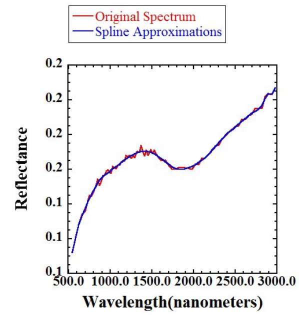
AUTOMATIC EXTRACTION OF UNIQUE SPECTRAL SIGNATURES FROM THE M^3 DATABASE Arun Saranath[1], Mario Parente[1], [1]College of Engineering, University Of Massachusetts, Amherst MA 01003 USA; asaranat@engin.umass.edu

Introduction: The surface of the moon consists of both Feldspathic and Mafic Minerals. The presence of these mafics such as spinels,olivines,pyroxenes are helpful in understanding the crustal composition of the moon and provide clues about the mechanism of crust formation [1]. Researchers have introduced a variety of spectral parameters such Band Ratio and Integrated Band Depth for M^3 data. The parameters were successfully used by scientists for detecting Mafics and Feldspaths e.g.[[1] [2] [3]]. We attempt to automate the process of extracting unique spectral signatures from the image.This would allow us to describe large images in terms of only a few spectral signatures. To find these unique signatures we use unmixing algorithms i.e. we attempt to find the "purest pixels". The unmixing is made harder due to the pervasiveness of intimate mixing and maturity trends [3].

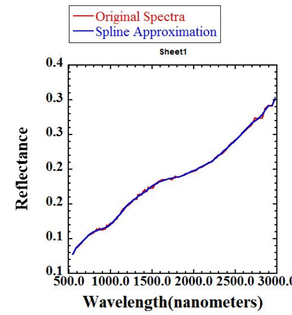
Data and Methods: The Dataset used was acquired by the Moon Mineralogy Mapper(M^3),aboard India's Chandrayaan-1 that acquired data in the 0.43-3.0 μm wavelength range. The data discussed were acquired in the lower resolution(global) mode that has 85 usable spectral bands. We process M^3 level-2 reflectance data [4] [5].

The parameters have proven to be highly susceptible to noise and instrument distortions. To ameliorate the effect of these distortions we fit the spectra using a high-penalty smoothing spline.

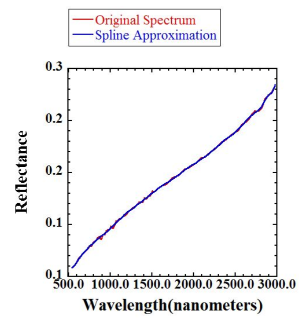
As can be seen from figure 1 these spline reduce high frequency noise but do not distort the important characterstics such as bands. The parameter maps thus created are now of a lower dimensionality and require fewer resources for future processing and storage .Once the parameters are calculated we use an Linear Unmixing Algorithm to find the 'pure pixels'. The Unmixing algorithm attempts to find these 'pure pixels' as spectra such that the other spectra in the image can be expressed as linear combinations of these spectra.



(a) Fitting spline to a spinel

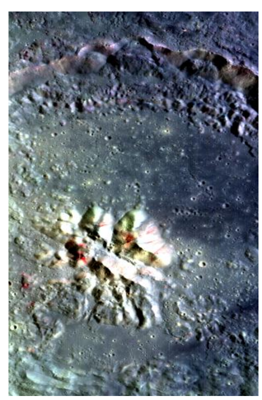


(b) Fitting spline to a pryoxene

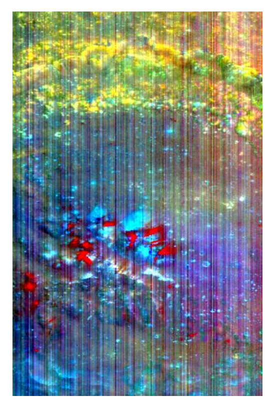


(c) Fitting spline to a plagioclase

Figure 1: Fitting Splines To Lunar Spectra



(a) Lunar Surface using M3 bands



(b) Map using Mineral Parameters

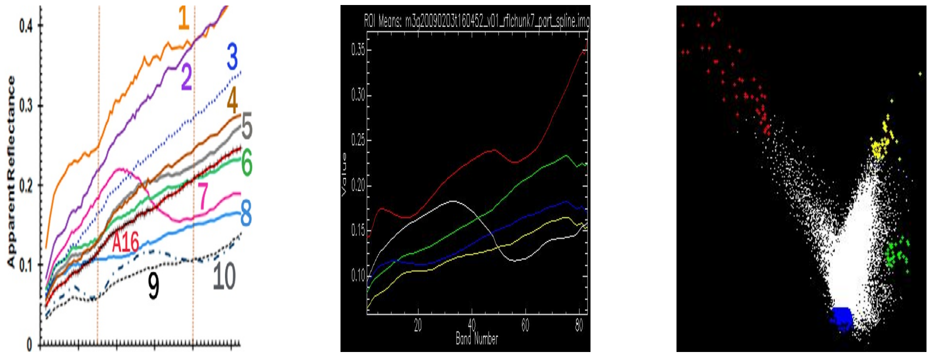
Figure 2: Parameter Map for a chunk of M3G20090203T160452(Lines 12401-13000)

