ASSESSMENT OF AUTOMATED CRATER DELINEATION IN HiRISE IMAGERY.

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Introduction: The delineation of impact craters following the local variability of the rims can be done by image analysis methods. We have recently proposed two independent approaches to tackle with this problem, which achieved a good degree of success yet on a relatively small dataset: one method is based on processing the crater images in polar coordinates [1], the other is solely based on morphological operators [2]. The initial results obtained on the automated delineations on a relatively small dataset extracted from HiRISE imagery, confronted with ground-truth sets (manually built contours), presented errors between about 2% and 10%, depending on the method and on the degradation status of the crater [3]. The polar method achieved globally higher performances, but was not always able to estimate a contour of the crater. On the contrary, the morphological method led to marginaly higher delineation errors but was always able to provide a detailed outline of the crater. Nevertheless, both algorithms still need improvements and their advantageous integration into a single one is currently underway. Now and here, we enlarge the testing dataset with more samples from different locations on Mars in order to better evaluate the degree of robustness of the morphological method.

Morphological method: At this point we only present a brief reminder of the method, for the details consult [2]: it consists of two main steps, filtering with connected operators and segmentation with the watershed transform. The filtering procedure suppresses the undesired components of the image while preserving the contours of the remaining ones (these are in fact reconstructed within the procedure). Then, the watershed transform is applied to the gradient of the filtered image on a circular mask built from the prior detection of the crater (manually or automatically); it produces one single closed contour, which should correspond to the real rim of the crater.

Datasets: The algorithm was evaluated on a set of 320 craters depicted from 4 HiRISE images (details on table 1). Our global visual description of the images separate them into smooth texture (datasets 1 and 3), rough texture (dataset 4) and a mixture of both (dataset 3). Furthermore, the image selection intended to cover the broadest possible diversity of crater preservation status, from pristine with complete and clearly marked rims to strongly degradated samples with large missing parts of the rim. Although most of the craters till 2.5 m in diameter (10 pixels) can be perceived, we fixed the minimal dimension to analyse at a higher value (5 m). Thus, the dimensional range varies from 5 m to 722 m.

Experimental results: The algorithm was applied individually to each crater of the datasets with the same fixed values of its parameters (some values are a function of the diameter of the crater). In the end, it was able to estimate a contour for all of them. Some examples, more and less favourable, are shown in Figure 1.

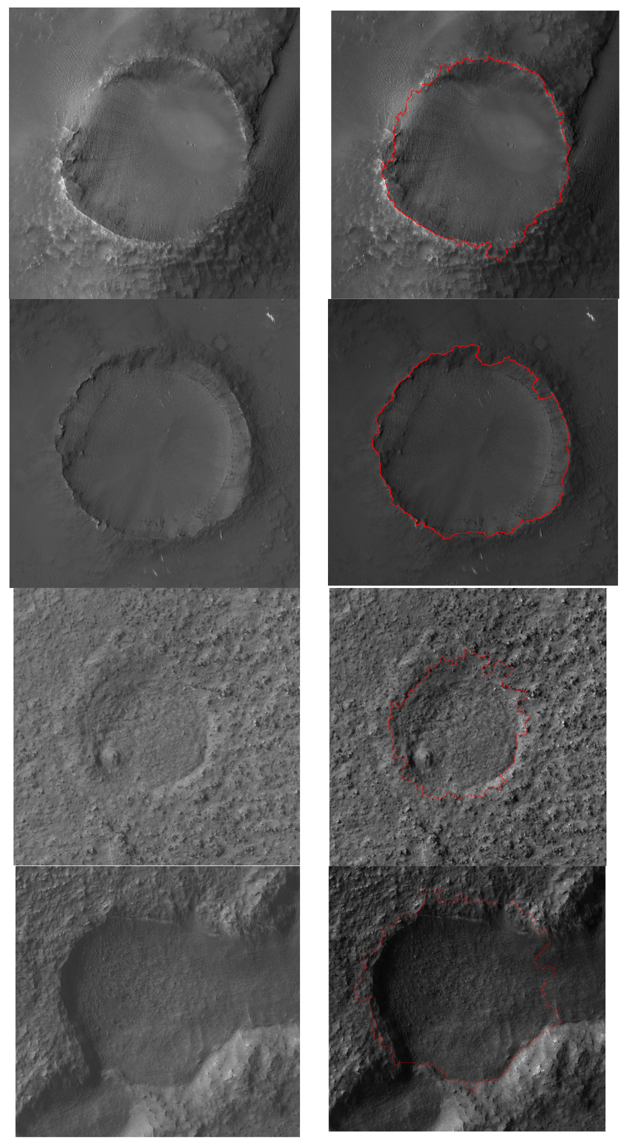

Figure 1: Contour delineations examples on HiRISE images, with crater diameter: (a) 287m, (b) 279m, (c) 71m, (d) 201m [image credits: NASA/JPL/Univ. Arizona].

