AUTOMATIC DETECTION OF RED-SLOPED SPECTRA FROM 7-BAND DAWN FRAMING CAMERA DATA USING A 1D CONVOLUTIONAL NEURAL NETWORK. R. Sakar[1], A. Nathues[1], and M. Hoffmann[1]

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Introduction: 1 Ceres is the largest object (963 km diameter) in the main asteroid belt. It is one of the remnant large-bodies that were mostly destroyed or removed during the erosion of the asteroid belt [1]. Ceres is thermally evolved and partially differentiated into a rocky core and an ice-rich mantle, and might still hold remnant brines in its interior [2].

At a first glance, using panchromatic images, the Cerean surface displays clearly distinguishable bright patches in an overall dark background, with global reflectance ranging between ~0.03 and 0.37. However, the surface displays much more diversity when seen at individual wavelengths. An attempt for a global classification of the Cerean surface using the 7-band Dawn Framing Camera (FC) data led to the identification of five principal surface lithologies [3]. These five classes were distinguished on the basis of their spectral slopes, and reflectances at specific wavelengths in the 7-band FC data.

Out of these five color lithologies, one of the relatively scarce, yet very distinctive, surface types was called "reddish site" by [3] that coincided with local concentrations of aliphatic organics, present locally in the northern hemisphere, as found via the Dawn Visible and near-InfraRed (VIR) data [4]. In the 7-band FC data the reddish site red organic-rich materials (RORs) exhibited a distinctive, steep, red-sloped spectrum over the full range of FC wavelengths [5].

One such key ROR site is located in and around the Ernutet crater, and the RORs are found associated with small (few hundred meters diameter) fresh impact craters [5]. But beyond the few sites in the northern hemisphere, such occurrences of RORs were mostly considered absent. However, recently a second ROR site was identified in a scarp within the Urvara crater [6].

This leads to the possibility for the presence of further ROR sites on Ceres. Based on the geological context of the RORs in Ernutet, the RORs cannot be definitively classified as endogenic or exogenic. In order to be certain of the origin of RORs, knowledge of the global distribution of this surface type is essential. Hence, to explore the surface of Ceres at the pixel level in real time we are implementing a 1D Convolutional Neural Network (CNN) to detect FC pixels that are spectrally similar to the Ernutet ROR spectra. Although, the presence of a reddish slope does not necessarily indicate RORs, a classified global map of red-sloped spectra could narrow down the search to a few potential locations that can be visually tested for organic materials using the VIR dataset.

Methodology: The 7-band FC data obtained during the High Altitude Mapping Orbit (HAMO) provides a complete coverage of the Cerean surface at a resolution of ~130m/pixels. Hence, a global HAMO color mosaic created using an in-house USGS ISIS script was used for the search for red-sloped pixels.

Due to the sheer size, the HAMO data was first split into 48 tiles. A small area from the tile containing the Ernutet crater was manually classified into red and non-red pixels for use as training data for the 1D CNN. The average spectral shape of all the red-sloped pixels, identified through visual inspection of the Ernutet area is shown in Figure 1. After several iterations of tuning the architecture and hyper-parameters, the model was able to classify pixels into red and non-red. Presently, we are still working on improving the classification accuracy of the model.

The 1D CNN implemented in this study comprises of four convolutional layers, four max-pooling layers, and two fully-connected layers. ReLU was used as the activation function for all but the last layer, for which a SOFTMAX activation function was used. To avoid overfitting, we added dropout layers and also implemented batch-normalization of the convolutional layers.

The training data (n=1201) was split into 50% as training data and 50% as testing data. The model was then trained for ~1500 epochs. The trained model was then applied to the tiles one by one and the predicted red pixels with the highest score were evaluated manually to test the accuracy of the model.

The output image indicating the probability of a pixel being red-sloped, was first classified into red and non-red by setting a 99.9% threshold. The binary image was then filtered with a 30x30 moving filter to find global clusters of the red-sloped spectra.

