ENDMEMBER DETECTION IN CRISM IMAGES USING GRAPHS N. Rohani[1], M. Parente[1], [1]Remote Hyperspectral Observers group, Electrical and Computer Engineering Department, University of Amherst, USA

Introduction: Automatic processing of hyperspectral images is an increasingly important task due to large volume of data produced by planetary machine, which outpaces the ability of researchers for manual analysis. Most of the automated approaches used in hyperspectral imaging are based on the representation of hyperspectral images as "clouds" of points in (Euclidean) spaces of dimension equal to the number of spectral channels. Endmember detection approaches aim at identifying the purest pixels (endmembers) in the image, a task which is complicated by the presence of intimate (nonlinear) mixing at every scale on planetary surfaces. Previous studies confirm that in the presence of mixing (areal or intimate) the most pure pixels are located at the extremities of the data cloud. These extreme points with unique spectral signatures are called endmembers. Endmembers detection for CRISM datasets is particularly challenging due to residual atmospheric contributions to the spectra, instrumental artifacts and effects of illumination geometry. Most of the available approaches assume global geometrical structure in the data cloud. The distortions existent in the spectra of CRISM images result in destroying global geometrical structure. Recently, Parente et al. [1][2] proposed an approach by assuming only local geometrical structure which outperformed other currently available methods. Continuing his work, we want to propose an approach that does not make any assumptions on the structure of the data cloud for detecting endmembers of CRISM images. We use graphs for modeling the images as they impose the least assumptions possible. Approaches based on graphs [3][4] have been used in image clustering and anomaly detection.

Method: We apply some standard preprocessing steps to the images to perform scientific analysis[5][6]. Thompson et al. [7] showed that performing a fine segmentation on the image and extracting the endmembers from the cloud composed by the average spectrum in each segment (superpixel) improves the unmixing performances. Therefore, we create a graph with the average of the superpixels as the nodes, the minimum size of each segment equal to 20 and spectral angle distance as the distance metric[7] . We build an edge between two nodes if the Euclidean distances between their spectra is below the average spectral distance between nodes in the whole image. In order to discriminate the boundary points from the central (mixed) points, we calculate a well-known measure of centrality called betweenness centrality [8] for all the nodes. It is shown in [9] that the boundary points have smaller value of betweenness centrality than the central points. The set of points with low values of betweenness centrality are more extreme than others on the boundary and therefore this set contains the endmembers. We also observed that endmembers exhibit longer spectral Euclidean distances from their nearest neighbors with respect to central points because central part of the data cloud is more dense. So, in the set of the points with the lowest value of betweenness centrality, we select the points with the larger sum of spectral Euclidean distances from their nearest neighbors. The resulting points are the candidate endmembers. For more description about the method, the reader can refer to [10].

Results and Discussion: In order to evaluate our method, we will apply it to a large set of CRISM images and here we show two examples (images FRT000094F6 and FRT00003E12). We selected the range from 1.1127μm to 2.6285μm in order to compare our results to the published endmembers spectra in the literature[11][12]. Manual mineral identifications are presented in Fig. 1 and Fig. 3 and are used for the validation of our results. The results of applying the algorithm to the images are shown in (Fig. 2 and Fig. 4), respectively. Comparing the obtained spectra (Fig. 2 and Fig. 4) with the ones identified by scientists manually (Fig. 1 and Fig. 3), we verify the proposed method detects the published endmembers properly. One advantage of the proposed method over other automated approaches is the fact that the number of the endmembers is not required beforehand. Our algorithm gives ranks to the candidate endmembers based on the aformentioned measures. We observed that the published endmembers of the two simulated images have the highest rankings and can be extracted from the list of the candidate endmembers as the most unique spectral signatures.

References: [1] M. Parente, et al. (2011) in *Lunar and Planetary Institute Science Conference Abstracts* vol. 42 2622. [2] M. Parente, et al. (2011) in *Geoscience and Remote Sensing Symposium (IGARSS), 2011 IEEE International* 1291 –1294. [3] D. Messinger, et al. (2011) in *Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS)* 1 –4. [4] R. Mercovich, et al. (2011) in *Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS)* 1 –4. [5] S. Murchie, et al. (2007) *J Geophy* 112(5):1 . [6] S. Murchie, et al. (2009) *J Geophy* 114(E00D07):1 . [7] D. Thompson, et al. (2010) *IEEE Transactions on Geoscience and Remote Sensing* 48(11):4023. [8] L. Freeman (1977) *Sociometry* 40:3541. [9] G. Destino, et al. (2008) in *Positioning, Navigation and Communication* 271 –275. [10] N. Rohani, et al. in *to be submitted to IGARSS 2013*. [11] J. L. Bishop *to be submitted*. [12] B. L. Ehlmann, et al. (2009) *J Geophy* 114(E00D08):1.

