AUTOMATING SHAPE ANALYSIS OF ROCKS ON MARS

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Introduction: A variety of processes, including impact, aeloian, volcanic, and fluvial, and processes, have shaped the surface of Mars. Each of these processes changed both the planet's surface and individual rocks that are transported or formed by the process. Thus, the nature of forces that were locally active werereflected in the form or shape of individual rocks in a region. The ability of a rover to determine the shape properties of rocks that it encounters is a critical element contributing to the in situ determination of geologic terrain features and possible active processes. We have developed an automated technique to allow a rover to quantify the shape and other geologic characteristics of rocks from two-dimensional visible wavelength images and three-dimensional stereo range data. With this knowledge, a rover would be able to direct its activities to regions of higher geologic significance such as identifying areas of long-standing water and to prioritize the downlink of data, thus maximizing the scientific return of the mission.

Shape Analysis: Shape is a geologically important characteristic of rocks. However, the shape of a rock is a complex property that can be difficult to describe precisely. A great deal of geological work has been conducted on classifying and categorizing the general appearance of microscopic particle grains with respect to various properties [1-5], and the same basic concepts remain applicable when scaled to the macroscopic realm of Martian rocks. In particular, the concepts of sphericity and angularity provide indicative measures of a rock's shape that could be used by a rover to obtain valuable information about the specimen's geologic origins and history [7].

Procedure: We begin by first segmenting the rocks from the background using a combination of image intensity and height data [6]. Various metrics are then used to quantify the shape of the rocks. Four two-dimensional measures were developed and implemented. The performance of each measure was characterized by analyzing images from the Pathfinder mission and ranking the rocks according to the measured properties. In two-dimensions, the shape is first characterized by the best-fitting ellipse to the outline of each detected rock using a direct least squares minimization algorithm **(Figure 1).** The eccentricity of this ellipse is an important characterization of the rock, providing information as to the composition and history. Next the total error between the fitted ellipse and the rock region is calculated. Information about the general ellipticity of the rock and can be used as a measure of its relative roughness. A third measure, sphericity, is then determined. Sphericity measures how close a rock is to spherical. The sphericity provides information on how far from its source a rock has traveled. Finally, we have developed a novel method of estimating the angularity of a rock. Angularity measurements are currently painstakingly performed by human estimation, which require large amounts of time and effort and which lead to unpredictable and statistically imprecise results. An automated method of estimation such as the one we have developed is a significant improvement, both in speed and efficiency, over these manual techniques.

Preliminary Results: Figure 2 shows the results of the four analysis on rocks identified on sample Mars Pathfinder image. The rocks are ranked for each measure. As the figure indicates, the metrics performed well on test images. Specifically given the outline of a rock, the measures provide an intuitive characterization of the shape of the rock. As the figure also indicates, eccentricity and sphericity are closely correlated as expected. Our next procedure is to compare our results Mars Pathfinder rock size distrubution identified by Golombek et al., [8].

References: [1] ASTM (1995). [2] Dudek G. and Tsotos J. K. *CVIU*, 68,2, 170-189 (1997). [3] Iivarinen J. et al. *Brit. Mach. Vis. Conf.* (1997). [4] Frost J D and Lai J D (1996). [5] Maerz N. H. and Zhou W, *Center Aggr. Res. Seventh Ann. Symp.*, BI-4-1 to BI-4-12. [6] Gor V. et al, *AIAA* (2001). [7] Krumbein W. C. and Sloss L L, *Stratigraphy and Sedimentation* (1951). [8] Golombek et al, (1997), *JGR* 102 E2, 4117-4130.