Results: From our preliminary results we observe the following:

1. There are several clusters on Ceres that display local concentrations of red-sloped spectra. Some of these identified areas consist of a single pixel that is red-sloped, while at other areas, several pixels are found to occur in proximity. Since the spatial resolution of the

HAMO tiles are ~130 m/pix, even single identifications are important as spectral mixing reduces the chances of identification with increasing pixel size.

2.   Some red-sloped spectra are not as steeply red as the Ernutet, or not over the full spectral range, and hence might indicate some other component, or could be the result of other processes and physical effects such as space weathering, grain size, and mixing with other surface types.

3.   Some red-sloped pixels are very similar to the Ernutet ROR spectra.

4.   A weak influence of topography is also apparent in the distribution of the red-pixels, which are often seen clustered around small craters. However, to establish such topographic influence in the spatial distribution of red-pixels, we would need further analysis.
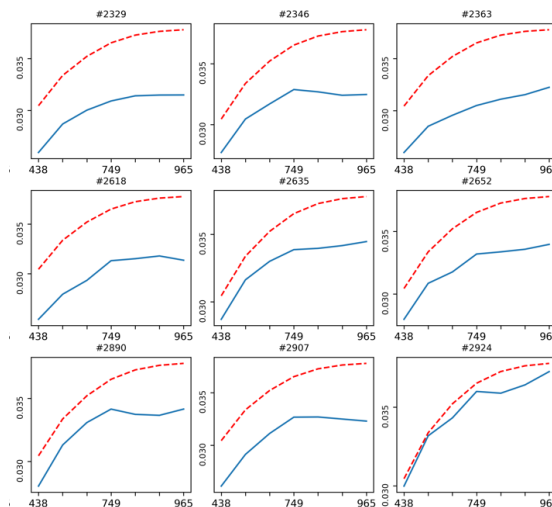
A few of the predicted red-sloped spectra from the model is shown in Figure 2. These spectra are from a single tile, for the purpose of demonstrating the classification results. Also, the pixels in adjacent subplots are not necessarily spatially adjacent. As it can be seen from the plots, some of the predicted spectra (solid blue) match closely the Ernutet average red-sloped spectra (dashed red). However, some spectra do not match so well. Hence, several cases of false positives are present. On the other hand, cases of false negatives might also exist. Presently, the model is still being optimized for better classification accuracy.

Conclusions: Based on our preliminary results, the surface of Ceres appears to contain several more locations that are spectrally similar to the Ernutet red-sloped spectra. Whether these areas actually contain RORs or something else would require their spectral analysis using data from the Dawn VIR instrument. A picture of the global distribution of RORs would not only refine our understanding of the geological evolution of Ceres, but also open new questions.

References: [1] Minton, D.A. and Malhotra, R. Icarus, **207 (2)**, pp.744-757 (2012). [2] Fu, R. et al. *Earth Planetary Sc. Lett.* **476**, p. 153-164. (2017). [3] Nathues, A., et al. Planetary and Space Science, **134**, pp.122-127 (2016). [4] De Sanctis, et al. Science, **355**(6326), pp.719-722 (2017). [5] Pieters, C.M., et al., Meteoritics & Planetary Science, **53(9)**, pp.1983-1998 (2018). [6] Nathues et al., (this LPSC).
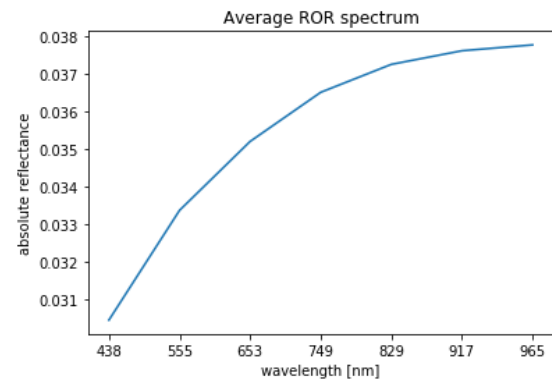
Figure 1. *Average FC color spectrum of red-sloped pixels from the Ernutet crater area that were identified as RORs from VIR.*

Figure 2. *Few examples of the predicted red spectra. Solid blue line indicates the identified red-sloped spectrum, dashed red line represents the average red-sloped spectrum from the Ernutet area.*