Table 1 – Overall performances on automated delineation of craters

Data set	HiRISE image	Location		# craters	Diameter (m)			Performance (%)		
		Lat	Long		min	max	mean	Correct points	Small errors	**Gross errors**
1	ESP_011491_2090	28.57N	271.51E	60	9	722	55	55.7	35.9	**8.4**
2	ESP_025757_2105	29.99N	312.51E	100	5	554	71	40.0	46.1	**13.9**
3	ESP_025555_1940	13.93S	69.60E	100	5	292	32	66.9	24.1	**9.0**
4	PSP_002139_1340	45.83S	16.69E	60	19	511	50	30.3	51.5	**18.3**

Visually, the results are normally very precise in clear regions of the rim (high magnitude of the image gradient) and also in relatively small lenghts of eroded (or missing) borders. The most insucessful situations are normally related to long borders with incomplete information or low image gradient.

A quantitative performance is obtained by comparing the contour estimates with manually created ground truth contours. Just relying on a perfect matching does not make a great sense so, like in many pratical applications, small errors are acceptable. Thus, we assume that detected contours within a band of a given width around the ground truth contour are small and acceptable errors (in our case the width of this band is 5% of the crater radius). Points outside this band are in fact considered the errors obtained (we name them distinctly as gross errors) and their proportion used as a distortion measure between both contours. The average performances per dataset are shown in Table 1 and are in accordance with the overall image textures appearances: the best delineations are on the smooth ones (datasets 1 and 3), with average errors around 9% and the worst on the rougher one (dataset 4), with the double of that value; the mixed texture (dataset 2) shows an intermediate error value of around 14%. The breakdown by crater and dataset can be observed in Figure 3, where in several samples there are no errors, while in some few examples (all from the 'difficult' textures) the distortion is above 50%.. But globally, 169 craters (54%) have errors below 10% and only 58 craters (19%) show errors above 20%.

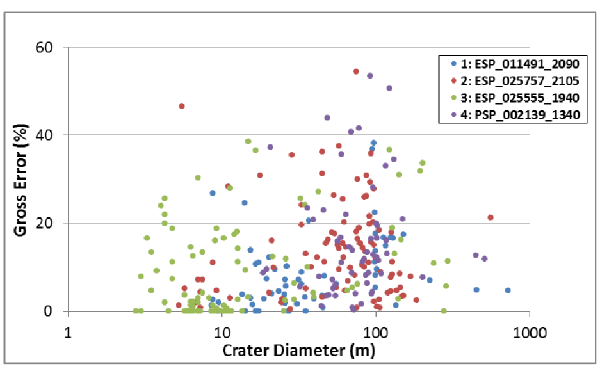

Figure 2. Delineation performance as a function of crater diameter.

Large scale delineations: To take advantage of this automated method for making crater delineations at large scale, we are currently establishing procedures to connect it to large crater datasets (catalogues or large outputs from automated crater detections). The conversion of the delineated contours from a raster to vectorial modes and the associated measures will be provided in standard formats, permitting an adequate edition and manipulation by every interested user in a GIS or similar platform.

Conclusions and future work: The delineation performances obtained now with an enlarged and more representative dataset (much more difficult examples are now included) are still very good. However, there is still room for significant improvement. We are currently working of the integration of both of our algorithms (this one and the polar one) to have a single and more robust method, and also enlarging the datasets on Mars with the corresponding ground-truth contours to have a more definitive view of its performance. The extraction of features from the delineated contours will be also implemented soon. Finally, we intend to apply as well this automated crater delineation method on the high resolution images of Mercury and the Moon.

References: [1] Marques JS, Pina P, 2013, An algorithm for the delineation of craters in very high resolution images of Mars surface, *Lecture Notes in Computer Science* 7887: 213-220. [2] Pina P, Marques JS, 2013, Delineation of impact craters by a mathematical morphology based approach, *Lecture Notes in Computer Science*, 7950: 717-725. [3] Pina P, Marques JS, 2013, Accurate delineation of impact craters by image analysis, *LPSC2013-Lunar and Planetary Science XLIV*, #1128.

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