Advancing Alpine Landform Monitoring: AI-Driven Tracking on Hourly Monoscopic Time-Lapse Imagery

Hanne Hendrickx[1], Xabier Blanch[1], Melanie Elias[1], Reynald Delaloye[2], Anette Eltner[1]

[1]TUD Dresden University of Technology, Institute of Photogrammetry and Remote Sensing, Dresden, Germany, [2]Department of Geosciences, University of Fribourg, Switzerland

Grabengufer landslide

Grabengufer rock glacier

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The dataset

- High spatial and temporal resolution

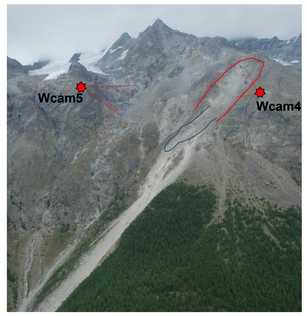
1. Problem statement – the dataset

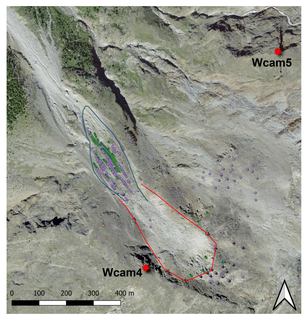
- **Large data availability** of monoscopic webcams or time-lapse camera in the European Alps, of for example rock glaciers and (permafrost affected) landslides.
- **High temporal resolution:** often hourly data.
- **Long time series**: often spanning decades.

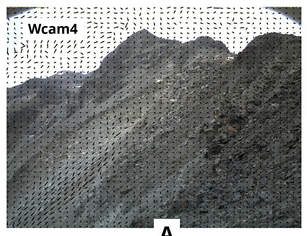
→ **Invaluable for geomorphic process understanding**, in this case rock glacier/landslide velocity

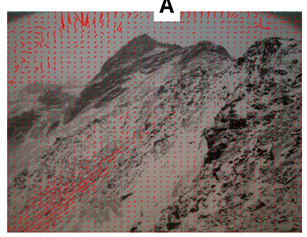
→ But images are low resolution and not installed in proper photogrammetric way (no camera calibration or ground control points)
→ Traditional tracking suffers from occlusion, light changes, varying snow cover and are too slow to handle big datasets

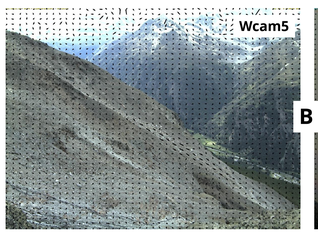
We need AI

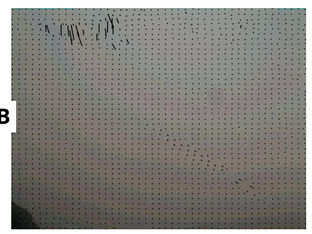












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PIPs++ [3]

- Fast
- Robust
- No preprocessing
- No retraining
- Easy

We need 3D information

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2D to 3D scaling [1]

- Fully automatic
- Reprojection error 2-4 pixels

We need Photogrammetry

We need ground truth

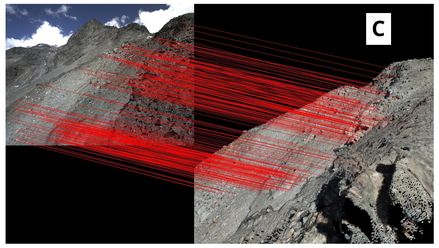
2. Persistent Independent Particle tracker: PIPs++ [3]

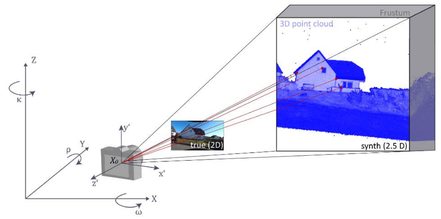
- **Traditional motion estimation:** an optimization problem – handcrafted feature or contrast/intensity based tracked in two (consecutive) frames only → Sensitive for light changes and occlusion + slow computation.
- PIPs++ uses **multi-frame temporal context** – iterative inference that searches for the target in all frames of a sequence.
- Utilizes **feature-update mechanism** – can deal with (gradual) feature appearance changes (light and snow conditions (A) and self-occlusion)
- Tracking through occlusion by using temporal priors (B).

→ Fast and robust tracking in real-world environmental applications

References:

1. Elias, M., Weitkamp, A., & Eltner, A. (2023). Multi-modal image matching to colorize a SLAM based point cloud with arbitrary data from a thermal camera. ISPRS Open Journal of Photogrammetry and Remote Sensing, 9, 100041.
2. Lindenberger, P., Sarlin, P.-E., & Pollefeys, M. (2023). LightGlue: Local Feature Matching at Light Speed (arXiv:2306.13643). arXiv. https://doi.org/10.48550/arXiv.2306.13643
3. Zheng, Y., Harley, A. W., Shen, B., Wetzstein, G., & Guibas, L. J. (2023). PointOdyssey: A Large-Scale Synthetic Dataset for Long-Term Point Tracking. http://arxiv.org/abs/2307.15055





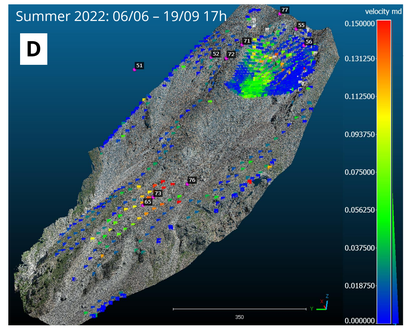
3. Image2Geometry: From 2D to 3D [1]

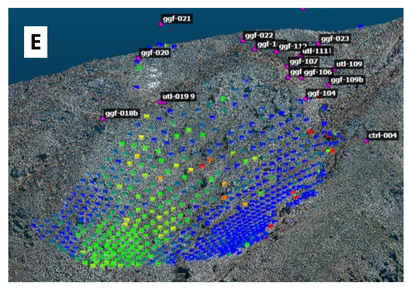
- Requires **high quality UAV-SfM point cloud data** and initial values for the external orientation of the camera (coordinates and viewing direction).
- Initial **synthetic image creation (C)** from the 3D point cloud in same perspective as image
- Image to synthetic image matching (C) applying **LightGlue AI matching** [2]**.**
- **Iterative process:** the more matches the better the perspective of the synthetic image
- 2D points with matched 3D values are used to estimate external and internal camera properties.

→ With this, 3D coordinates can be calculated for each pixel covered by the synthetic image.

4. Validation and results

- **Better spatial and temporal coverage** of landform displacements (D).
- Preliminary validation yield good correspondence (85%).
- Validation difficult when no GPS points are in direct view of the camera (E).
- Resolution and accuracy very dependent on camera properties, viewing angle and distance, and quality of the UAV data for scaling.
- Approach preliminary tested on other datasets: tracking glaciers, flow velocity in rivers, ….





4 **Results**

We need time (and funding)

5 **Outlook**

Open source, fully automatic pipeline for processing entire image sequences

Contact
First Author

Contact
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