Macroscopic texture of the Martian surface: application of a filtering method using Mars Eexpress HRSC data.

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Introduction: We present here a method based on a filtering process to quantify the "macroscopic texture" of a planetary surface at the scale of a few pixels. We apply it to an impact crater on the Martian surface, using images from the High Resolution Stereo Camera onboard Mars Express.

Background: Texture content analysis is understood differently depending mostly on the scale of the analysis. In photometry, the texture corresponds to the surface boundary state inside pixels from sub-millimeters to centimeters scale [1]. In digital image processing, the texture is used to quantify a homogeneous aspect of an object inside an image and the scale of the analysis (few pixels) is larger than in photometry. Hence it is called "macroscopic texture".

Texture content analysis in digital image data has received much attention during the past decades in the context of image classification and segmentation [2]. With the increase of the spatial resolution obtained with the latest cameras onboard planetary missions, powerful tools developed for texture analysis can be adapted to the description of planetary surfaces. Indeed, it provides a characterization of the macroscopic texture at the scale of a few tens of meters.

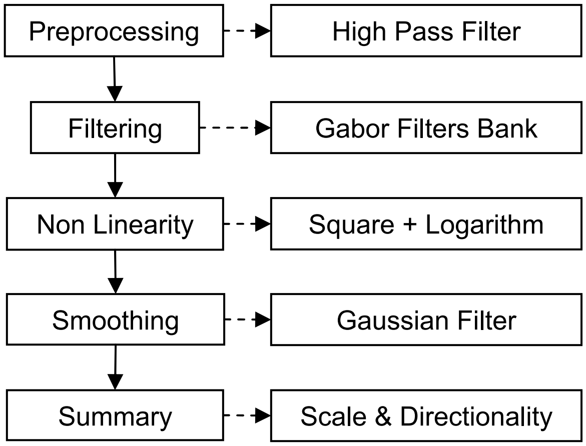

Figure 1. Steps of the filtering process

Method: Figure 1 shows all the steps of the process to be applied on high resolution planetary images. First, a preprocessing step corrects each pixel from the mean grey level around it; it consists of the division by a large mean filter (50 pixels wide), corresponding to a high pass filter. Then the result is convolved with a set of 12 Gabor filters. Those filters are described by a spatial product of a sine and a Gaussian function. We used 3 different sine frequencies (see Figure 2) combined with 4 directions (0°, 45°, 90°, 135°).

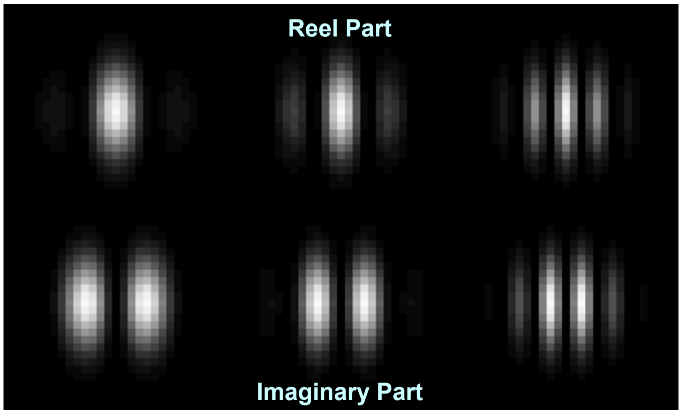

Figure 2. Different frequencies of the Gabor filters. The distances between two maxima correspond to 8, 6 and 4 pixels from left to right.

In the next step a local energy function is applied, consisting of a non-linearity and smoothing component. For each planetary image, 12 energy images are obtained (3 frequencies x 4 directions). In order to summarize this information, we calculate, for each filter frequency, the average and the standard deviation of the 4 corresponding energy images. As a result, a high value of the mean image corresponds to a strong answer at the considered filter frequency and then to an important texture at this scale. A high value of the standard deviation image corresponds to a strong directionality of the texture, whatever the direction.

Results: As a demonstration, we apply the method described above to a nadir image from HRSC with a spatial resolution of 12 m/pixel, acquired during orbit 24, over the Gusev crater area (Figure 3). Upon initial inspection, the ejecta texture appears rougher than its surroundings. Indeed, this will be confirmed and quantified in the following analysis.

