IMPACT CRATER DETECTION ON OPTICAL IMAGES AND DEMS.

J. R. Kim[1] and J-P. Muller[2], Department of Geomatic Engineering, UCL, London UK, [1] jkim@ge.ucl.ac.uk , [2] jpmuller@ge.ucl.ac.uk

Introduction: Impact craters are crucial landmarks for geodetic control as well as being interesting geological research targets themselves . Several methods have been developed to automatically detect impact craters but none are as yet practical or have been sufficiently tested[1][2][3]. We have developed an automatic impact crater detection algorithm for optical images [4]. It is based on a focusing strategy using texture analysis and ellipse fitting [5] on local edges. Currently, the technique works well for craters of medium size but fails for very large impact craters. There is also some confusion between local edges derived from the images and the crater rim due to of solar illumination condition. Therefore, the detection process for real applications has been developed using fusion techniques exploiting both DEMs and optical images. This new algorithm introduces crossover checking on multi-images and a verification stage using templates so that a correct crater numbering is possible according to their size. Examples are shown of its assessment.

Overall algorithm: Inputs currently consist of MOC ISIS level 2 images and MOLA based DEMs. Individual detection is performed using each input separately and merged by a registration process so that impact crater counting and 3D reconstruction is possible. The most important factor in optical image based processing is the illumination. Sometimes, the boundary edge line of an impact crater is very ambiguous with low sun elevation angle. There is no good solution for such intrinsic problems. Consequently, a crossover checking process in a set of multiple images is necessary. The overall structure of the algorithm is shown in Fig 1).

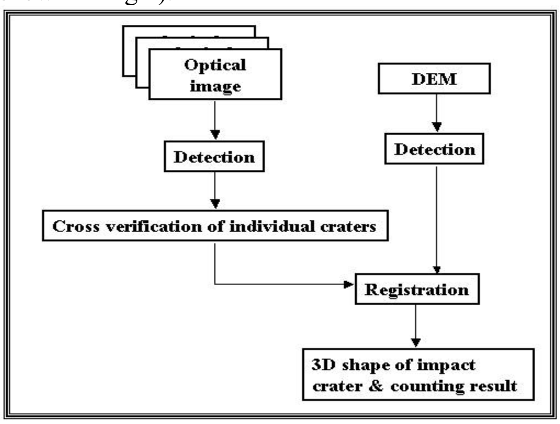


Figure 1. Overall processing chain for impact crater detection using images and DEMs

Optical image processing: The detection method for optical images is shown in Figure 2 below. Firstly, a region of interest (RoI) is detected through a texture analysis, which in our case is a simple combination of a co-occurrence matrix and k-mean classification. Local edges are then thresholded in these RoIs and compared against a direct ellipse fit. If the fitting ratio is more than some critical value, a final verification step is applied directly. Otherwise, every edge segment needs to be regrouped to fit into one ellipse. Currently, we are using an edge grouping method via a Hough space search. Through these steps, the output ellipses include all true impact craters and some false ones (e.g. hill, valley or geological feature with illumination effects). From a large number of candidates, which are chosen from the fitting process, the "true" craters are validated. Template matching, which is popular in some machine vision applications such as face recognition, can be used in the validation process. We used a FFT (Fast Fourier transformation) based cross-correlation checking method with a small modification [6]. On the boundary of the candidate crater, a sub region is extracted and resampled spatially and radiomatically. The templates are then chosen considering the size of the candidate crater and rotated with the image index files' sun elevation angle. Tables 1 and 2 show some examples of the validation process. In the case of FFT and wavelet, most of the false impact craters are successfully detected and eliminated. Currently, reliable detection results are only produced when craters have diameters less than 100 pixels size according to our testing results to date. To address this size limitation, we used a DEM based crater detection.

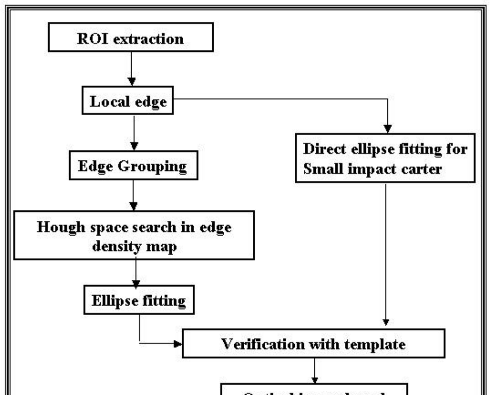


Figure 2. Impact crater detection on optical images

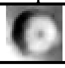
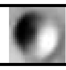
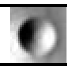
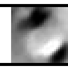
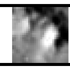
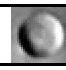
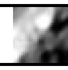
Template	T-2	T-1	T-3	T-4	T-5	T-6
						
Corre-1	0.83	0.74	0.63	0.26	0.68	-0.43
Corre-2	0.72	0.60	0.45	0.17	0.68	-0.22

Table 1. Example of template based validation process

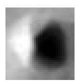
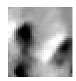
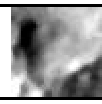
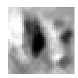
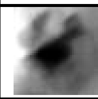
Tem-plate	F-1	F-2	F-3	F-4	F-5
					
Corr-1	-0.58	0.36	0.50	-0.24	-0.45
Corr-2	-0.46	0.32	0.39	-0.11	-0.32

Table 2. Example of false impact crater discrimination using different scale and illumination condition (*Corre-1 : FFT & resampling based correlation *Corre-2 : FFT & wavelet based correlation)

The detection result for poor input image quality is illustrated in Figure 3. This figure shows that some impacts are not detected because the outer edge lines do not clearly form ellipses. That's why a crossover check is necessary.

