Dealing with "too much data": Automated Structure-from-Motion Processing of Time Lapse Imagery at Nàłùdäy, Yukon, Canada

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This document is a snapshot of work in progress. In the following pages we give the context for the goals of this research project, it's current state and an overview of our future work. In presenting this unfinished work as part of this session on Big Data, Machine Learning and Artificial Intelligence in Glaciology, our hope is to foster collaboration and discussion on how to cope with the vast amount of data being collected in modern research, particularly in the area of time lapse photography. The approach we outline here is continually evolving as we explore more ways to efficiently process large image datasets.

Why automate Structure-from-Motion processing?

The use of structure-from-motion (SfM) has become commonplace in glaciology (e.g. Ryan et al, 2015; Mallalieu et al, 2017; Bash et al, 2018)

- SfM uses computer vision and overlapping images to reconstruct topography in 3D
- Drones, aerial surveys, terrestrial cameras and high-resolution satellite imagery are all used to investigate glacier change using SfM
- The resolution and repeat times of these platforms must be balanced with the scale of problems being investigated in any given study

The ease with which imagery can be acquired now means that more data exists than can be easily processed using current SfM methods

- Current manual interventions include placement of ground control, precision and accuracy assessments, and other interactions with a graphic user interface
- Additional pre-processing, such as image exposure adjustments or identification of useful imagery, must also be streamlined to make SfM reconstruction efficient


Drone survey (photo credit Eleanor Bash)

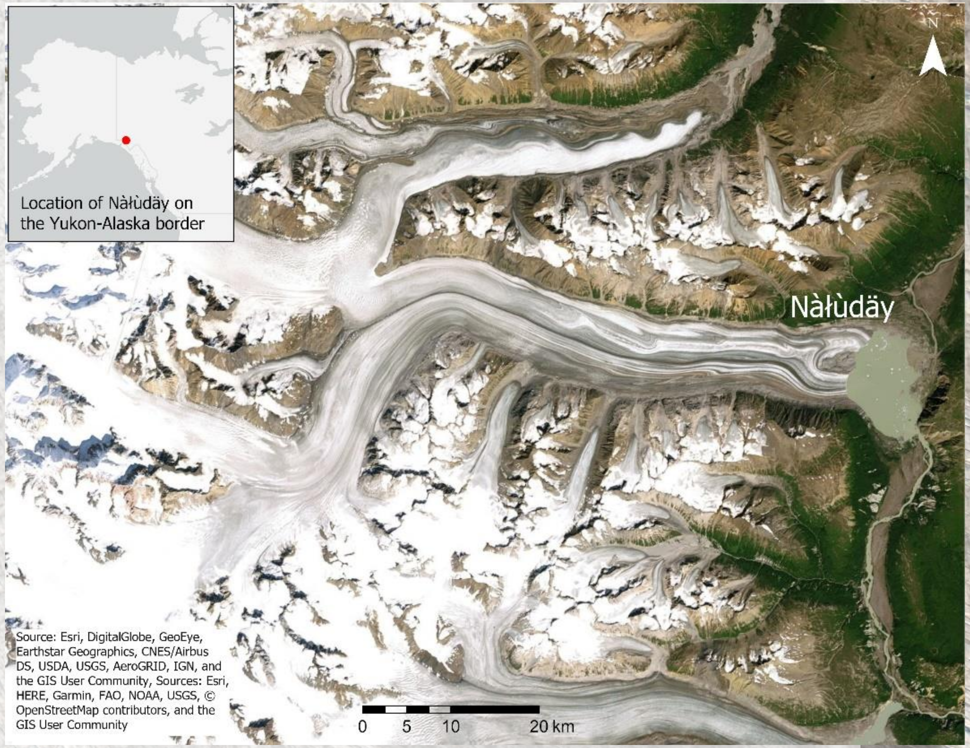

Time lapse camera (photo credit Eleanor Bash)


Manned aircraft survey (photo credit Luke Copland)

Nàłùdäy, Yukon, Canada – a representative surge type glacier

Nàłùdäy (Lowell Glacier) is a surge-type glacier in the St. Elias Mountains, Yukon, Canada. In the past it has surged on ~10 year cycles, with the most recent taking place in 2009-10 (Bevington & Copland, 2014).

