Predicting Glacier Thickness: A Machine Learning Approach

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GOAL OF THIS PROJECT: CONSTRUCT A MODEL THAT DETERMINES GLACIER THICKNESS WITH A MINIMUM MEAN ABSOLUT ERROR. IMPLEMENT A CONVOLUTIONAL NEURAL NETWORK TO ADD INFORMATION FROM GLACIER IMAGES

Introduction

- This study aims to determine glacier thickness based on observational data.
- In this study, three different Machine Learning algorithms were used.
- It explores the possibility of improving the model for predictions by adding information from images of glaciers.

Motivation

- Rising temperatures globally leads to increased melt from glaciers.
- Increased melting poses a risk to societies based along rivers fed by glacier discharge, and directly impacts sea level rise.
- Determining the thickness of glaciers help to better predict river activity and sea level rise.

Methods

SOURCES OF DATA (SATELLITE IMAGES, FIELD MEASUREMENTS)

GLATHIDA CONSORTIUM (2020): GLACIER THICKNESS DATABASE 3.1.0. WORLD GLACIER MONITORING SERVICE, ZURICH, SWITZERLAND.
RGI 6.0 CONSORTIUM, 2017. RANDOLPH GLACIER INVENTORY - A DATASET OF GLOBAL GLACIER OUTLINES, VERSION 6.0. BOULDER, COLORADO USA.
NSIDC: NATIONAL SNOW AND ICE DATA CENTER.

- Dataset consists of ice thickness measurements + set of informative features (2321glaciers and ice caps).
- Each glacier have been gridded to a 20x20, 100x100 lat-lon pixel grid
- For training the model we used the 20x20 grid data. For predictions we used the 100x100 grid data

Regression BDT

GOAL: Regional training into global prediction

LightGBM — Simple initial model

XGBoost — Alternative to LightGBM

OPTUNA — Hyperparameter optimization

Regression NN

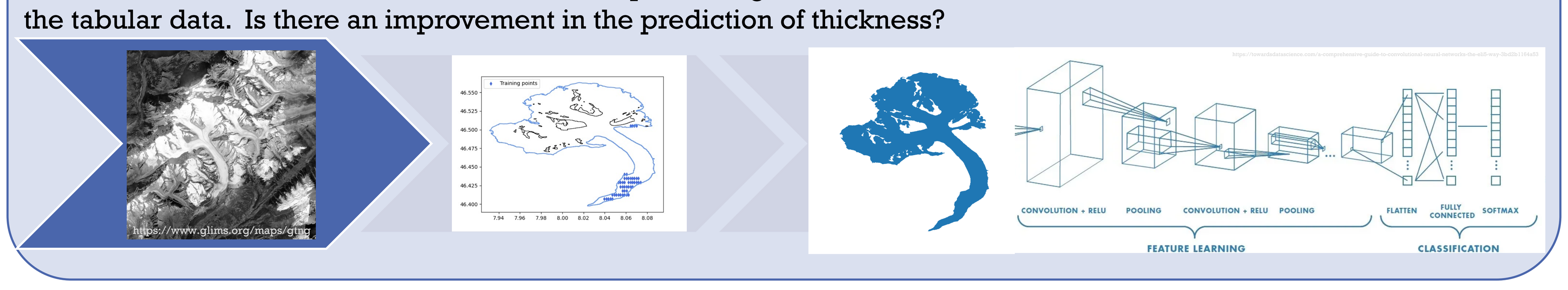
GOAL: Beyond BDT. Additional information from images

TensorFlow — Alternative to both BDT

learn — RandomSearchCV for Hyperparameter optimization

Convolutional Neural Network

GOAL: Obtain additional information on the shape of the glaciers and link it to the tabular data. Is there an improvement in the prediction of thickness?



