QUANTITATIVE SPECTRAL MIXTURE MODELING APPLIED TO VIKING LANDER IMAGES

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A quantitative analysis is made of a series of Viking I and II Lander images made at differing illumination/viewing geometries. The spectral reflectance of each pixel in each image is fit, using a nonlinear least-squares fitting technique, to an algorithm which relates reflectance to the mixing of two or more components, illumination/viewing geometry, particle size, and the amount of shade/shadow found in the pixel.

For the Viking Lander image we model the scenes as linear (macroscopic) mixtures of soil and rock endmembers, the spectral reflectances of which are taken from pixels in each image. These pixels are chosen using principal component analysis (PCA) techniques, as described in Adams et al. (1985). The shade endmember is defined as a spectrum with zero reflectance at all wavelengths. PCA shows that the scenes are illuminated by direct sunlight and by indirect lighting from the atmosphere or the Landers themselves.

Explicitly the reflectance of a Viking Lander pixel can be modeled as

$$r = f(R, g1, g2, S, I)$$

where R is the ratio of soil to rock abundance in a pixel, g1 is the solar phase angle, g2 is the phase angle of indirect lighting, S is the relative amount of shade, and I is the ratio of the intensities of indirect to direct lighting. R is the main parameter of geological interest which must be solved for. g1 can be determined accurately from simple geometric considerations. This equation is custom designed by combining the general algorithms from Johnson et al. (1986) as modules. One must also solve for the parameters g2, S, and I. The viability of the fit is determined by:

1) the correspondence between the visual cues in the shade image (image of S) with the raw image,
2) the correspondence of pixels of extreme R with pixels in the raw image whose texture and shade flag them as highly likely soil or rock components, and
3) the systematics of the I image caused by a reasonable source of indirect lighting (the sky or spacecraft).

To summarize, we can quantitatively model Viking Lander images by:

1) identifying the major sources of spectral variation in a scene with PCA,
2) custom designing an algorithm to model these variations,
3) fitting the algorithm to the data, giving physically meaningful parameters at each pixel, and
4) redisplaying images of these parameters.

References

1. Adams, J.B., M.O. Smith, and P.E. Johnson (1986), "Spectral Mixture Modeling: a New Analysis of Rock and Soil Types at the Viking Lander 1 Site", J. Geophys. Res., (in press).
2. Johnson, P.E., M.O. Smith, and Adams, J.B. (1986), "Quantitative Determination of Mineral Abundances and Particle Sizes from Reflectance Spectra", submitted to J. Geophys. Res.