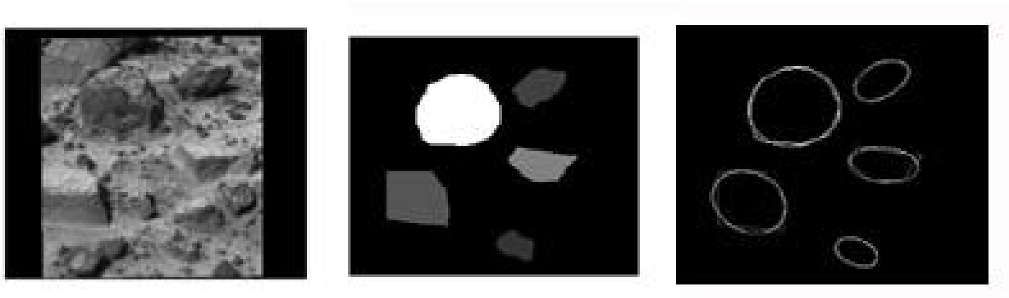

Figure 1 a) Original image taken from the Mars Pathfinder landing site, b) rocks identified from image, c) ellipses fitted to rock outlines.

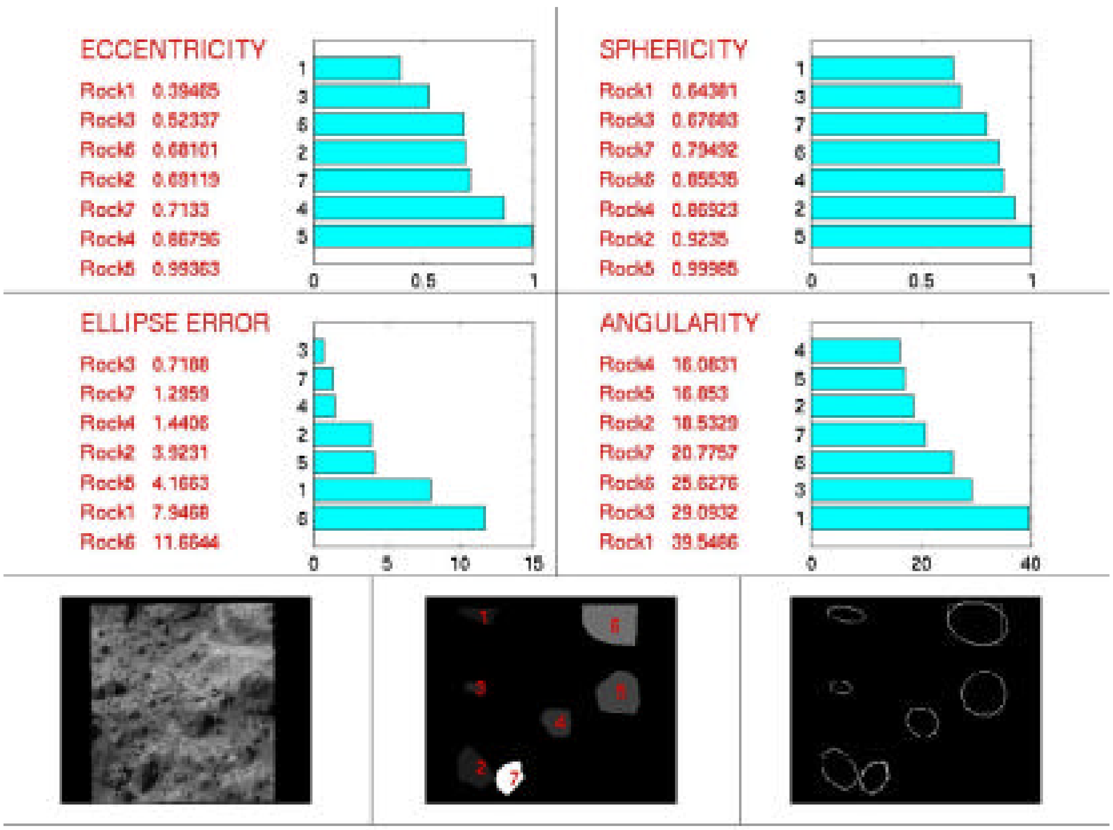

Figure 2 Two-diminsional measures for rocks identified in a Mars Pathfinder image. Results show ranking of each rock for four measurements.