DEVELOPMENT OF AN AUTOMATIC SYSTEM FOR REMOTE MONITORING OF MOUNTAIN GLACIERS USING DEEP LEARNING

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Glaciers are a source of fresh water and are crucial for the Almaty region, both from an environmental and social point of view. However, glaciers continue to shrink at an alarming rate and this will reduce freshwater inflows. In this paper, we present a machine learning approach to support environmental monitoring with a focus on glaciers. Our approach is based on semi-automatic mapping from Landsat 7 and ESRI satellite images. We use remote sensing tabular data to create a model that identifies and delineates both clear ice and debris glaciers from satellite imagery. Remote sensing allows parameters such as snow cover, glacier height and ice index to be estimated at large geographic and time scales. We use machine learning methods to automate methods for mapping glaciers from satellite imagery, and we also use semantic segmentation, a deep learning approach that performs pixel-based image classification. The result is published to a web application that allows experts to visualize and correct model predictions with the ultimate goal of speeding up the glacier mapping process.

Key words: glacier monitoring, remote sensing, machine learning, deep learning, web-application.

Introduction

Monitoring glaciers using remote sensing is the key to environmental monitoring of the Tuyuksu glacier in the Almaty region. Glaciers are a source of fresh water and are of decisive importance for the Almaty region from both ecological and social points of view [1]. However, glaciers continue to shrink at an alarming rate, and this could lead to a decrease in the freshwater resource. This problem requires effective and efficient methods for observing and delineating glaciers in order to monitor changes and plan systematic management of water resources and glacial hazards to prevent risks.

To solve this problem, remote sensing offers a variety of methods and tools that can be used to monitor glaciers [13, 12]. Remote sensing allows the estimation of parameters such as snow cover, glacier height, ice index, accumulation and ablation of snow on geographic and time scales. Based on the above data, an application was developed for delimiting glaciers and visualizing changes in the area of the Tuyuksu glacier. However, the efficiency and accuracy of these methods are influenced by cloud cover, highly variable snow conditions, and spectral similarity of supra-glacial debris with moraines and bedrocks [3]. These errors are addressed to some extent through the application of methodologies in the Google Earth Engine application and through manual intervention. However, it is labor intensive and time consuming, for this reason it is recommended to use machine learning models.

Machine learning models can help solve the boundary problem more accurately and classify the area into glaciers and the earth's surface.

Using the Tuyuksu glaciers as a research area, available Landsat satellite imagery and glacier tags provided by the World Glacier Monitoring Service (WGMS) Global Ground Ice Measurements from Space (GLIMS) were used to develop the application. Using these techniques, an application was developed that augments the pipeline, dataset, and basic methods that can be used to automatically extract glaciers from satellite images. The developed application deploys a web-based tool to demonstrate how glaciers are extracted and visualize the change in glacier area.

Tuyuksu glacier and brief historical notes

In recent years, projects for monitoring natural resources, the technosphere, environmental disasters and disasters have become especially relevant. Currently, assessing the response of glaciers to climate change, as well as forecasting changes in the volume, state, regime and dynamics of glaciers are of great scientific and practical importance in connection with global warming. The thickness and volume, area, internal structure of glaciers to solve such problems, it is necessary to know such important and insufficiently studied characteristics as the hydrothermal state, as well as the relief of the ice cover.The current Continental glaciation of the Earth consists of 198 thousand individual glaciers with a total area of 726800±34000 km2. It is necessary to constantly monitor their dynamics, if not for the entire population, then for regional samples of glaciers in the largest river basins. The Central Tuyuksu glacier is the main test of the World Glacier Monitoring System and has been systematically studied for more than half a century. The Central Tuyuksu glacier is a classic Valley Glacier with a clear feeding zone and a tongue extending along the valley, as shown in Figure 1.

The length of the open part is 3.5 km, the width is 1.5 km, in the lower part(glacial tongue) 0.3 - 0.4 km, the area of the open ice is 3.1 km2. The average height of the snow line in 1973-1983 is 3040 m. the open end of the glacier descends to 3400 m. The thickness of tuyuksu ice is on average 50 m, up to a maximum of 100 m. As of 1983, the volume of ice is about 150 million m3. The lateral Moraine joined the last Moraine and created a giant shaft about 300 m high, which surrounded the Valley of the Malaya Almatinka River and made it difficult to access the glacier. A significant part of the glacier is located 1.4 km below this Moraine. On average, the glacier shrinks (retreats) by 10 m per year, resulting in a significant lake from Meltwater in the summer between the last Moraine and the tongue of the glacier. Table 1 shows changes in the area of the Central Tuyuksu glacier in 2000-2010. According to Table 1, in the period from 2000 to 2010, the area of the glacier decreased by 0.163 km2. As a result of the melting of the glacier, there are changes in the climatic conditions of the region in the direction of warming.