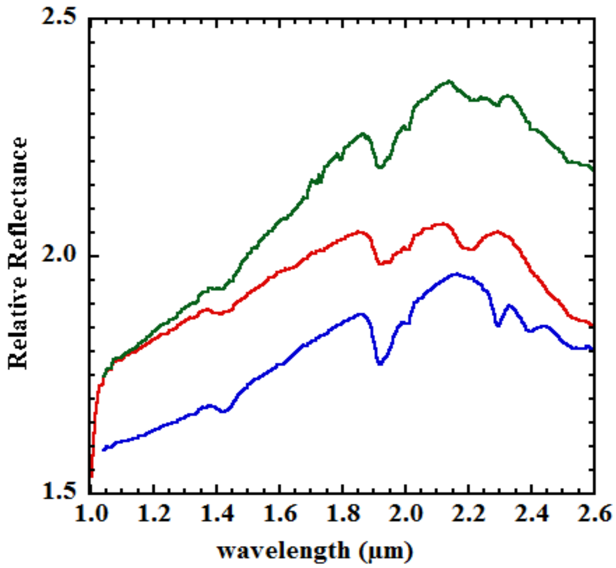

Figure 1: Endmembers of CRISM Image 94F6 found by scientists(Al-smectite=red, Fe^{2+}=green, Fe/Mg smectite=blue)[11].

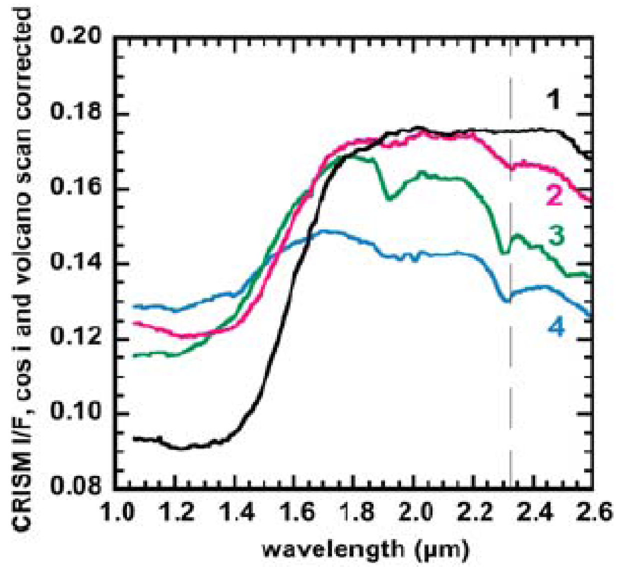

Figure 3: Endmembers of CRISM Image3E12 found by scientists[12](Fig. 17 (d)). (Olivine=(1), Serpentinixed Olivine=(2) which is another representation of Olivine, Mg card=(3), Fe/Mg smectite=(4))

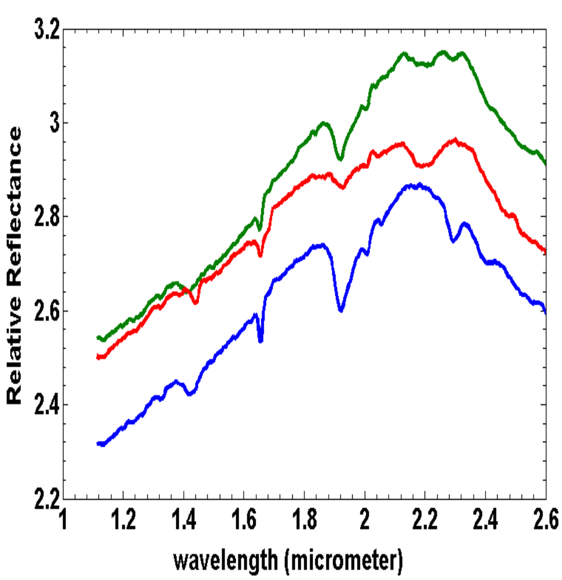

Figure 2: Endmembers of CRISM Image 94F6 Extracted by the Proposed Method. (Al-smectite=red, Fe^{2+}=green, Fe/Mg smectite=blue)

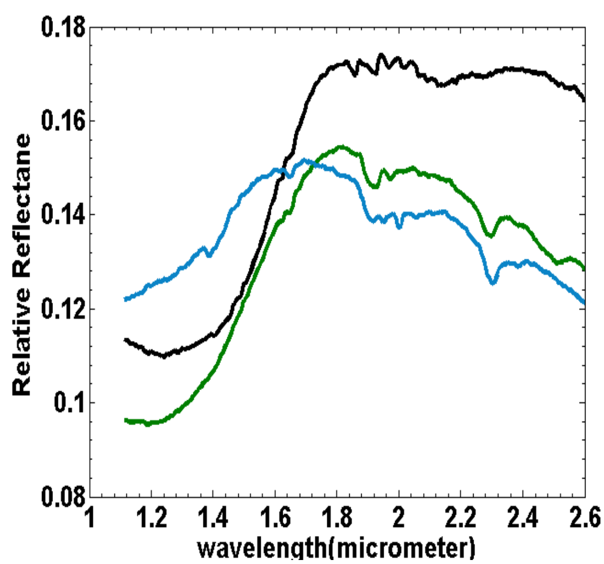

Figure 4: Endmembers of CRISM Image3E12 Extracted by the Proposed Method. (Olivine=black, Mg card=green, Fe/Mg smectite=blue)