- We are using time lapse cameras, manned aerial surveys, and satellite investigate surge timing and causes at Nàłùdäy
- High temporal resolution imagery is import for capturing surge dynamics in detail, limiting the utility of satellite and aircraft surveys
- Frequent image acquisition with time lapse cameras will allow for analysis of ice elevation, velocity, and hydrological changes throughout the surge cycle



Nàłùdäy is 34 km long, 5 km wide, and heavily crevassed from past surges. Access on the ice and surrounding terrain is challenging as a result.

- SfM requires a minimum of three surveyed locations to orient topography in the real world, these can be ground points or camera locations.
- The terrain at Nàłùdäy makes placement and identification of survey points on the ice surface or surrounding terrain challenging to impossible

Time Lapse Imagery at Nàłùdäy, Yukon, Canada

Two time lapse cameras were installed at Nàłùdäy in July 2019, each consisting of:

- Nikon D5600 with a variable zoom lens fixed at 18 mm
- photoSentinel Digisnap Pro
- External battery and solar panel
- Survey tripod dug into the ground and fixed in place by cairns

Photo credit: Eleanor Bash

Photos were collected at 2 hour intervals, to allow for selection of the best images for reconstruction. Due to a malfunction at one site, imagery was collected only from July 12 – 25.

Photo credit: Eleanor Bash

Images were filtered for those containing the least overhead shadows and one mid-day (09:00-17:00) image per day was selected for reconstruction.

On July 1 a manned aircraft survey collected imagery over Nàłùdäy with a Nikon D850. A differential GPS was used to mark the location for each image.

Structure-from-Motion Processing of Time Lapse Imagery

Two-camera time lapse set-ups are easily transferred to many applications outside of glaciology. Thus, we focus our efforts on streamlining and automating processing with this type of set-up. Several steps are needed to go from imagery to change detection using SfM:

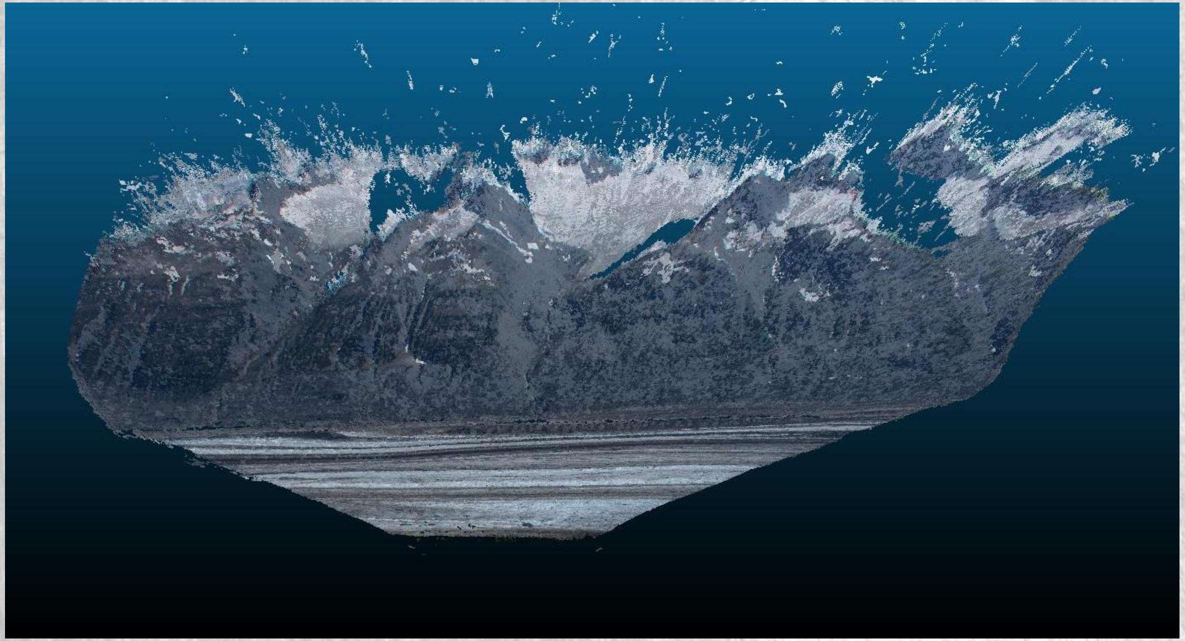
To alleviate the need for ground control in the orientation step, we present a method for orienting point clouds derived from time lapse cameras using existing high resolution point clouds from manned aircraft surveys.

The benefit of the method outlined here, is that it can be performed once and point clouds from subsequent time steps can be oriented using the same rotation matrix.