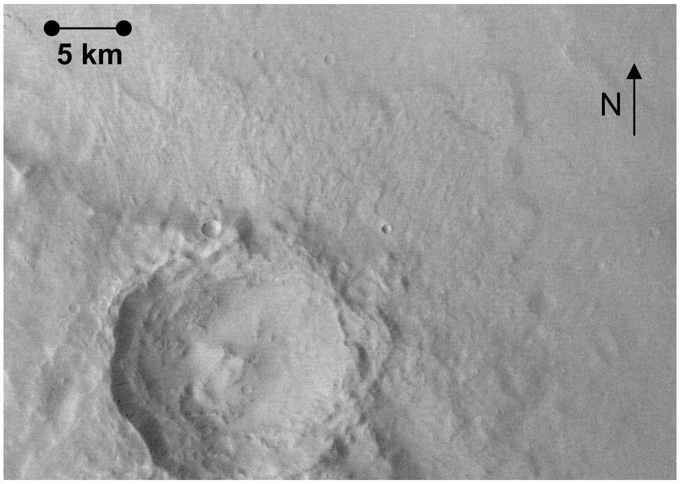

Figure 3. Crater's ejecta (Lat -7°, Lon 184° W).

The standard deviation images show no significant directionality, so they are not displayed here. Figure 4 shows the mean images resulting from the filtering process. First, the ejecta blanket is clearly visible in the mean image which corresponds to the rougher texture. In particular, the difference in roughness between the ejecta and its surroundings is apparent when using the two larger filters (6 and 8 pixels) but not when using the smallest one (4 pixels).

An explanation could be that the crater is partially covered by dust. This dust effectively smoothes out the surface roughness thereby masking the high frequency relief. From [4] we obtain the thermal inertia values for the ejecta blanket and its surroundings as 74.5 +/- 11 and 65.7 +/- 11 (J m^{-2} K^{-1} $s^{-½}$). These values are small when compared to other regions of Mars (max. 800), thus probably corresponding to loose, fine surface dust and very few rocks [4]. Hence, the rocks of the ejecta are covered by dust and therefore, no significant variations in thermal inertia are detected. Despite this, our process allows for the detection of some texture due to the rocky ejecta.

Conclusion: This tool provides us with a powerful method for the description of the surface texture. This relates, in this case, to the relative thickness of dust deposit on the surface. Therefore, this method constrains some geological and geomorphological properties of the considered area. It may lead to a systematic analysis and classification of the Martian surface texture.

References: [1] Cord A. et al. (2003) Icarus, 165, p. 414 – 427. [2] Reed T. R. and du Buf J. M. H. (1993), CVGIP: Image Understanding 57, 359-372. [3]. Randen T. and Husoy J. H. (1999), IEEE Transactions on Pattern Analysis and Machine Intelligence 21 (4), 291-310. [4] Putzig, N. E. et al. Global thermal inertia (…), Icarus, in press, (2004).

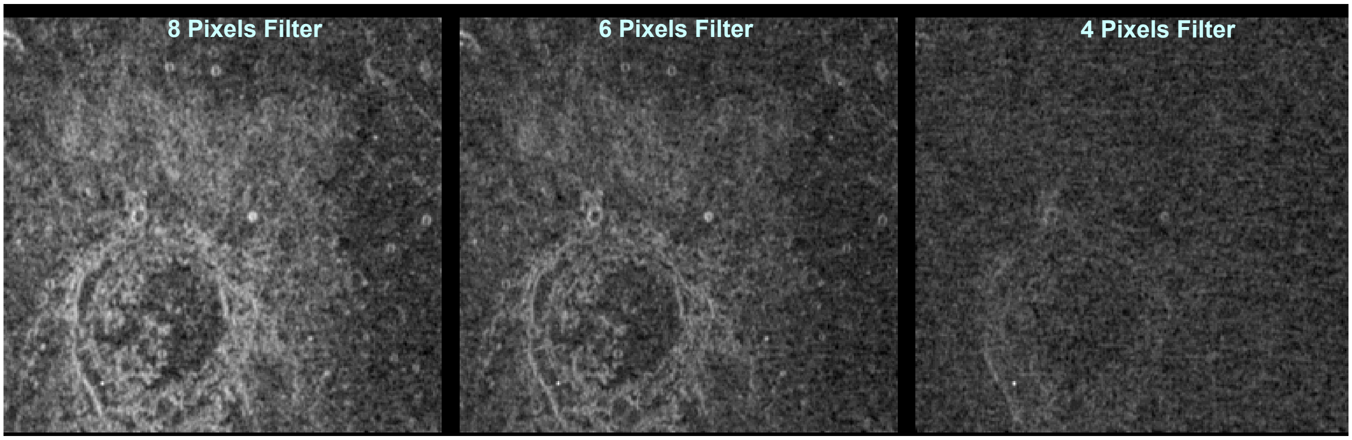

Figure 4. Result of the filtering process: Mean images for the different filters.