

PIXEL-SCALE FEATURE DETECTION IN SPACECRAFT IMAGES: APPLICATION TO VIKING ORBITER FRAMES. L. Wilson^{1,2}, D. N. Ashcroft¹ and J. B. Garvin². (1) Dept. Environmental Sciences, Univ. of Lancaster, Lancaster LA1 4YQ, U.K.; (2) Dept. Geological Sciences, Brown Univ., Providence, RI 02912.

The highest-resolution Viking Orbiter frames have image scales of less than 10 m/pixel and can be used to identify features whose sizes are of the order of several pixels (1). In general it is not possible to obtain unique information about features smaller than this. However, if some separate information about the types of features to be expected is available, it may be possible to make useful deductions from the brightness values of even single pixels.

An example of this relates to the Viking Lander sites. The Lander images (2) show a distribution of boulders with sizes up to several m at each site (3,4,5), and one might expect a very small number of the largest boulders to be resolvable in Orbiter frames (1). More numerous, however, should be examples of unresolved boulders whose bright, sunward-facing sides contribute to unusually high DNs (data numbers, proportional to surface brightness in photometrically decalibrated images) for certain pixels and whose shadows contribute to unusually low DNs for others. In images with low solar elevations, the second type of event should greatly dominate the first. At fairly high solar elevations, the most common spatial correlation between anomalous pixels is expected to be the occurrence of a bright pixel immediately adjacent to a darker than average pixel. However, at all solar elevations it may happen that a single pixel contains both the sunward face of a boulder and the foot of its shadow. This pixel may, therefore, show only a minimal brightness anomaly, and no boulder will be "detected" unless the shadow is long enough to produce at least one unusually dark pixel in this case. The anomalous brightnesses of pixels caused by the presence of discrete features with significant relief will, of course, be superimposed on a distribution of pixel DNs due to the distribution of surface slopes at a horizontal scale length equal to or greater than the pixel size. There is, therefore, inevitably a statistical aspect to the identification of small features producing anomalous pixels.

We have tested these ideas on part of frame 452B09 which shows an area near the Viking 1 lander site with a solar elevation of 42.2°. Table 1 shows the distribution of pixel DN values in the region defined by lines 450 to 600 and samples 600 to 1000 in this frame. An approximately gaussian distribution of brightness levels is found, with three outliers to the main distribution having DN values of 88, 120, and 121. The probability of these outliers belonging to the main part of the distribution is less than 10⁻⁵. To give an alternative impression of the significance of these brightness variations, Table 2 gives the distribution of the angular tilts, positive towards and negative away from the Sun, of the surface elements corresponding to individual pixels. Brightness variations have been converted to tilts using the Lommel-Seeliger function, so that if D is the value of a pixel DN and B is the mean DN for the scene, the tilt T of the surface element corresponding to this pixel is given by the solution of:

$$\frac{D}{B} = \frac{\cos(I-T)}{\cos(I-T) + \cos(E-T)} \frac{(\cos I + \cos E)}{\cos I}$$

where I and E are the angles of incidence and emergence at an untilted surface element.

Table 2 shows clearly the main distribution of brightnesses corresponding to surface undulations (the mean tilt is -0.08° and the RMS slope is 1.105°), superimposed on which are the three anomalous pixels with DNs corresponding to tilts in excess of 5°. Location of these pixels on the original image shows them to be strongly spatially correlated: Table 3 is a listing of the anomalous area and its surroundings. The suggested interpretation is the presence of a boulder with a diameter of about 10 m (the image scale is 7.70 m/pixel in this frame) (3).

This study of a small area in one Viking Orbiter frame has shown that the automated detection of discrete features at the limits of spatial resolution has some value. There is clearly a considerable potential problem, however, in discriminating between the brightness distributions produced by undulating surface topography at the pixel scale and the presence of sub-pixel-sized boulders (or, for that matter, craters) on an otherwise nearly flat plain. Also, care must be taken not to misinterpret anomalous pixels produced by corrections for transmission errors from the spacecraft. We are currently studying the extent to which algorithms for detecting near-pixel-size features in digital images can be safely automated, thus minimizing operator intervention, and also the extent to which they can be made self-adaptive for incorporation into more general image-analysis programs. Finally, such analyses can help bridge the resolution gap between lander images, Earth-based radar data (at cm wavelengths) and high-resolution orbital images.

Table 1. The numbers, N, of pixels having a given data number, DN, on Viking Orbiter frame 452B09 within the area defined by lines 450 to 600, samples 600 to 1000.

DN:	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104
N:	0	1	0	0	0	0	0	7	15	97	238	720	1429	2772	3923	4883	6008	7859
DN:	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122
N:	8682	8012	5959	3330	1469	555	134	33	4	2	1	0	0	0	0	1	1	0

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Table 2. The numbers, N, of pixels having a given tilt, T, towards (positive) or away (negative) from the Sun within the area defined in the caption to Table 1. The mean tilt is -0.082° and the RMS slope is 1.105° .

T:	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8
N:	0	1	0	22	1055	4201	14814	16541	17301	2024	167	7	0	0	2	0

Table 3. DN values in the vicinity of the anomalous pixels (values underlined) based on a mean DN of 105 (see Table 1). The mean value within this area is in fact 110.1, but this does not influence the identification of the anomalous pixels.

		SAMPLES									
		607	608	609	610	611	612	613	614	615	
		474	108	105	109	109	109	109	109	109	111
		475	109	108	109	109	111	111	109	109	109
		476	105	109	105	109	109	110	111	111	106
		477	107	109	109	109	111	114	113	111	111
	LINES	478	107	107	111	<u>120</u>	<u>121</u>	107	105	107	109
		479	110	109	109	107	97	<u>88</u>	97	105	111
		480	109	110	109	110	107	103	107	109	113
		481	105	108	109	107	109	107	108	109	110
		482	107	110	105	108	109	109	105	109	109

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