A COMPARISON OF AUTOMATED AND MANUAL SURVEYS OF SMALL CRATERS IN ELYSIUM PLANITIA. C. S. Plesko[1], S. P. Brumby[2], and E. Asphaug[3], [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,

Introduction: Small impact craters are some of the most interesting, and most abundant features on Mars. There are now so many images of the surface of Mars that the dataset exceeds the Mars community's ability to analyze in detail by conventional manual methods. To overcome this bottleneck, we have developed an automated technique to rapidly survey images for interesting features, specifically small impact craters. We demonstrate that the accuracy of our automated crater counts are comparable to manual counts by human experts[1], and are useful in culling large datasets for images that merit expert examination.

Background:

Manual Counts. Manual counting done by experts can produce highly accurate crater surveys on a given image. However, it takes a long time to produce a detailed survey, and each image must be counted several times by different trained people in order to eliminate perceptual biases. This process can take months for just a few images. Rapid manual counts by untrained personnel are much less accurate- count results can vary by a factor of ten[2], and still take hours per image. When the dataset contains hundreds of thousands of images, it becomes unwieldy for manual surveys, and the conclusions of those surveys can remain controversial if different counts disagree.

GENIE. GENetic Imagery Exploitation[3,4], is a software suite that automatically generates image processing tools (e.g. C or IDL algorithms) from point-and-click user input. It uses advanced artificial intelligence techniques such as genetic programming[5] and support vector machines[6] to develop the algorithms. Users mark example pixels in an image or images that belong to a feature of interest, and also mark example pixels not of interest. GENIE then develops a human-readable script to detect the feature of interest. This script can be applied automatically to a large number of images for very rapid results, or modified as appropriate.

Method: For this study we compared the results of an expert manual count, conducted by Hartmann and Berman[1] to the results obtained by GENIE generated algorithms on the same images.

Elysium Planitia. This area was chosen because it is relatively simple to survey. The surface is covered with flat, young lava flows, the craters are sparse enough that they do not overlap, and there is very little dust to obscure small craters.

Expert Manual Survey. In their study, Hartmann and Bermann selected MOC images of Elysium Planitia, and, with a team of students, counted the number of craters in each image, averaged their numbers, and binned them by diameter.

Automated Survey. We selected three regions[7,8] from the Hartmann and Berman study that had an abundance of small craters, and datapoints from multiple manual counts. We then marked up examples of craters and non-craters [Fig.1] and evolved a GENIE algorithm on a sub-sample of each image and applied the finished algorithm to the entire image [Fig 2.]. Graphical results were filtered for circularity, and binned into diameter ranges established by Hartmann and Berman for comparison.

Results: The GENIE generated algorithms successfully detected craters in the MOC images. At small diameters the automated counts were very accurate compared to expert manual counts. For Large diameter craters, automated counts correctly identified the crater, but tended to also identify a large region of ejecta. Thus, the GENIE results are presently most accurate for the smaller craters – by far the most challenging for humans to count.

High Accuracy. Individual results are shown in Table 1. At small diameters, the GENIE results are comparable to expert manual counts. The GENIE algorithms detect both the crater and part of its ejecta blanket, which introduces a systematic bias that scales with crater size, and pushes craters into larger size bins. This bias is modelable and correctable.

Massive Time Savings. The greatest advantage of automated counts over manual counts is the amount of time saved. It takes only seconds running on an average Linux desktop to apply a finished GENIE algorithm to an image and obtain a list of craters with statistics on location of centroid, diameter, and circularity. Depending on the complexity of the data and desired detail of a training set, it takes less than half an hour of human effort to prepare a training image for GENIE to use in algorithm development. Depending on the training dataset and computer it runs on, it takes GENIE from a few minutes to a few days of unsupervised and parallelizable processor time to grow a new algorithm. This finished algorithm may then be applied to any number of images as above. Compared to the months or years it takes to train a human expert, and the hours to weeks required to manually process every image, this is a massive advantage.

Reproducibility. Perhaps equally important, an algorithm for crater counting in a dataset provides a reproducible standard. We envision the development of a set of standard algorithms for use in counting craters on various terrains, both on Mars and on other planets, so that a user-independent quantitative metric for crater statistics can be obtained, and linked to quantitative descriptions of terrain populations, degradation, ages, etc.

