AUTOMATIC LUNAR CRATER DETECTION AND MAPPING. Y. Cheng¹ and A. Huertas¹, ¹Jet Propulsion Laboratory, Calif. Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109. Yang.Cheng@jpl.nasa.gov.

Introduction: JPL has been developing algorithms for autimatic crater detection for a decade. Applications included orbital determination from images of small bodies [1] and real-time crater detection and matching for TRN (Terrain Relative Navigation [2]) and pin-point landing. More recently, the availability of high resolution (~0.5m) imagery acquired from orbit by the NAC (Narrow Angle Cameras) on board the LRO (Lunar Reconnaissance Orbiter) makes it possible to automatically detect, describe and map craters as small as 5 pixels (~2.5m) in diameter. While earlier algorithms focused on detection and matching of fresh craters because of their increased saliency, our recent algorithm has been enhanced to successfully detect eroded craters as well. Specifically, our group has started detecting and mapping craters in NAC images of 25 regions of interest covering 20km x 20km each. The crater data is provided to the LMMP (Lunar Mapping and Modeling Project) managed by the Marshall Space Flight Center in Huntsville, and to specific users currently designing missions for future Lunar landings. We present results of the evaluation of the performance of the algorithm and an example of crater detection statistics and maps for a region in the South Aitken Basin Interior (SABI.)

The Algorithm: The algorithm focuses on the ellipticas shape of the craters, whether fresh or eroded, present in NAC images. It can be applied however to LRO's WAC (Wide Angle Camera) images which at 100m per pixel would allow detections as small as 500m diameter craters. The algorithm uses knowledge of the Sun angles and implements a multi-scale analysis of the image, and incorporates crater appearance models. Sun elevation is a non-critical factor if the illumination incidence angle is between 15 and 75 degrees. SABI NAC images have around 65 degree sun incidence angles. A crater locking mechanism optimally determines the best location and shape of the crater rims. A measure of crater freshness is derived from the image intensity gradients. For fresh craters the rim contour can be very precise. For eroded craters, the rim is a best estimate from the gradient information. Future analyses from millions of detected craters should help derive a more informed measure to locate the eroded crater rims that is consistent with geophysical models of impacts and erosion. Currently we use crater sharpness as an indication of crater hazardousness to help determine landing risk. Eroded craters represent risk in terms of the boulders in and around them and the short baseline slopes estimated from digital elevation maps of the area. The output of the detector is a crater list including the location, semi-axes lengths, ellipse orientation, sharpness, and a measure of confidence, for each crater detected. A set of Matlab routines generates, statistics and spatial thematic maps for each image. These can be mosaicked to generate information for larger areas.

Performance Evaluation: Recently we have started computing a number of metrics that describe the performace of the crater detector. Fig. 1 shows a 500m x 500m portion of NAC image M103189611R. The 1128 craters delineated by a human using a special tool are shown in Fig. 2.



Fig. 1. 500m x 500m sub-image in the SABI site.



Fig 2. Reference craters delineated by human.

The human had no prior knwoledge of the algorithm nor of results on any image. Applying the crater detector generates automatically the 896 craters in Fig 3.



Fig 3. Craters detected automatically

Fig 4 and Fig 5 illustrate size-frequency and abundance plots. Note that the algorithm does as well as the human in terms of numbers of craters up to the limit of resolvability of the algorithm (~2.5m diameter.) The human can see craters as small as 1.2m diameter. A resolution roll-off occurs in both curves at about 2.5m, undicating that craters smaller than that are undercounted.



Fig. 4. Size-frequency distribution plot of craters

Fig. 5 shows that the algorithm underestimates the area of the craters, or alternatively that the human overestimates the size of the craters, as with the larger crater on the lower part of the image. Taking into account the resolution roll-off, the plots suggest that 25%-30% of the surface area is covered by craters.



Fig 5. Crater abundance plots

Reginal Results: We have detected craters from eleven 2.5km x 25km NAC images in the SABI region shown in Fig.6 The corresponding SFD and CFA plots are illustrated in Fig 7 and Fig. 8, respectivelly.



Fig. 6. Boxes show 5km x 25km pair acquired by twin NACs.



Fig. 7. Size-frequency of craters in 11 NAC images



Fig. 8. Crater abundance in 11 NAC images

References:

[1] Y. Cheng at al, "Optical landmark Detection for s/c navigation", AAS 2002.

[2] Y. Cheng and A. Ansar, "Landmark Based Position Estimation for Pinpoint Landing on Mars," IEEE ICRA2005