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3D multi-resolution mapping of RSLs at Valles Marineris

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Abstract

We demonstrate techniques and results of multi-resolution 3D mapping of the whole of the Valles Marineris (VM) area of Mars using stereo images from the Mars Express High Resolution Camera (HRSC), Mars Reconnaissance Orbiter (MRO) Context Camera (CTX), High Resolution Imaging Science Experiment (HiRISE) and the ESA ExoMars Trace Gas Orbiter (TGO) Colour and Stereo Surface Imaging System (CaSSIS). Following this, we demonstrate the methods employed for the automated detection and tracking of the Recurring Slope Lineae (RSL) features over the mapped region using CTX and repeat HiRISE images along with their associated 3D information.

1. Introduction

RSLs are metre-to decametre-wide dark streaks found on steep slopes, which grow during the warmest times of the year, fading during the cooler periods and reappearing again (but not necessarily in exactly the same place). The origin of these features is strongly contested, with some authors suggesting they are formed by surface water [1] or brine and others suggesting they are completely dry processes [2]. The implications of each of these formation mechanisms is fundamental to constraining Mars' water budget and habitability.

The VM area is where the highest concentration of RSLs is found on Mars as well as being the sole location where the triple point of water can be reached during the Martian summertime. This study focuses on multi-resolution 3D mapping of the whole VM area using the cascaded HRSC-CTX-CaSSIS-HiRISE dataset, and automated RSL detection and tracking using the CTX and repeat HiRISE images. We focus on techniques and will publish the results of the multi-resolution 3D mapping and RSL tracking.

2. Multi-resolution 3D mapping

Previously, within the completed EU FP-7 iMars (http://www.i-mars.eu) project, a fully automated multi-resolution Digital Terrain Model (DTM) processing chain was developed at UCL for NASA CTX and HiRISE stereo-pairs, called the Co-registration ASP-Gotcha Optimised (CASP-GO), based on the open source NASA Ames Stereo Pipeline (ASP) [3], tie-point based multi-resolution image co-registration [4], and the Gotcha [5] sub-pixel refinement method. The CASP-GO system guarantees global geo-referencing congruence with respect to the aerographic coordinate system defined by HRSC, level-4 products and thence to the MOLA, providing much higher resolution stereo derived DTMs. By mid 2018, CASP-GO has been used to process ~5,300 planet-wide CTX DTMs [6] which are now being published through the ESAC Guest Storage Facilities (GSF) [7].

In this study, we refined and updated the CTX 3D mapping results for the whole VM area using a hybrid processing approach combining the CASP-GO method and the new ASP MGM method [3]. In addition, multi-resolution HRSC level 2 stereo images are being processed at UCL using CASP-GO to merge with the existing DLR HRSC level 4 DTMs to create a mosaiced base map of the VM area. A few TGO CaSSIS stereo images are currently being experimented with to form the cascaded HRSC-CTX-CaSSIS-HiRISE 3D dataset, which will be completed by mid June, 2019.

3. Super-resolution restoration

Within the completed EU FP-7 Planetary Robotics Vision Data Exploitation (PRoViDE) project (http://provide-space.eu), we developed a novel super-resolution restoration (SRR) algorithm called Gotcha Partial Differential Equation based Total Variation (GPT) SRR [8] to restore distorted features from multi-angle observations using advanced feature and area matcher and regularization approaches, achieving a factor of 2x-5x enhancement in resolution for repeat-pass HiRISE images [9].

More recently funded by the UKSA CEOI (SuperRes-EO project), we have further developed the SRR system using advanced machine learning algorithms, applied to Earth Observation (EO) data. The new Multi-Angle GPT with Generative Adversarial

Network refinement (MAGiGAN) SRR system [10,11] not only retrieves subpixel information from multi-angle distorted features from the original GPT SRR algorithm, but also uses the losses calculated from feature maps of the GAN network to replace the pixel wise difference based content loss of the original GPT algorithm in order to retrieve high texture detail.

We have ported most of the MAGiGAN SRR system to a GPU array and are about to form a training dataset from CTX and HiRISE images to apply this back to CTX and HiRISE images.

4. RSL detection and tracking

Studying the transport and formation processes on the Martian surface requires accurate measurements of dynamic features and the underlying 3D static surface. Tracking of such dynamic features has never been achieved automatically before due to the fact that detection and classification methods usually require a static reference frame and do not perform well when the feature itself is changing all the time. Previously, we demonstrated a new approach to detect and track the dynamic features by extracting the “static part” of the Martian surface through SRR using repeat-pass HiRISE observations.

Due to the ability of the SRR technique to extract super-resolution for static features, we are able to restore matched (unchanged) features and meanwhile automatically track the unmatched (dynamic) pixels to characterize and measure the “change”. Combining with a feature classifier, the detected dynamic changes can be further classified to known dynamic features, such as RSLs.

Previously, we reported on our initial RSL detection and tracking results of one of the RSL sites (centre coordinates: 41.6°S, 202.3°E) at Palikir Crater using the GPT SRR dynamic feature masking and SVM based classification from 8 repeat-pass HiRISE images [12].

In this study, we show modifications of the RSL detection and tracking system that involves a deep image network for better classification results at the VM area. The detection will be demonstrated using both CTX and HiRISE (where detection from CTX is positive) images. Tracking of the RSL features will be demonstrated using repeat HiRISE images.

5. RSL modelling

In the final stage, adding the 3D information derived from the multi-resolution DTMs, detected and tracked RSL features will be associated with their slopes and orientations, providing a more comprehensive interpretation of the RSL formation processes in 3D.

6. Future work

In the longer term, we aim to provide a regional map of RSL occurrence, with associated growth rates, timings (including inter-annual variability) and topographic information (including slopes and orientation) as well as uncertainties associated with the detection results.

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