Structure-from-Motion Processing

Agisoft Metashape Professional (v 1.5) was used to reconstruct topography from the time lapse and aerial imagery.

Metashape's 4D scene reconstruction uses tie points from time series imagery to reconstruct camera positions and internal parameters, as well as topography. This allows the reconstructed surfaces throughout the time series to be oriented in the same relative coordinate system.

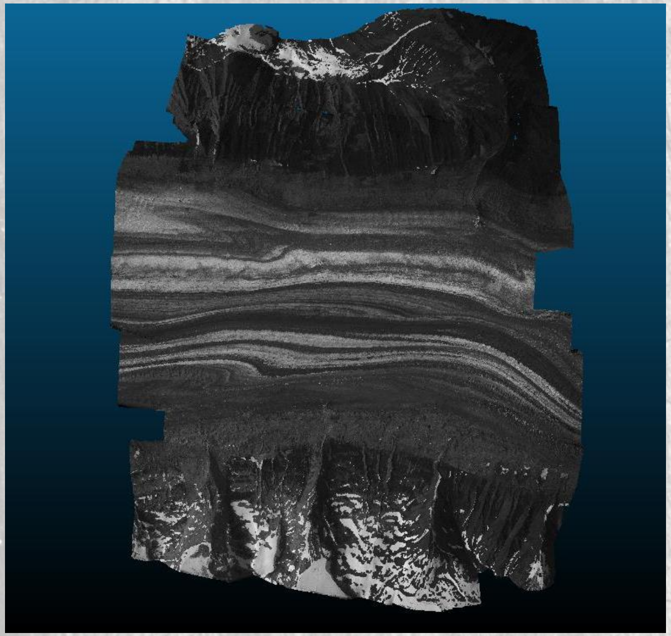


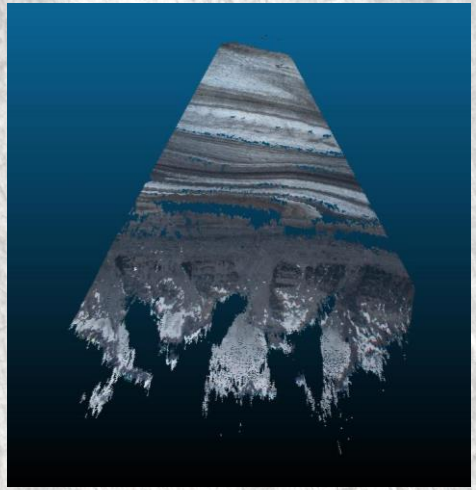
This image shows 14 point clouds reconstructed from the July imagery. By using the 4D alignment process all the clouds align well with each other, although they still lack real world coordinates. This allows for one transformation to be calculated and applied to an entire time series.

Automated alignment based on topographic features

The point cloud derived from the manned aircraft survey will be used as a reference point cloud to orient the time series point clouds reconstructed from time lapse imagery. The alignment algorithm is based on Persad & Armenakis (2017).

This point cloud alignment uses distinctive topographic features selected automatically by identifying points with curvature maxima (i.e. topographic high points). A histogram descriptor is created using local slope and distance between points in a local neighborhood. The keypoints are scale invariant, making the descriptor a robust method for aligning point clouds with differing scales, rotations, and translations.





By identifying keypoints in both the terrestrial and aerial point clouds, distinct topographic features can be automatically aligned through matching keypoint descriptors.

Due to the pandemic, this work is not yet complete. When finished, we will make the alignment tools developed in Python available at https://github.com/ellie-b

Future opportunities for automation and applications

Automating orientation of point clouds with no ground control opens new doors for working with time lapse imagery and structure-from-motion. This work is ongoing, with plans to fully test this process and refine it to efficiently run with large point clouds.

Further work is focusing on limiting researcher intervention in the image pre-processing step. This work is exploring ways to select useful images, including identifying criteria for image properties that enhance reconstruction.

If successful, these methods will allow us to create dense time series of glacier change for analyzing surge processes at Nàłùdäy. In particular, looking at hydrologic links between surface and subglacial water, and how hydrology plays a role in surge timing and propagation.

The availability of detailed time series for glacier surface change will be a rich data set for machine learning in glaciology and other disciplines such as ecology or geomorphology.

Thank you for your interest!

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This work is being undertaken as part of a post doctoral research program at the University of Calgary and the University of Waterloo, Canada. We are interested in finding opportunities to improve on our methods and collaborate on new endeavors related to image analysis and glacier surges.

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