Automated Procedures for Detecting Martian Dust Devils. A. Gibbons[1], F. Yang[1], P. Mlsna[1], and P. Geissler[2] [1]Electrical Engineering Department, Northern Arizona University, Flagstaff AZ 86001 USA. [2]Astrogeology Team, U.S. Geological Survey, Flagstaff AZ 86011 USA.

Introduction: The towering plumes of dust produced by dust devils on Mars are significant for several reasons. The capacity of dust devils to loft dust skywards contributes to the dust load of the atmosphere and is suspected to play a role in the initiation of local and global dust storms. The plumes provide a useful indication of the presence of mobile materials on the surface, and the distinct tracks left by the passage of dust devils are evidence of efficient erosion of the surface, particularly in mid- to high-latitudes. With wind speeds of several tens of meters per second, the dust devils present obvious hazards to robotic and manned exploration of the Martian surface, and a knowledge of their characteristics and distribution in time and space is essential for safe landing site selection.

Dust devils have been visually spotted in orbital images from both Viking [1,2] and Mars Global Surveyor [3,4], but the enormous volume of the available data sets makes this manual approach untenable except for limited surveys. The tracks left by dust devils have also been used to monitor dust-devil activity [5], but this approach is limited to places where the dust cover is thin and is subject to uncertainty about the longevity of the tracks. An efficient, computer-based algorithm for identifying active dust devils would greatly expand our knowledge of the frequency, locations, and seasonal variability of dust devil activity.

Approach: We have begun to explore the application of numerical pattern recognition techniques to the problem of locating Martian dust-devils in orbital imagery. Three characteristics of dust-devils can be exploited by this approach: (1) the plumes appear as localized bright clouds with a finite range of dimensions; (2) the plumes cast shadows with known orientations; and (3) the plumes are present in particular images of any given area but are absent from others.

We have divided the problem of identifying dust devils into several steps. The first step is to locate possible candidate plumes, using a scalable matched filter. Second is to classify the candidates to separate likely plumes from other surface features (such as crater rims) that are misidentified by the filter. The final step is to reject static features such as hills and knobs that appear unchanged in multiple images.

Identification of Plume Candidates Our initial approach to locating candidate dust devils is to convolve the image with a linear filter constructed of the sum of Gaussian functions, such as shown in Figure 1.

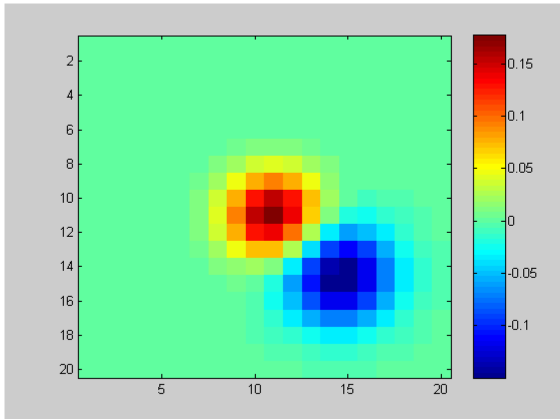

Figure 1: Filter kernel for identifying potential dust plume candidates, constructed as the sum of Gaussian functions.

The advantage of an analytically derived kernel is that it is readily scalable to various image resolutions and can be easily adjusted to match the orientation and length of shadows, depending upon the time of day.

The cross-correlation of the filter with the image is then normalized and thresholded so that only the strongest responses are retained as input to the next step.

Classification of Plume Candidates: Many spurious features are identified in the filtering process, if the tolerance is set such that all the genuine dust devils are matched. It is thus necessary to narrow down the list of candidates to those that best match the traits of actual dust-devils. Our initial approach to this task is to extract brightness profiles from the candidates along three axes as shown in Figure 2, fit polynomial functions to the profiles, and use the coefficients of the polynomials as a basis for acceptance or rejection by a neural network that has been trained on example dust devils. An advantage of this approach is that many of the parameters of interest for studying dust devils, such as their breadth and height (from shadow lengths), are easily extracted from the profiles and their polynomial fits.