Table 1: Set of Parameters Used

Parameter	Description	Purpose
IBD-1000	1 μm integrated band Depth	Useful in identifying the presence of minerals containing Fe^{2+} such as Olivine, Pyroxene
IBD-2000	2 μm integrated band Depth	Useful in identifying the presence of minerals Pyroxene, and Mg-bearing Spinels
BD-1250	1.25 μm band Depth	Captures the presence of Plagioclase
BD-2300	2.3 μm band Depth	Pyroxene especially High Calcium Pyroxene Favored
BD-1900	1.9 μm band Depth	Pyroxene especially Low Calcium Pyroxene Favored
OLINDEX		Highly positive in the presence of Olivine

The Parameters:

Mineral Identifiers: - This group is used to identify minerals of interest. Fe^{2+} bearing Mafics such as olivine and pyroxene generally have bands at either 1000nm or



(a) Mineral Samples identified in [2].(SOURCE:- Figure 3(c) [2])

(b) Spectra at Pixel selected by SMACC in parametric space

(c) Projection Of parametric Data Cloud marking specta locations

Figure 3: Fitting Splines To Lunar Spectra

2000nm due to the presence of Fe^{2+} in the crystal structures. Mg-bearing spinels have a band at 2000nm. Plagioclase exhibits a feature near 1250nm if it contains some FeO, but this not always seen. The first three parameters attempt to capture these features. The IBD-1000 return high value(bright pixels) is highly positive for olivine and pyroxene, while IBD-2000 highlights pyroxene and spinels. The BD-1250 is used to find crystalline plagioclase.These together form one map with IBD-1000,IBD-2000 and BD-1250 being R,G and B respectively. On this map spinels are seen in Red, olivines in Cyan and pyroxenes in yellow/orange and crystalline plagioclase is tagged in blue. This can be seen in 2b

Family Identifiers: - Two different members of the pyroxene families have been identified on the moon, both exhibit bands at both 1000nm and 2000nm, they only differ in the location of the minimum which depends on the amount of calcuim in the crystal . The parameters described above are not sufficient to discriminate between low and high- Ca pyroxene, so two parameters are selected help discriminate between them. The BD-2300(band depth at 2300nm) prefers High-Ca pyroxene while BD-1900(band depth at 1900nm)prefers the Low-Ca pyroxene. The OLINDEX similarly is defined to favor Olivines. These parameters together provide complete discrimination between all minerals with bands at 1000 nm. In the second map, the BD-2300,OLINDEX and BD-1900 are used as R,G and B respectively.The High-Ca pyroxene is megenta, the low-Ca pyroxene is cyan and while the Olivine is in green. A map similar to the one shown in 2b can be created in this case too.

Results: As an example we chose a well studied lunar feature i.e. the Theophilius Central Peaks. The various minerals here have been previously explored in [2]. This area is known to have samples of various different Minerals as can be seen in figure 3a.In [2] the entire theophilius crater is considered but the image considered here only contains the central peaks and as such of the sample spectra shown in figure 3a only samples 1 (High Ca-pyroxene),2 (plagioclase),6 (olivine),7 (spinel),8 (plagioclase) are present in the image selected . A projection of data cloud in parameter space is shown in figure 3c.The location of pixels corresponding to mineral signatures is marked in the cloud. It can be clearly seen that pixels with spectra closest to the mineral spectra are the extreme pixels of the cloud and such can be selected by unmixing algorithms. The end-member detection using SMACC was performed on this data cloud [6]. The pixels corresponding to the end-members in the parameter space are shown plotted in figure 3. The end-member found by SMACC include all the classes in the image i.e. spinel, olivine, pyroxene(both high an low Ca) and plagioclase .This process can be automated and used for End-Member detection for Lunar Data and we can use a Pure Pixel Unmixing Method on the data cloud in the parameter space.

An important factor that has not been considered yet is the maturity the spectra. But as has been shown in [3] this can also be represented using parameter. The addition of these parameters is expected to help discriminating between spectra of the same family that appear slightly different due to Maturity effects.

References: [1] e. a. Pieters, C. M. (2011) *J of Geophys Res* 116(E00G08):14. [2] D. e. Dhingra (2011) *Geophysical Research Letters* 38:4. [3] e. a. Nettles, J W (2011) *Journal of Geophysical Research* 116:12. [4] e. a. Green, R. O. (2011) *Journal of Geophysical Research* 116:31. [5] y. v. . . i. p. j. . J. d. . J. a. R N Clark et al, title =Thermal removal from nearinfrared imaging spectroscopy data of the Moon .
[6] J. H. G. e.a (2004) *Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery X In Proceedings of the SPIE* 5425:14.