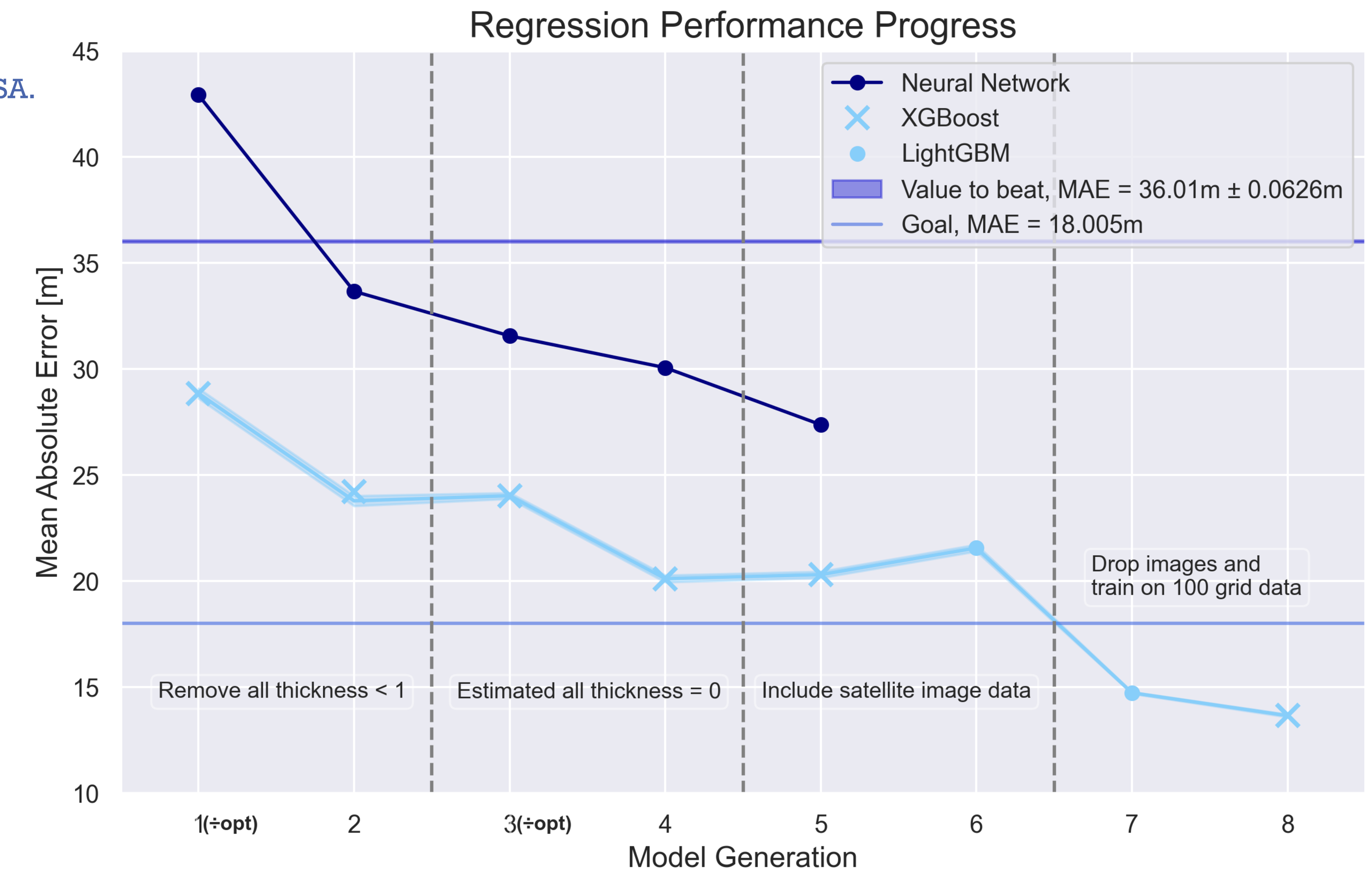


Figure 1: Tracking the performance progress to obtain a model with a minimum MAE

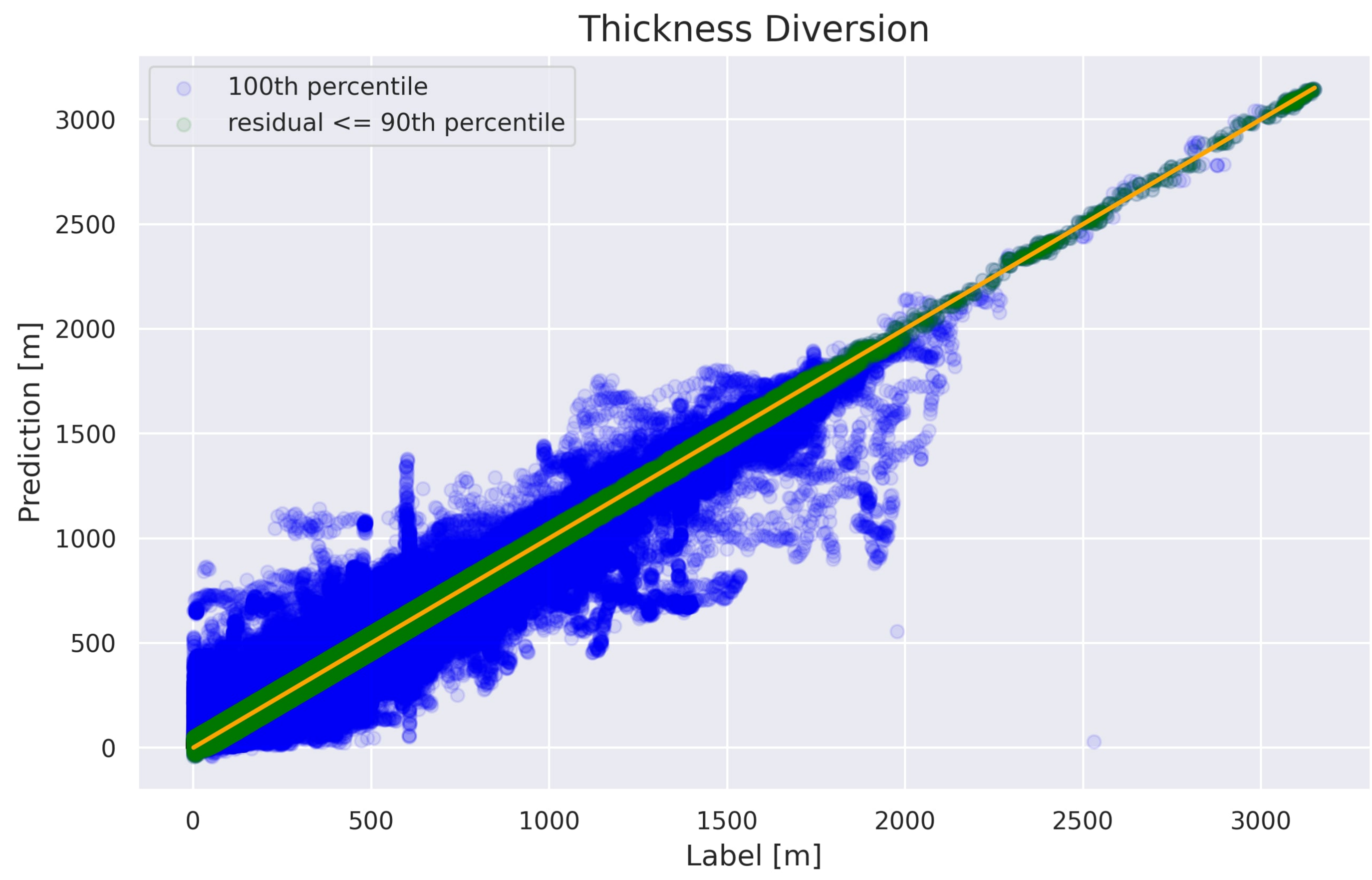


Figure 2: Trained by our best model XGBRegressor + Optuna. MAE Cross-Validation: 13.65 +- 0.07 m. Data: 100x100 grid. Preprocessing: replace 0 m thicknesses by mean values from other models (Millan et al (2022), Farinotti et al (2019)).

Results

- XGBoost had the lowest mean absolute error and thus was the best at predicting glacier thickness.
- Using the Convolutional Neural Network with satellite images, did not improve the precision compared to the other models.
- Further work could include adding additional features to the data, such as latitude and longitude to the satellite images and surface temperature at the location of the glacier to increase the precision of the prediction models.

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Summary

This study aims to determine glacier thickness based on observational data. Determining the thickness of these glaciers may help to better predict increased river activity and sea level rise. We found that the best model was the XGBoost. In this work the CNN did not significantly improve our predictions. For future work we will focus on improving the CNN and add more features to the data.

Photo: Josephine Kande