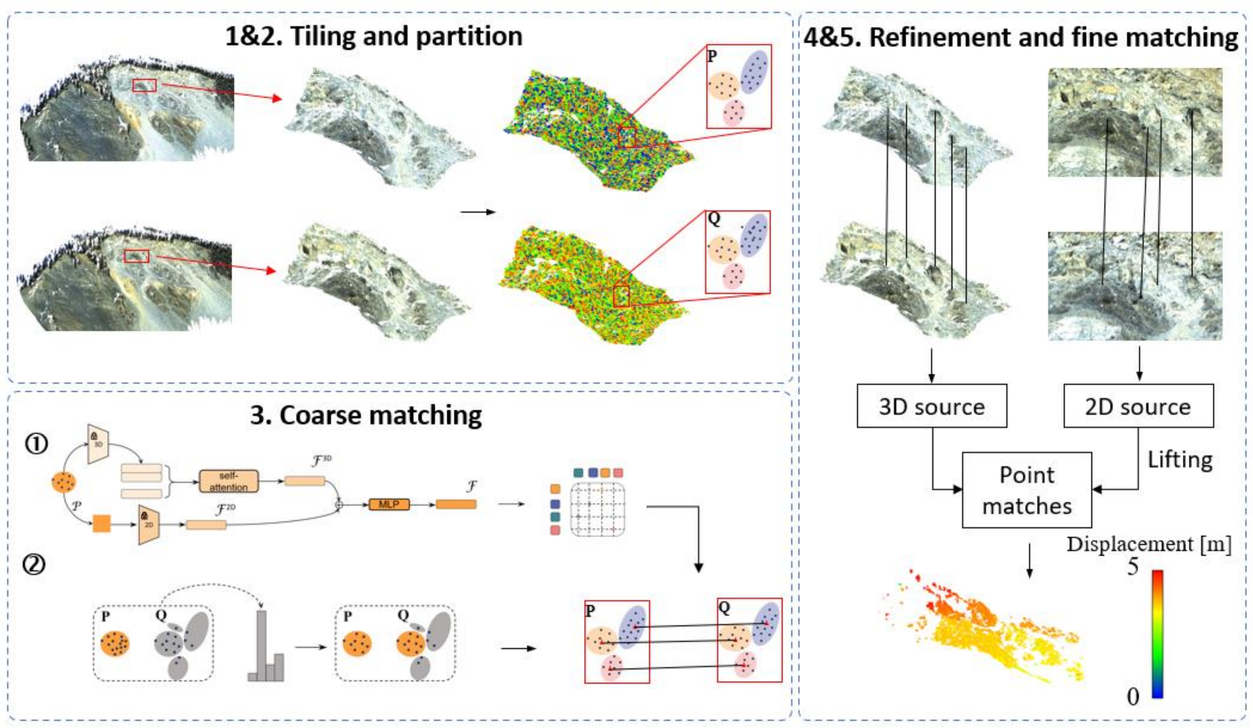
Brienz landslide:

- Time epochs: 2020 February and November
- Scans: Riegl VZ-6000 scanner
- Images: built-in camera, 80 per epoch
- Scan resolution: around 0.08 m / 2 km
- Image resolutions: 2560 x 1920



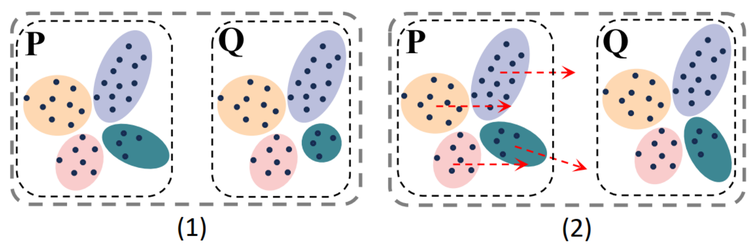
Base map source: ©swisstopo

Methodology



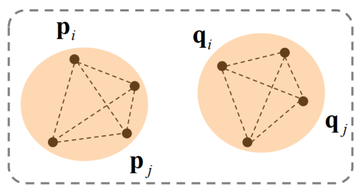
Candidate Generation for Coarse Matching

A source patch as being matched to a target patch if they exhibit the highest similarity based on their patch properties, even when (1) their shapes and sizes differ or (2) their orientations deviate from neighboring patches.



Refinement

Candidate patch matches with low quality are filtered out before fine matching. The criterion is based on the Mean Squared Displacement Difference (MSDD), where N represents the number of matches, and $i \neq j$.



$$\mathrm{MSDD} = \frac{1}{2N} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} \left| \|\mathbf{p}_i - \mathbf{p}_j\|^2 - \|\mathbf{q}_i - \mathbf{q}_j\|^2 \right|$$

Quantitative Results

Figure 1. Mean displacement magnitude comparison of different methods with ground-truth around six TS prisms