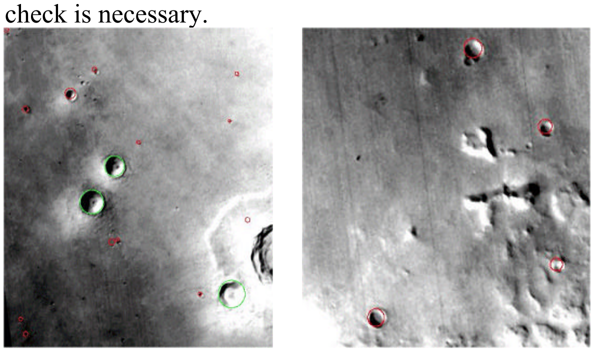


Figure 3. Detection results in optical images

DEM based processing: DEM based detection is much simpler than the corresponding optical image based one (see Figure 4). The focusing method is replaced with the extraction of high slope areas. Instead of the noisy local edge in an optical image, the ridge points of gridded DEMs are used for the ellipse fitting. Figure 5 shows an example detection result. The big impact craters, which are not detected in optical image due to edge linking problem, are here identified.

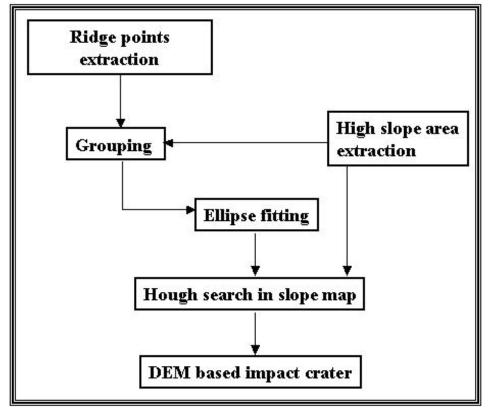


Figure 4. Impact crater detection on DEM

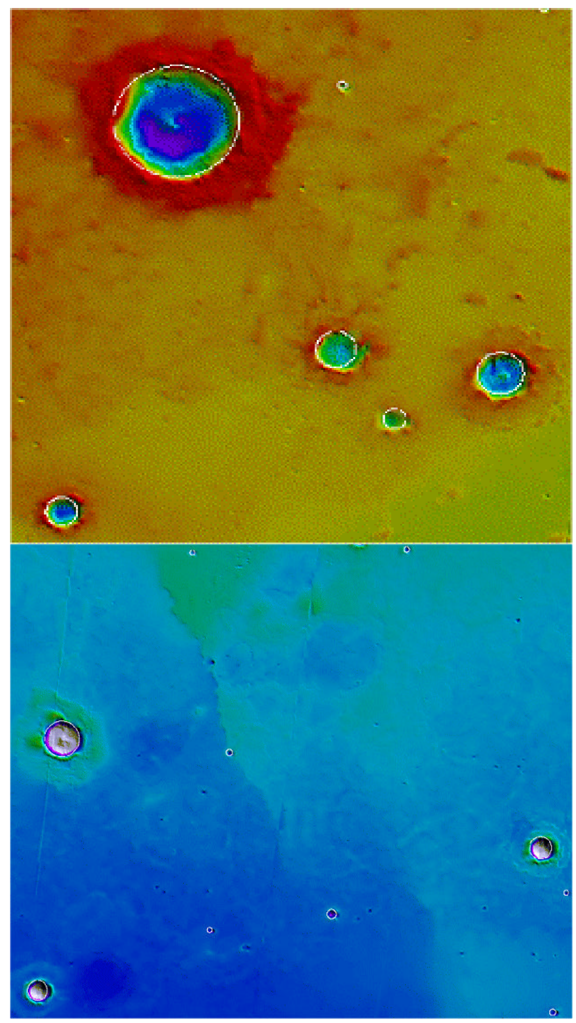


Figure 5. Example detection result in MOLA DEM

Registration and verification: As seen from the previous results, the detection of craters in optical images are sometimes imperfect and DEM based detection can't detect small-scale craters. Clearly there are some current limits to machine vision techniques. For example, some impact craters are not clearly distinguished even with a trained observer if severe illumination effects are present. On the other hand, it is impossible to detect craters of only several km diameter scale in a MOLA based DEM. Consequently, the detected outputs from individual images and DEM need to be cross verified and merged. It is very well known that positioning errors exist in MOC and MOLA images [7]. However, the matching of center points of detected impact crater can be relatively easy. Then the crater footprints can be integrated.

Further work and applications: The final output is in ascii text format of the location of the centers of the best-fitted circles and radius or the ellipse's major and minor axis. However, adjacent areas can be re-examined to detect the correct crater rim even considering illumination effect. Also the MOLA altimeter's points can be re-interpolated using these boundary points to rebuild 3D crater shape. The integration with image index information and SPICE will be tried to apply to real geological and geographical examples in future.

References:

[1] Leroy, B. G. et al. (2001) *Image and Vision Computing*, 787-792 [2] Diamond eye web site http://www-aig.jpl.nasa.gov/public/mls/diamond_eye [3] Michael, G (2002) Vernadsky-Brown symposium [4] Kim, J.R et al. (2001) CD-Rom [5] Fitzgibbon. A, et al. (1999) *IEEE PAMI*. 463-474 [6] Burt, P.J. (1982) *IEEE Conf. Pattern Recognition Image Processing*.. 269-274.[7] Kirk, R.L et al. (2001) *LPSC* CD-Rom