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Automated real-time ice ablation readings using in situ cameras and computer vision techniques

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Triggered by climate change, glaciers are retreating world-wide at alarming rates. Since glacier melt can contribute significant proportions to hydrological catchment runoff, it is important to know how much meltwater glaciers can still release under decreasing ice volumes. For a better water resources management, a near real-time mass balance estimate would thus be desirable. On short time scales, glacier mass balance models are usually uncertain though, and they rely heavily on field data for calibration and validation. Because acquiring field data is resource-intensive, most studies rely exclusively on annual or seasonal data sets.

To provide an improved data basis for near-real time analyses produced within the CRAMPON project (Cryospheric Monitoring and Prediction Online), we aim at measuring glacier point ablation automatically, remotely and with high temporal resolution. For this purpose, we have equipped nine ablation stakes on Rhonegletscher, Grosser Aletschgletscher, Findelengletscher and Glacier de la Plaine Morte, Switzerland, with an additional setup: attached to each ablation stake, another aluminum stake construction holds a solar-powered camera at about 1m distance. As the ice surface melts, the camera slides down the ablation stake, takes RGB images of the bottom 50cm at 20min intervals, and sends the images to a server. Colored tape markers of known width and spacing serve as a scale reference on the stake. The total sequence of markers using eight different colors is shuffled to allow for a unique identification of sub-sequences of four markers.

By means of computer vision, the distance of the ablation stake top from the ice surface is obtained automatically: the stake is identified by finding collinear points of high color saturation on an image, i.e. the tape markers. The base point at the ice surface is given, because it has a fixed relative position to the camera. Individual markers are identified by their color, while the color sub-sequences provide the total position on the stake. A pixel-to-metric scale is calculated for each image from the known marker tape width and spacing, which also accounts for the perspective skewness of the stake. A reading uncertainty estimate of 2mm is derived from noise in the scale calculation. This estimate includes the quality of the detected marker bounds, image pixel size and the precision of the actual marker positions as error sources. Images with bad weather conditions are rejected by the processing.

The so-obtained ice melt time series between subsequent image pairs is aggregated to daily values. The results show good agreement with manual readings. In addition to the suggested image processing, we discuss two alternative approaches: by detecting tape markers through a template matching and tracking their location on the images over time, the alternatives avoid the reconstruction of the stake top position while being more sensitive to longer data gaps. We conclude that the presented setup is well-suited to automatically and remotely determine real-time ablation rates with low effort.