Future Work: This work exclusively used panchromatic MOC imagery. The information per pixel available increases rapidly with the number of spectral bands. Thus automated count accuracy improves dramatically when applied to multispectral imagery such as THEMIS or HRSC data. In the future we will apply GENIE to the analysis of features in multispectral datasets.

References: [1] W. K. Hartmann and Berman, D. C. (2000) JGR, 105, 15011-15026. [2] C. S. Plesko et al. (2002) Proc. SPIE, 4480, 139-146. [3] S. P. Brumby et al. (1999) Proc. SPIE, 3812, 24-31. [4] (see also http://genie.lanl.gov). [5] J. R. Koza (1992) Genetic Programming: On the Programming of Computers by Natural Selection, MIT. [6] S. J. Perkins et al. (2001) Proc. SPIE, 4381, 286-295. [7] M. C. Malin et al. (1998) Cat. no. SP1-21904. [8] M. C. Malin et al. (1998) Cat. no. SP1-23804.

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Image	Diam.(m)	GENIE	HB1	HB2
SP1-21904a	22	0.303		
	31	0.741		
	44	0.707		
	63	1.382	0.9	1
	88	1.280	0.5	0.6
SP1-21904b	22	0.073		
	31	0.247	0.25	0.3
	44	0.160	0.06	0.08
	63	0.073	0.045	
SP1-23804	22	0.189		
	31	0.128	0.2	
	44	0.189	0.15	
	63	0.149	0.1	0.08

Table 1. Observed number of craters near a given size per square kilometer in three scenes, counted automatically by GENIE algorithms, and by W. K. Hartmann[1] (HB1), and D. C. Berman (HB2).

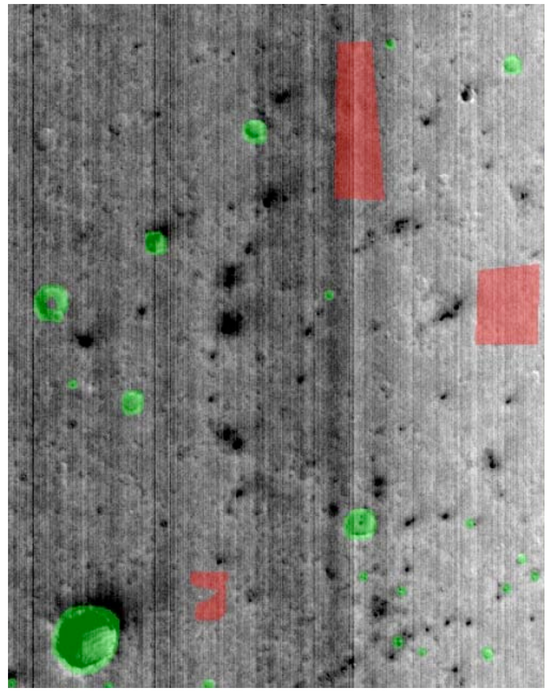

Figure 1: Human generated GENIE training file, from MOC NA SP1-21904.

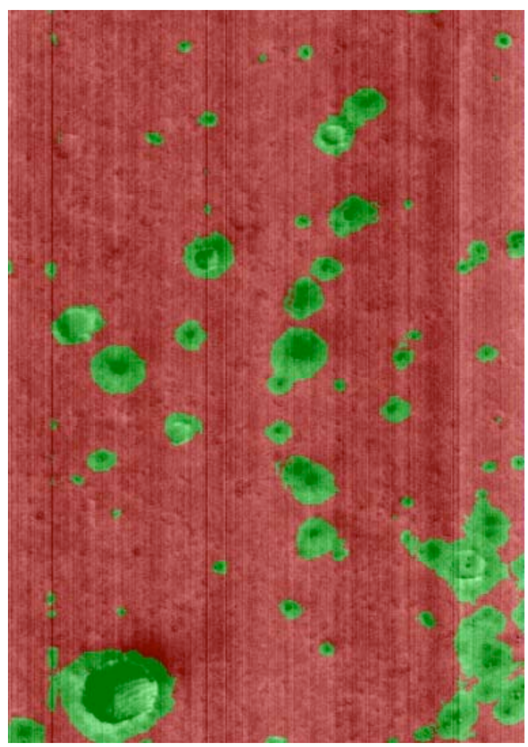

Figure 2: GENIE automatically generated graphical results, from MOC NA SP1-21904.