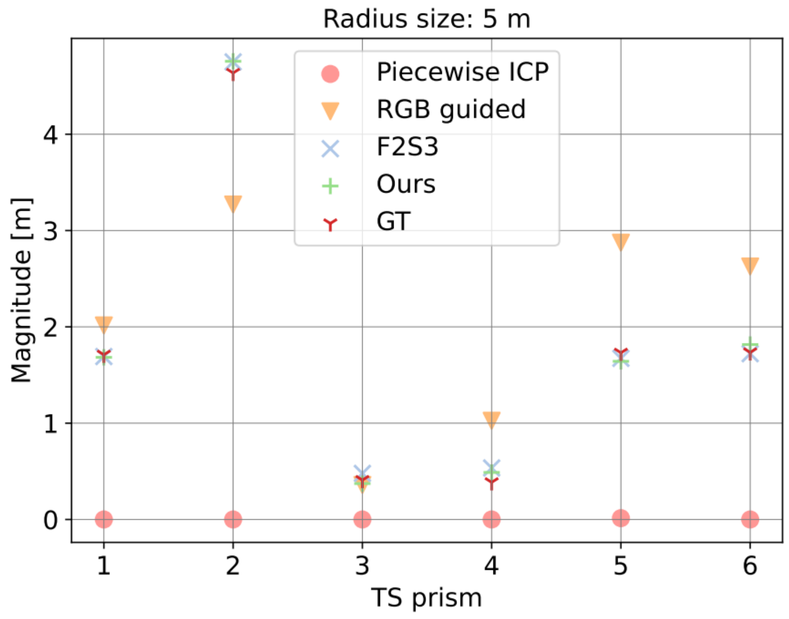
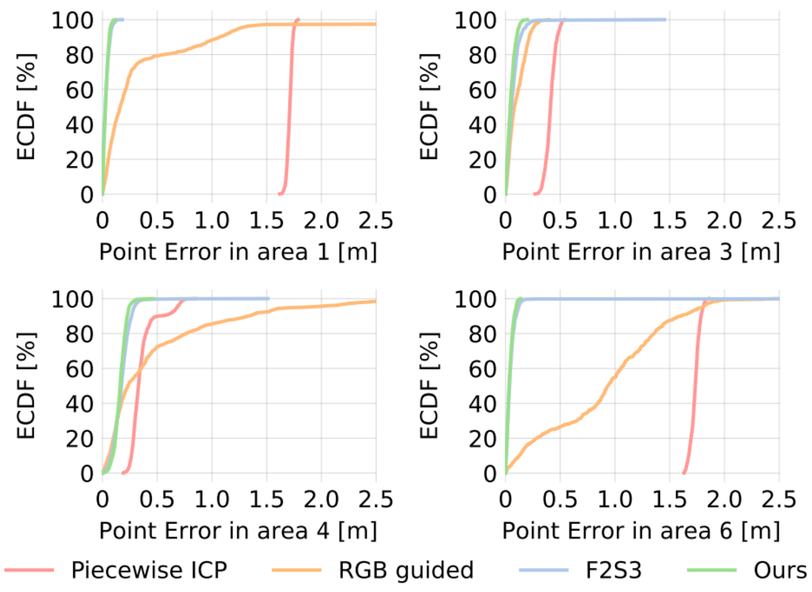


Figure 2. Empirical cumulative distribution funcction (ECDF) of point errors around four TS prisms



Qualitative Results

Figure 3. Density comparison of estimated 3D displacements in two selected regions

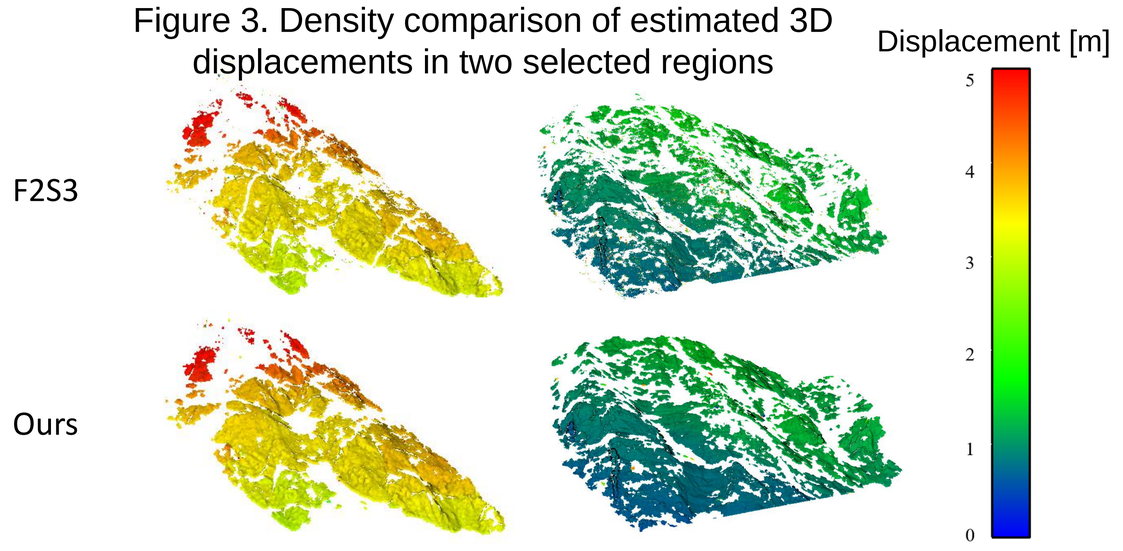


Figure 4. Visualization of estimated 3D displacement vectors from our method in a selected region

Conclusion

- We propose a **coarse-to-fine matching** method that utilizes both **TLS point clouds and RGB images** to estimate dense Displacement vector fields.
- Compared to existing methods, our approach achieves higher density and improved accuracy in selected regions.
- Furthermore, our method could be generalizable to:
  - external camera cases, with known camera parameters;
  - multi-epoch cases, by sequentially processing epoch pairs.