AUTOMATIC CRATER COUNTS ON MARS. C. Plesko[1], S. Brumby[2], E. Asphaug[3], D. Chamberlain[4], T. Engel[5], [1]University of California, Santa Cruz, cplesko@es.ucsc.edu, [2]Los Alamos National Laboratory, brumby@lanl.gov, [3]University of California, Santa Cruz, asphaug@es.ucsc.edu, [4, 5]University of California, Santa Cruz.

Introduction: Impact features are some of the most interesting, and most common, features on the surface of Mars. They provide clues about the relative age, local composition, and local erosional history of the surface, and are interesting features of themselves in that the processes by which they form and distribute their ejecta are not entirely clear. [1, 2] An enormous amount of surface image data has been gathered in the last decade. It is now necessary to develop automated tools for feature extraction. We will present the latest results in an ongoing [3-5] effort to develop feature extraction algorithms for the Martian surface, specifically a suite of automated crater counting tools.

GENIE: GENIE, or GENetic Imagery Exploitation is an automatic feature extraction software package developed by the Rapid Feature Identification Program (RFIP) at Los Alamos National Laboratory [6]. It uses techniques from genetic algorithms (GA) [7-9] and genetic programming (GP) [10] to construct spatio-spectral feature extraction algorithms for multi-spectral remotely sensed imagery. Both the algorithm structure and the parameters of the individual image processing steps are learned by the system. GENIE has been described at length elsewhere [11-13], so we will only present a brief description here.

GENIE is given one or more images, and a 'training' image file in which the user shows GENIE what to find, marked in green, and what to ignore, marked in red. The program then generates a population of random algorithms that are evaluated against the training file. Only the most successful algorithms are allowed to go on to build the next generation. The algorithms then 'evolve' to find a program that will return a result that solves the problem specified by the training file. (Figure 1)

Feature extraction algorithms developed by GENIE are human readable IDL or C code that may be subsequently applied to any image. Once the results of the GENIE algorithm are compiled, the (graphical) results are run through a program in IDL that separates and tabulates the detected blobs into a list of objects and the pixels they contain. These objects are then run through a circle finder that selects out the most circular blobs and returns a list of centroids, maximum/minimum radii, variance, and total number of circle candidates.

Results: GENIE was trained on a subset of THEMIS daytime IR image I02045002RDR (top panel of figure 1), which is located in Terra Tyrrhena, in the equatorial southern hemisphere (image center at -15.671N, 84.895E) [14]. The image is marked by many craters of various sizes, types, and conditions. The final algorithm had a detection rate of 98% of given true pixels detected as true, a false alarm rate of 10% of given false pixels detected as true (middle two panels of figure 1). The primary sources of error were very small craters. The algorithm generalized well to out of sample training data (bottom panel of figure 1) but still had trouble with small craters.

The graphical GENIE results for the entire I02045002 image were then tabulated and sorted by diameter, and a relative size-frequency distribution plot [15] was generated for the scene. (figure 2) For the plot, $R=D^{\square_n}N/A(D_b-D_a)$, $D=(D_aD_b)^{1/2}$, D_a and D_b are the lower and upper diameters of the bin respectively, $\square_n=-3$, a normalization value, N is the number of craters in the bin, A is the total area of the scene, and (D_b-D_a) is the bin size, in this case 100 meters.

Conclusions: We have successfully developed automated crater counting algorithms and are able to use them to generate a database of craters for each image processed that includes location of the crater's centroid, estimated radius, and estimated accuracy of detection. The process is limited to craters of diameter no smaller than roughly three times the resolution of the image, and no larger than craters of diameter that will fit within the image.

Future Work: Mars, especially in the post-THEMIS era, opens up a treasure trove for students of planetary impacts. Notably, impact craters have been discovered on Mars to be accompanied by associated structures that extend for many hundreds of kilometers, including detailed ray patterns and secondary streamers. The most stunning example is the fresh crater of the Cerberus plains presented by McEwen et al. (2003). As a long-term goal, we plan to use the above techniques to map the extent and distribution of such structures by keying to the desired signature (e.g. ray patterns) in the multispectral THEMIS imagery. In order to achieve that goal, we intend to first refine our current algorithms and apply them to larger test regions to generate detailed general crater counts. We also hope to develop algorithms to count specific types of craters such as rampart craters and clustered secondary craters.

References:

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[14] Christensen et al. (2003). http://themis-data.asu.edu/img/I02045002.html
[15] N.G Barlow (1988) Icarus, 75, 285-305.

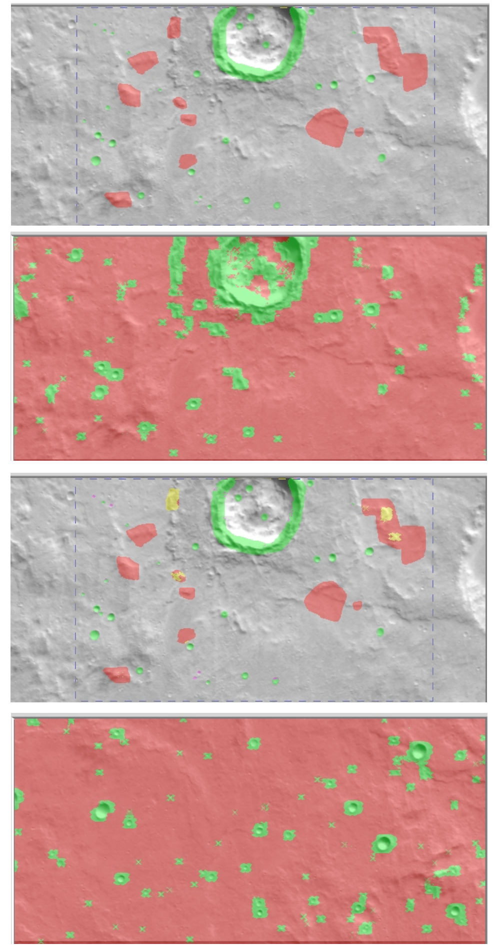

Figure 1. (Top to bottom) GENIE input file, results file, comparison of the two, result of algorithm on data not in the training sample.

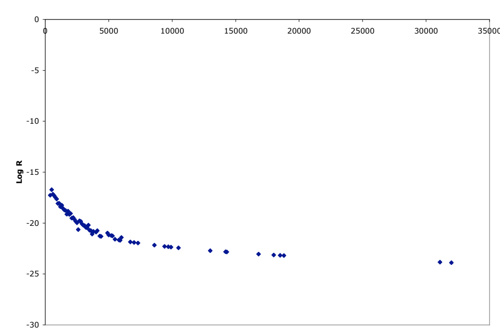

Figure 2. R-plot of craters autodetected in THEMIS daytime IR image I02045002