On the Uniqueness of Crater Patterns at the Lunar South Pole.

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This paper investigates the uniqueness of crater spatial distribution at the lunar South Pole and determines the conditions under which the local crater patterns can be used for manned or robotic surface mission localization. Recent advances in automatic small crater detection (down to 2-4 meters in diameter) allows for crater mapping of large areas of the lunar surface without any manual intervention. Circular sub-regions of these crater maps with a radius of 15-35m contain a set craters (crater constellation). Comparison of these local crater constellations in neighboring regions reveal the conditions under which they are unique and usable in automatic localization techniques.

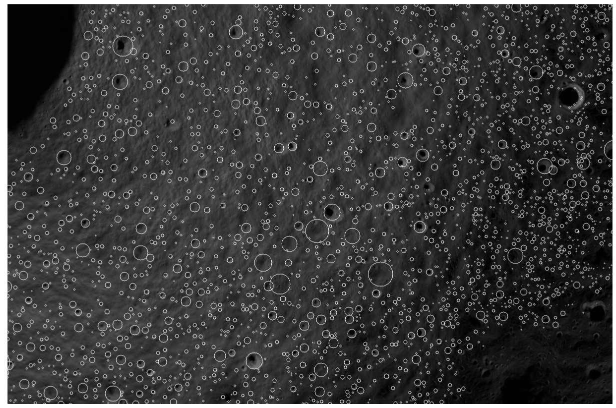

Figure 1: Typical crater detection results in LRO-NAC images (1m/pixel resolution).

Proposed Method

Automatic crater detection methods [1], [2], [3], [4], use as input either images or digital elevation models (DEM). The methods that use DEMs benefit from illumination condition invariance but are limited to craters that are larger. This is due to the fact that current DEM products have lower resolution than the imagery. The method proposed in this paper uses both image and DEM information to detect craters fully automatically in various illumination conditions and at size that approaches the image ground resolution. The fully automatic crater detection method [5] used in this paper can detect successfully craters down to 4 pixel in diameter (Figure 1). For the LRO-NAC imagery, used in this work, the method can detect craters of diameter 4 meters or larger. The ability to detect craters of this size enables the development of a method to match local DEM sub-regions using not only using general 3D information but also using more discrimant features such as crater locations. The paper investigates the uniqueness of crater spatial distribution in circular regions similar to the ortho-projected imagery and 3D panorama processed from a surface rover stereo camera system. The location of the crater centers is measured from the center of each panorama. Each crater in the given panorama is described by its horizontal and vertical coordinates to the center of the panorama. A panorama is described by a set of N two-dimensional vectors where N represents the number of craters detected in the given panorama. Note that in the current representation no information about the crater diameter is used. Matching between two panoramas is done by computing the distance between two sets of vectors. If the distance between two vectors falls below a fixed threshold their corresponding panoramas are considered to be identical, and their uniqueness score decreases. A query panorama, is compared with all panorama locations in a rectangular search sub-region centered in the center of the query panorama. The width and height of the rectangular search subregion are chosen to match the maximum a priori localization uncertainty. The distances between the query panorama and each of the panoramas extracted from the search sub-region are computed using the distance between the vectors corresponding to the crater locations. The absolute difference between the second lowest distance and the lowest distance is a measure of the uniqueness of a crater constellation in the query panorama. The uniqueness score defined above is large when the query panorama is unique in the search subregion, and the uniqueness score is low otherwise.

We have conducted a set of experiments to determine how the size of the panorama affects the panorama uniqueness score. Figures 6a,b,c,d show the uniqueness score histogram for panoramas of radius 15m, 25m, 30m and 35m respectively. The horizontal axis of each histagram describes the distance score between two panoramas. It can be noticed that a larger panorama radius shifts the histogram peak twoards larger uniqueness score values. As expected larger panoramas have a higher uniqueness score than smaller panoramas. The size of the search subregion is 250$\times$250m. A second experiment consists in reducing the search subregion size to 125$\times$125m while keeping the radius of the panorama constant at 25m. The results are as shown in Figures 6b and e.

Conclusons and Future work

This paper investigates the uniqueness of the local crater distribution at the lunar south pole and formulates a novel approach for the localization of manned or rover lunar surface missions. Unlike Martian surface where 3D and image based localization achieves with meter accuracy, lunar albedo often lacks discriminant features. However, the crater rich lunar surface contains locally distinguishable regions that can be used in alternative and potentially more accurate localization methods.

Based on the encouraging results of this work, future research will be directed into the incorporation of more complete crater characterization features(size, age, location) to improve the description of the local crater constellations. The new feature set will be used to estimate the use of crater constellation for rotation estimation. Finally, the results will be tested under conditions where one or multiple craters are not detected to determine the robustness of the proposed method to inaccuracies in automated crater detection algorithm.

References

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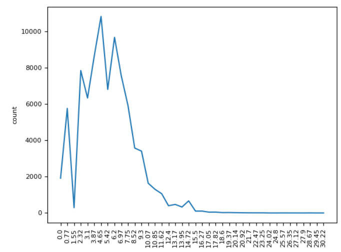

Figure 2: a. Uniqueness scores histogram for 15m radius panorama, 250 $\times$ 250m search sub-region

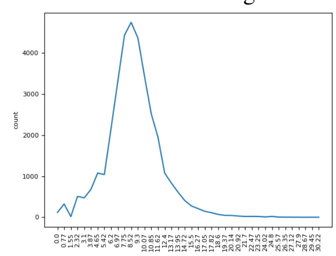

Figure 3: b. Uniqueness scores histogram for 25m radius panorama, 250 $\times$ 250m search sub-region

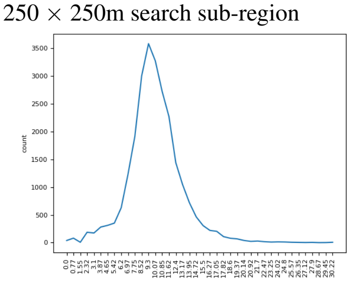

Figure 4: c. Uniqueness scores histogram for 30m radius panorama, 250 $\times$ 250m search sub-region

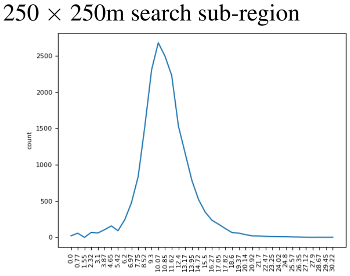

Figure 5: d. Uniqueness scores histogram for 35m radius panorama, 250 $\times$ 250m search sub-region

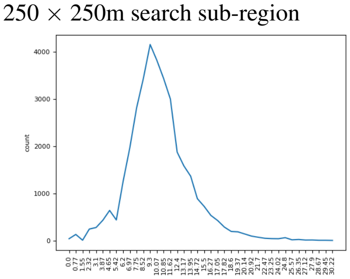

Figure 6: e. Uniqueness scores histogram for 25m radius panorama, 125 $\times$ 125m search sub-region