Automatic Crater Classification using Machine Learning

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Introduction

- Secondary craters are formed from the impact of the ejecta expelled during the primary crater formation
- They contaminate the process of crater counting through CSFD (Crater Size-Frequency Distribution) method leading spuriously high surface age estimation. Therefore, it is necessary to eliminate them beforehand
- To distinguish primary craters from secondaries, various morphological features could be used
- Features such as irregularity and eccentricity describing crater shape are commonly used to quantify the difference between primaries and secondaries. Besides, different incident velocities result in different crater depths, thus features related to crater depth could well express the difference too. Primary and secondary craters differ not only in their own features but also in density, as the existence of chains or clusters affects crater density a lot (a total of 32 features - 24 of which are of chains and cluster arrangements) [1]
- This study currently focuses on extraction of shape and depth based parameters

Features extracted :

1. **Irregularity** : Difference between the boundary and the fit circle of a certain crater

$$\mathrm{Irr} = \frac{\sqrt[2]{\frac{\sum_{i=1}^{n}(r_i - R)^2}{n}}}{R}$$

2. **Eccentricity** : Measures the ovalness of an ellipse / helps measure how circular it is with reference to a circle

$$\mathrm{Ecc} = \sqrt[2]{\left(1 - \frac{b^2}{a^2}\right)},$$

3. **Rim Integrity** : Estimation of the fraction of complete rim that was traced. It implies the degree of boundary destruction
4. **Depth-to-Circle Diameter ratio** : Considering the difference in elevation between the average fitted circle height and the deepest point within the crater as depth and taking the diameter from a circle fit as the diameter for this ratio

$$d_c/D = \frac{\overline{hc} - hc_{min}}{D}$$

5. **Depth-to-Ellipse Major Axis ratio** : The major axis of a fitted ellipse is taken as the diameter for this ratio

$$d_e/A_{maj} = \frac{\overline{he} - he_{min}}{a}$$

6. **Depth-to-Ellipse Minor Axis ratio** : Here the minor axis of a fitted ellipse is considered as diameter