Extrapolating the results obtained from the transformation of the tuyuksu glacier into the future over the course of a century and a half, we can assume that, in contrast to the reduction of area and length, the glacier should have ceased to exist by 180-220, that is, by the end of the XXII - XXIII centuries.at the beginning, N. N.

Palgov suggested that in the middle of the XX century, the Tuyuksu glacier may become extinct by 2340, but it will not disappear at all.

Rapid melting of the glaciers of the Trans-Ili Alatau poses a number of direct threats to Mountain and Foothill settlements. For residents of settlements, landslides, flooding or, conversely, river overflow decreases, as a result of which the supply of fresh water decreases.

It is necessary to monitor the dynamics of changes in the Central Tuyuksu glacier. The use of remote survey methods, in particular re-Space surveys, is currently the most diverse for monitoring. In no other way can it be possible to simultaneously cover the entire area of the glacier, repeat observations and make a preliminary forecast of the evolution of the Glacier based on data analysis, and assess the ecological state of the studied area.

EXPECTED RESULTS

Remote sensing offers complementary information that can be used to monitor glaciers.

Automated methods for glacier mapping from satellite images

Machine learning techniques can play a significant and positive role in speeding the process up. We apply machine learning techniques to automate methods for glacier mapping from satellite imagery.

Develop the web-based tool

Additionally, we deploy our models as a web-based tool to demonstrate how machine learning can complement, rather than supplant, existing workflows.

Remote monitoring of glaciers

Remote sensing allows the estimation of parameters like snow cover, glacier elevation, and ice index over large geographical and temporal scales.

We are requesting raw Landsat 7 images used to create labels using the Google Earth Engine. In addition to the raw Landsat 7 tiles, we calculate the Normalized Difference Snow Index (NDSI), Normalized Difference Water Index (NDWI), and Normalized Difference Vegetation Index (NDVI) and add them as additional bands to the tiles. Vector data corresponding to glacier labels are loaded from the GLIMS regional database system. The preprocessing steps include converting vector data into image masks, cropping the input image and vector data to the Tuyuksu boundaries, and slicing the mask and fragments into 512 × 512 pixels.

Result 5.1

Automatic system for remote monitoring of mountain glaciers https://monitoringglacier.herokuapp.com / websites can be used. When opening the site, an interactive map of the Earth with satellite images was displayed on the screen (Figure 7). On the left side of the interactive map, there are functions for enlarging or stitching the map, performing the necessary or extracting data, tools for drawing various lines or shapes on the map surface, and processing and growing layers. To the left of the interactive map, there is a toolbar and a toolbar that controls map layers. Toolbars II "Inspector", "create graphics", "save map in HTML or image format", "delete all built objects", "open local vector / bitmap data", "convert JavaScript Earth Engine to Python"," change base map", "create time interval", "launch timslider".

The graph of the annual mass balance of the Tuyuksu glacier according to the given data. Shown here is the balance between accumulation (snow fall) and ablation (snow melt) on a glacier. The graph shows that ablation is superior to accumulation.

Glacier Mapping Tool To support the work of geospatial information specialists to delineate glaciers accurately we developed an interactive glacier mapping tool.

This interactivity supports the process of validating models, identifying systematic sources of error, and refining predictions before release.

The tool allows users to test our segmentation models on different sources of satellite imagery. Users can visualize predictions in the form of polygons and edit them to obtain a glacier map for the area of interest.

Conclusion

Monitoring, Management and Environmental Protection are the most important and complex tasks facing humanity, and effective data analysis is the key to solving them. The active development of Geoinformation systems and Remote Sensing of the Earth has led to the accumulation of a huge amount of structured information. Together with significant advances in cloud computing, this has created the conditions for the emergence of large cloud Geodesy processing platforms, the most popular of which is the Google Earth Engine. It combines satellite images and geospatial data sets into a single catalog, allowing them to be analyzed on a planetary scale. In addition, the platform itself is open source and free for non-commercial use.

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