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

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Monoscopic webcams or time-lapse cameras in the European Alps capture geomorphic processes with high resolution, proving invaluable for studying periglacial landforms like rock glaciers and permafrost-affected landslides over long time series, spanning decades. This capability becomes more significant when considering the temporal acquisition frequency; often hourly or daily. Despite their utility, managing the vast volume of hourly photographs requires efficient automatic image processing using Artificial Intelligence (AI) techniques.

This research aims to acquire high-quality landform velocities from monoscopic time-lapse cameras, verified by GNSS surveys, using an AI-enhanced particle tracker PIPs++ (Zheng et al., 2023). This model performs well without additional training, swiftly processing consecutive images. The algorithm tracks points without assuming movement direction and in multiple timesteps instead of frame-by-frame. Moreover, the model incorporates a template-update mechanism, allowing for changes in feature appearance, making it more robust in real-world applications. This flexibility accommodates occlusions (e.g., fog), self-occlusion (e.g., deforming boulders), or challenging lighting conditions. Real-world velocities will be derived by scaling images using high-resolution 3D models from UAV or ALS data through an image-to-geometry approach, matching 2D images with synthesized 2.5D images (Elias et al., 2023). While a fully automatic scaling is under development, initial results indicate the need for adjustments to the algorithm by Elias et al. (2023), leading to a semi-automatic workflow.

The approach is tested on a fast-moving landslide (up to 2 m per year) and rock glacier (70 to 100 m per year) at the Grabengufer site (Swiss Alps). The site is extensively monitored, with bi-annual dGNSS surveys, a permanent GNSS installation, and three time-lapse cameras since 2010/2013, covering a landslide, a rock glacier, and a torrent below. A temporal selection of the time-lapse data was made to test our approach, resulting in velocity vectors validated by GNSS measurements. Initial results are promising, demonstrating the model's rapid performance (two min for 400 images, tracking features through a temporal window of 19 frames, on a NVIDIA RTX A6000, with a GPU of 48GB) and tracking through occlusion when encountering fog. Validated by discrete GNSS measurements, our approach enables a spatially more continuous understanding of landform movement, allowing data acquisition where in-situ measurements are not possible due to logistical and safety constraints.

The overall goal of this research is to derive reliable velocity values at high temporal resolution from low-cost monoscopic time-lapse cameras. To achieve this, an open-source workflow will be developed, applicable to research sites where validation data is limited or where other remote sensing monitoring techniques fail due to high landform displacements.

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