Automated Detection of Eskers in Hillshaded Digital Elevation Models Using Convolutional Neural Networks

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Abstract

Sea-level rise constitutes a significant risk for over 600 million people in the Low-Elevation Coastal Zone. Considerable uncertainty exists over the magnitude of possible future sea-level rise, because of poorly understood processes governing the stability of ice sheets (continental sized glaciers). One such uncertainty is how meltwater interacts with ice under a warming climate. Understanding of this process is limited by the inaccessibility of the subglacial zone, which lies beneath 100s to 1000s of m of ice. One approach to address this uncertainty is to investigate areas where ice sheets have retreated, i.e., where their beds are easily accessible. Eskers are landforms that record the location and dimensions of former subglacial meltwater channels, and are common in glaciated regions. Recent years have seen a dramatic increase in the availability of high-resolution Digital Elevation Models (DEMs) of glaciated regions, providing the opportunity to make detailed measurements of eskers from remotely sensed data. Manual mapping of these features at the required level of detail is not feasible over the large areas occupied by palaeo-ice sheets (e.g. most of Canada). We propose an automated method for detecting eskers in hillshaded digital elevation models, based on Convolutional Neural Networks (CNN). The automated method maps esker locations to facilitate detailed morphometric study of their form. Multiple CNN models are trained and tested via a specially–designed algorithm with built–in mechanism for selecting an optimal model. Training and testing imagery data were obtained from a test area in Canada, consisting of 1041 esker positive JPEG files and 37000 esker negative JPEG files. The CNN model performance on previously unseen images with and without eskers yields high sensitivity and specificity respectively and we use the model outputs to elicit esker features from the images. Discussions focus on how timely identifying esker locations enhance our understanding of why, how, and how fast the sea level rise might happen. We also highlight the importance of gaining such knowledge in a timely manner within the context of the United Nations Sustainable Development Goals (SDGs)–particularly SDG #13 and others relating to poverty and food security.

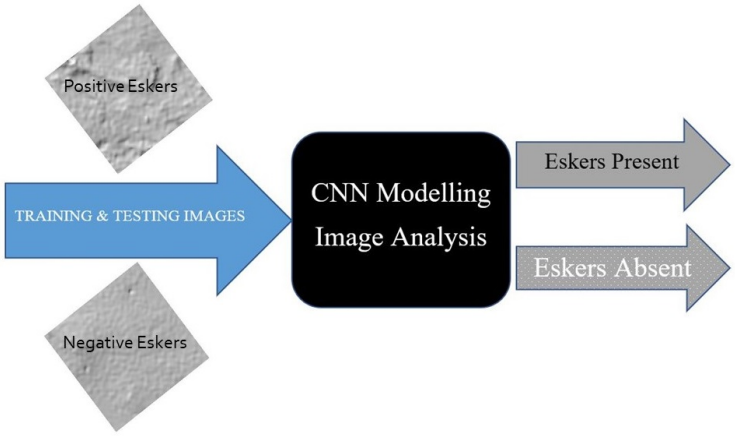

Figure 1: A graphical illustration of a CNN model with imagery data as input

Key Words: *Big Data, Convolutional Neural Networks, Data Science, Digital Elevation Models, Eskers, Glacier Surface Elevation, Ice Sheet Hydrology, Machine Learning, Meltwater Channels, Supervised Modelling*