AUTOMATIC DETECTION OF SUB-KM CRATERS ON THE MOON. L. Bandeira, M. Machado, P. Pina, CERENA/IST/UL, Lisbon, Portugal, {lpcbandeira, marlene.machado, ppina}@tecnico.ulisboa.pt.

Introduction: Many crater detection algorithms (CDA's) have been presented in the last decade [1], but their testing in truly extensive and diversified datasets is yet to come. Our approach is progressively being improved and tested, each time with larger datasets of images of the surface of Mars [2, 3, 4] and Phobos [5]. Thus, the intent of this work is to show that the current version of our method achieved a maturaty and robustness that indicate it to be applied in a generalized way, that is, to other datasets that include different types of geological formations and also from different planetary bodies, with diverse ages and crater densities, and that its results have a high degree of accuracy that compares to those obtained by human analysis of images. Therefore, we are training and testing our approach on the Moon, using a high resolution image mosaic captured by the Terrain Camera of Kaguya (SELENE) to detect craters with diameters in the range 100 m to 2 km.

Methodology: Our CDA is particularly well-suited for accurate selection of craters from amongst a set of candidates it also selects using the combination of Haar-like image texture features and a robust classifier [6], SVM-Support Vector Machines. For the selection of crater candidates - portions of an image that contain crescent highlight and shadow shapes indicating possible presence of craters we use multi-scale shape filters based on mathematical morphology operators [7], followed by the extraction of texture features (the Haar-like) which are computed for these candidates but also for some non-crater samples, like performed in previous work [3]. These features for which a label (crater or non-crater) is assigned, are then used to train the SVM classifier, which afterwards is used for classifying all other candidates simply into 2 classes: crater and non-crater.

Dataset: To test the performance of our CDA we used a portion of the Kaguya (SELENE) [8] Terrain Camera (TC) Evening illumination tile set, released by the SELENE team [9], with ~10 m/pixel of the Moon's surface, and recently re-released by Astrogeology/USGS [10]. The selected scene is centered on Sinus Iridum (44.1°N, 31.5°W); it extends ~30 km (north-south) by ~15 km (east-west) and covers ~ 438 km^2 of a plain of basaltic lava. In this scene we have manually cataloged 3660 craters having diameters between 23 to 1400 meters. A total of 346 craters and 692 non-crater candidates were selected from another region of the same image mosaic to train the classifier. Note that the training set contains less than 18% of the craters in the scene (within the search range). Thus, our experiment corresponds to a likely use of the CDA, where user wants to train the CDA on small image and use the CDA to find craters in the large image.

Results: The objective of our CDA is to automatically survey craters larger than 100 m (14 pixels) but smaller than 2 km (280 pixels) in diameter. The lower limit stems from the minimum number of pixels required by the classifier to make a determination, the upper limit is arbitrary, and on this work it corresponds to the largest crater present in the test site. Figure 1 shows the results of applying our CDA to the test scene.

To evaluate the performance of our CDA we measured the detection percentage D = 100 x TP/(TP + FN), the quality percentage Q = 100 x TP/(TP + FP + FN) and the branching factor B = FP/TP. Here, TP stands for the number of true positive detections (detected craters that are actual craters), FP stands for the number of false positive detections (detected craters that are not), and FN stands for the number of false negative "detections" (non-detection of real craters). D can be treated as a measure of crater-detection performance, Q as an overall measure of algorithm performance, and B as a measure of delineation performance. Table 1 resumes these results.

Table 1: Performance of our CDA

	D (%)	Q (%)	FDR (%)	B
Test site	91.49	78.35	15.49	0.18

Conclusions: The detection performance obtained (D = 91%, B = 0.18) can be considered very high, being top ranked among the results obtained with this algorithm, whatever the surface tested. Moreover, and although the tiny surface that was sampled to train and test the algorithm seems already to be representative of Sinus Irudim surface characteristics, we still need to develop further experiments before expanding the algorithm all over this region to survey and detect the other craters. Assuming that the crater density measured now in these areas is kept for the entire region, we estimate that more than 100,000 craters with diameters above 100 m are awaiting to be detected. This is now the ongoing work for our algorithm.

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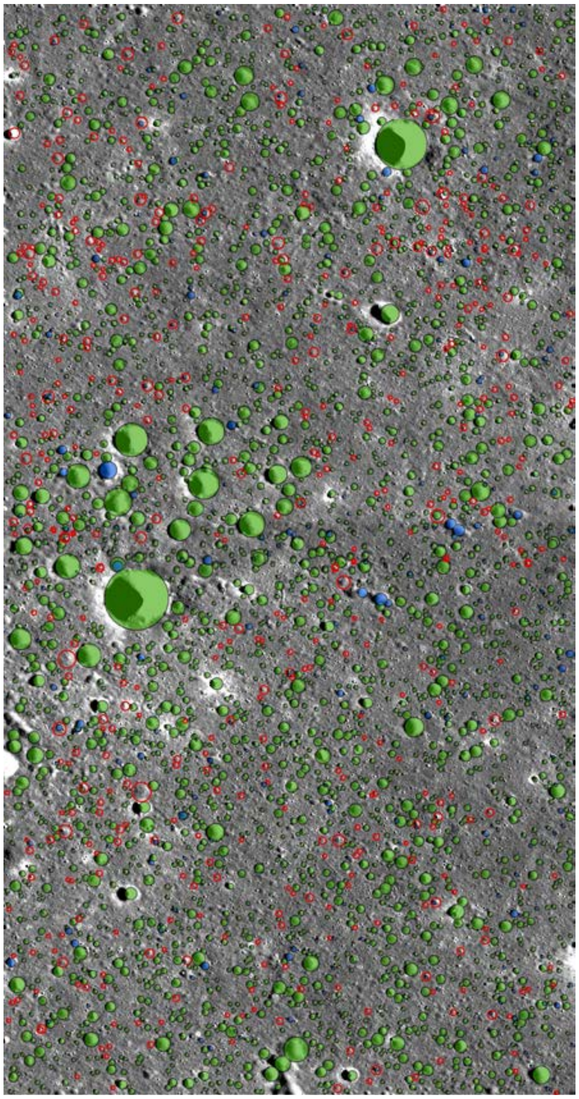

Figure 1 - Craters detected by our CDA in a 28,8 x 15,2 km^2 test site of the Evening illumination TC image mosaic. True detections are shown by green circles, false detections in red and missed craters in blue.