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Detection abilities of secondary craters based on the clustering analysis and Voronoi diagram

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Abstract

We propose two automated methods for recognizing cluster of candidate secondary craters with lunar crater spatial distribution. In these approaches, we evaluated the spatial distribution of craters by using the group average method in one of the hierarchical clustering analysis, or by using the Voronoi tessellation. In these procedures of identification of secondary craters, we compare the result of evaluation for observed spatial distribution of craters with the result of evaluation for ideally random spatial distribution of craters. We demonstrated for some regions on the lunar surface. As a result, Voronoi-based approaches hold better to identify candidate secondary craters than another method.

1. Introduction

We can estimate relative and absolute ages of geological units on the lunar surface with crater counting. This method is called as crater chronology and based on an assumption that each impact cratering occurs randomly to the lunar surface. In contrast to these primary craters, secondary craters are formed by ejecta blocks from primary crater formation and constitute clustering craters. As a result of the clustering, the secondary craters show a biased spatial distribution of craters. For the crater chronology, researchers have to exclude secondary craters and their regions from the surface image including primary and secondary craters based on his or her subjective views. We can identify most of secondary craters with unique shape and spatial distribution of craters [1]. However, the secondary craters produced by high-velocity ejecta fragments are more circular and may be less clustered than the adjacent secondary craters, and it can therefore be difficult to distinguish from primary craters. So, it has been suggested that individual differences in the recognition of secondary craters exist [1, 2].

2. Test area

Fig. 1 shows the region where our identification algorithms were applied (on Mare Crisium). The left and right images are including more and less secondary craters, respectively. The green circle means the rims of each craters more than 400 m in diameter. The range of crater diameter (D > 400 m) is constrained by crater saturation which occurs in the less than 400 m in average on the lunar maria [3]. All green-circled craters were detected by our visual inspection from Terrain Camera/Kaguya images which were acquired at low sun elevation.

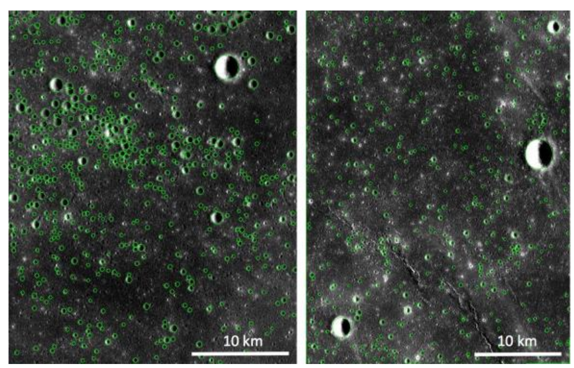

Fig. 1. Target craters for our evaluation.

3. Method

3.1 Clustering analysis

We developed a method based on [4] algorithm. We considered scale variation of craters and adopted the clustering analysis of group average method. On the other hand, we prepared 1000 times of ideally random spatial distribution of craters with same number of evaluated region, so the average and standard deviation of clustering analysis (clustering level vs. clustering parameter) could be calculated to compared with observed crater's result.

3.2 Voronoi diagram

We developed a method of Voronoi tessellation that has been utilized for spatial distribution of many kinds of targets such as engineering and scientific researches (e.g., galaxy clusters, [5]). The Voronoi tessellation is the way of subdividing a space as items (here, theirs craters). In this partitioning, all positions (pixels) in target area belong to nearest craters, so we could estimate the area of each crater (called as Voronoi area). The Voronoi area relates to the clustering of craters, and then small Voronoi area means the candidate clustering craters. We applied the Voronoi tessellation to observed crater spatial distribution and ideally random spatial distributions (1000 times). After that, the result of Voronoi diagram of observed craters were compared with the average and standard deviation of ideally random spatial distributions.

4. Results

Fig. 2 and 3 show the results of each method.

The clustering analysis method provides a reasonable identification of secondary craters even though we set variable thresholds. Especially, quite a lot of primary craters are identified as clustered craters because of characteristics of this clustering analysis that examines the nearest distance between each crater and cluster. On the other hand, the Voronoi based method that evaluates relationship between adjacent all craters has positive result.

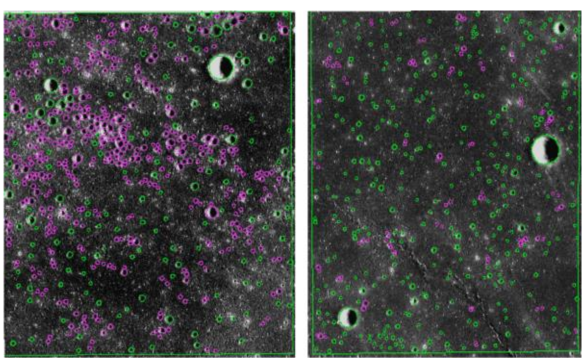

Fig. 2. Secondary crater based on clustering analysis. Magenta circled craters are identified as clustered craters (secondary craters).

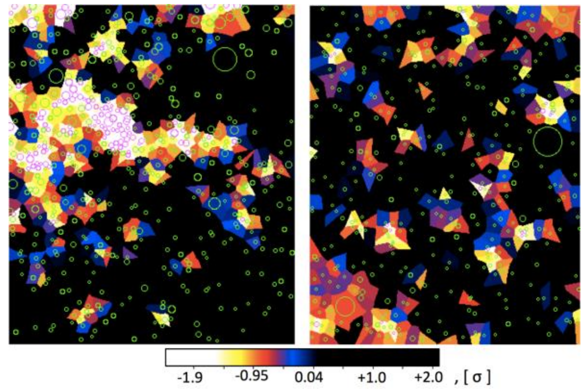

Fig. 3. Secondary crater based on Voronoi diagram. Magenta circled craters are identified as clustered craters (secondary craters). The colored polygonal area means the difference from ideally random spatial distribution of craters.

5. Summary

We assessed two methods for identification of secondary craters with spatial distribution of craters. The Voronoi based method provides a positive result for detecting secondary craters.

References

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