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Anomaly based Method for Martian Surface Dynamics Analysis

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Abstract

With 40+ years of visible observations of the Martian surface from orbit, it has been discovered that the Martian surface is very dynamic in certain areas. With the amount of data and the small number of change datasets identified to date, a fully automated or semi-automated method is preferred to help identify potential candidates. In this research, a method based on autoencoder and anomaly detection is proposed for this purpose. Comparison is done to assess the performance of the method for different Martian changes. Further experiments have been done to help analyse Martian surface dynamics.

1. Introduction

The Martian surface has been found to be very dynamic with the observation of features such as Recurring Slope Lineae (RSL) [1], only observable at the highest resolution of HiRISE (25 cm/pixel) and hypothesized to be caused by the existence of water, transient features such as new impact craters, and latitude-limited features such as “Araneiform”, spider-like features [2] in southern high-latitudes over the SPRC, and many others.

Automated detection methods on Martian surface features have been more and more widely developed for different Martian features such as craters [3] amongst others, as well as the usage of deep learning methods [3][4]. Automated change detection method showever are not as widely developed, and mostly are supervised and feature-based. Misregistration is an issue in change detection research, especially with pixel-based algorithms.

2. Method

A method has been developed for automated co-registration of Martian image pairs [5] with both images automatically coregistered and orthorectified to HRSC orthorectified images and mosaiced orthorectified images to HRSC DTMs [6][7] and CTX orthorectified images to CTX DTMs [8] using the Automated Coregistration and Orthorectification (ACRO)[9] algorithm based on SIFT (Scale-Invariant Feature Transform) and ring matching to obtain coregistration with a typical accuracy of half the size of the base image pixel. The first image can then be mapped to the second image with a denoising autoencoder to encode the effect of different viewing conditions. Anomaly detection which is also called outlier detection or novelty detection is used to narrow down candidates on unpredicted change from the difference image result.

To test the automated method, annotated datasets are made from different high-resolution Martian image pairs from CTX, HRSC, MOC-NA, and Viking images for different Martian surface dynamics, such as dark slope streaks, dust devils, and uniquely polar features. Performance of different anomaly detection algorithms are tested for different dataset. Further analysis is done to candidates and further data around areas of interest, such as around the Nicholson crater to look at features of interest in the area by looking at the appearance/disappearance of dark slope streaks.

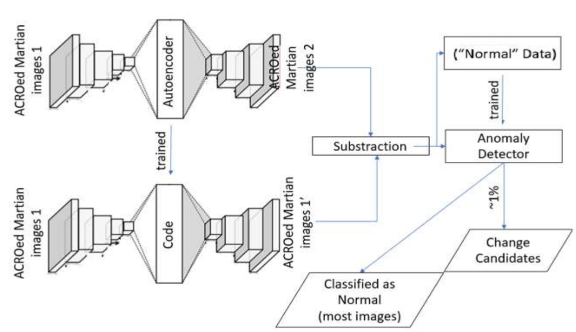

Figure 1: Schematic view of the overall change detection algorithm [5]

3. Results

Automated method is proposed to narrow down changes on on different Martian image pairs. The method is tested by comparing the result to annotated change detection test dataset. Changes are detected when image tiles are flagged as change candidates with changed pixels in a rasterized change mask obtained by annotating change shapefiles in the image pairs. An Isolation forest is obtained from the shortest decision tree to isolate anomalies. This works as an anomaly detector on all the test datasets, while a Gaussian Mixture Model, where probabilistic model is used to find subpopulations works best for polar image.

By looking at more data around the Nicholson area from images obtained in MY 31-34 (from the total non-HiRISE high-resolution observation available: 140 for 10 MY), obtained ~20 new slope streaks appearance per Martian year per 10,000 km^2, while no obvious disappearance of dark slope streak, corresponding to previous research where slope streak from Viking images were still observable in MOC images [10]. More examples will be given for dark slope streaks on the eastern Noctis Labyrinthus as well as for polar features.

4. Summary and Conclusions

An automated method has been developed to narrow down change candidates on Martian image pairs. The method works by inputting multi-instrument images that have been automatically coregistered and orthorectified to Martian base HRSC or CTX images to a denoising autoencoder. An anomaly detection algorithm is used on the subtracted images. An example of an application is given to observe the appearance and disappearance of dark slope streaks on Nicholson crater.

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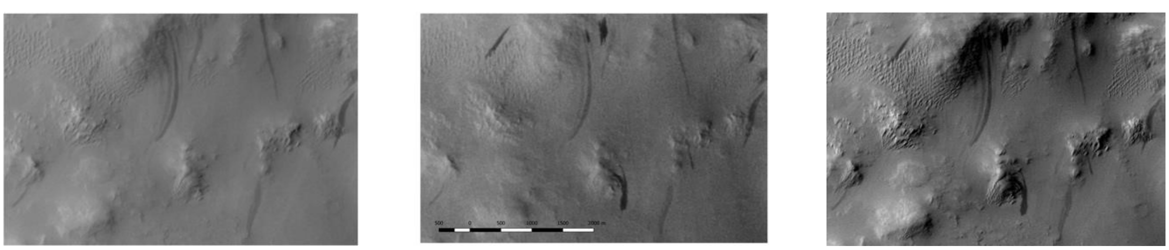

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Figure 2: Example of dark slope streaks appearance detected in Nicholson crater between MY 31-32 and the same features detected automatically in MY 34