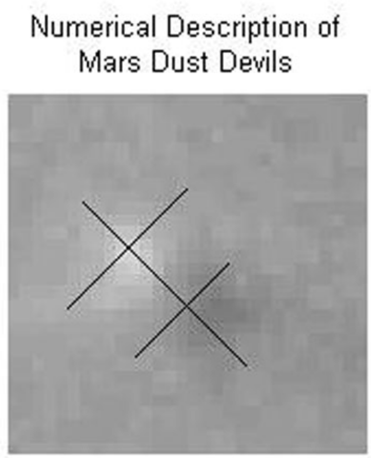

Figure 2: Profiles along which the brightness of candidate dust devils is extracted for input to a neural net classifier.

The vectors formed by the polynomial coefficients are next fed into a simple neural network with two hidden layers that has been trained to recognize dust devils. The neural net is adept at distinguishing between dust devils and crater rims (the surface features most commonly mistaken for dust devils) because the profiles are clearly different (Figure 3).

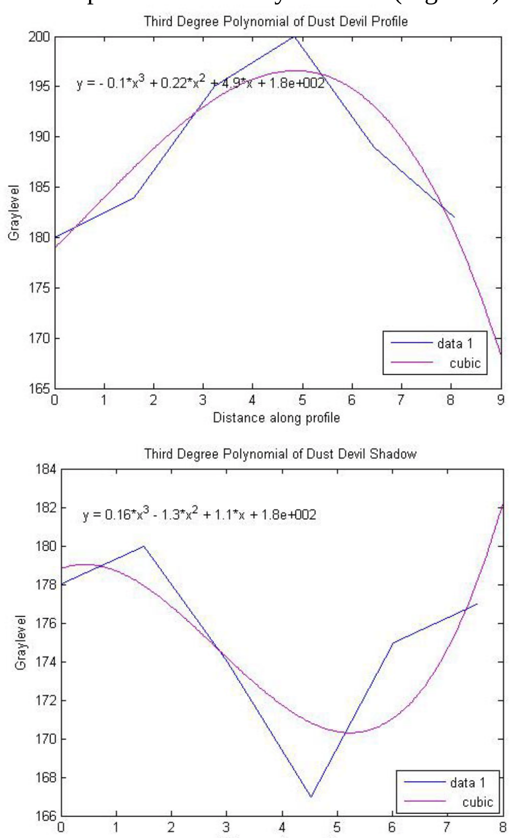

Figure 3: Polynomial fits to example profiles of a dust devil (top) and a crater rim (bottom).

Rejection of static topography: Topographic features that resemble dust devils but do not change from one image to another can be identified by repeating the analysis on images of the same area taken at different times, and excluding candidates that repeatedly occur in the same locations. Mars Global Surveyor MOC Wide Angle Camera images are ideal for this purpose, having multiple redundant coverage of much of Mars' surface over a period of two Martian years, long enough to establish seasonal patterns in dust devil activity.

Future Work: Tasks still remaining to be tackled include tuning the parameters of the filter and the profiles to identify dust devils of different shapes and sizes, rejecting static surface features such as hills and knobs, quantifying the errors of omission and false identification in each step, applying the algorithm to various diverse sources of orbital imagery, and testing the sensitivity of the approach to noise and atmospheric obscuration by hazes and similar phenomena. Preliminary results of these experiments will be presented at this meeting.

References: [1] Thomas, P., and Gierasch, P. J. 1985. Dust devils on Mars. Science, 230, p. 175-177.
[2] Wennmacher, A., Neubauer, F. M., Patzold, M., Schmitt, J., Schulte, K. 1996. A Search for Dust Devils on Mars. Lunar and Planetary Science, volume 27, page 1417. [3] Edgett, K. S., Malin, M. C. 2000. Martian Dust Raising and Surface Albedo Controls: Thin, Dark (and Sometimes Bright) Streaks and Dust Devils in MGS MOC High Resolution Images. 31st Annual Lunar and Planetary Science Conference, March 13-17, 2000, Houston, Texas, abstract no. 1073. [4] Biener, K. K., Geissler, P. E., McEwen, A. S., and Leovy, C. 2002. Observations of Martian Dust Devils in MOC Wide Angle Camera Images. Lunar and Planetary Institute Conference Abstracts 33, 2004. [5] Balme, M. R., Whelley, P. L., and Greeley, R. 2003. Mars: Dust devil track survey in Argyre Planitia and Hellas Basin. Journal of Geophysical Research (Planets) 108, 5-1.