$$d_e/A_{min} = \frac{\overline{he} - he_{min}}{b}$$

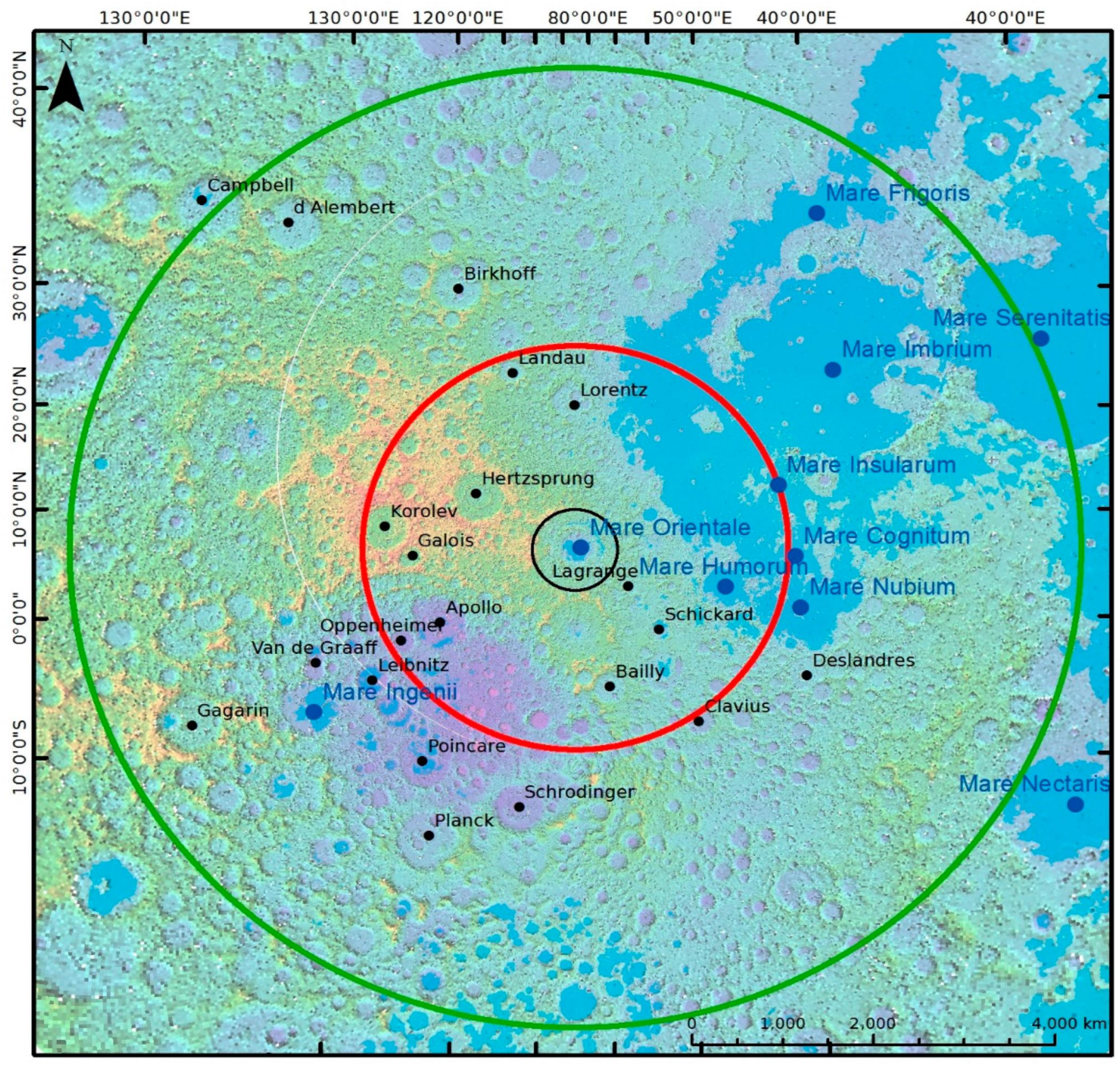
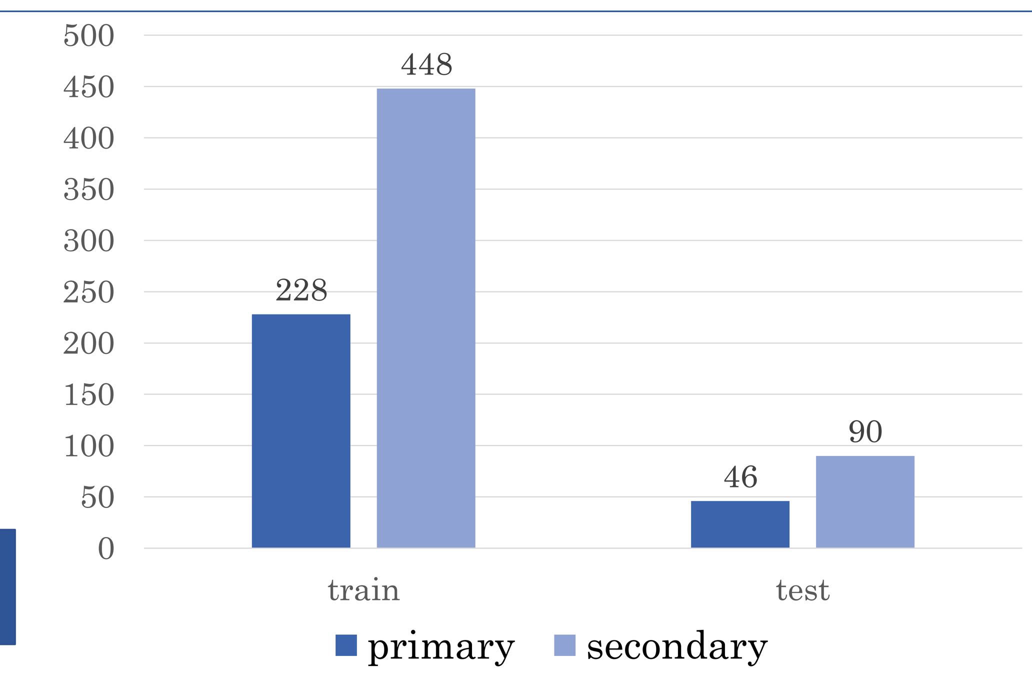


Fig 1. Sketch map showing the geomorphological setting of the investigation area for machine learning training and testing. Background map is a hillshade image from Lunar Orbiter Laser Altimeter elevation data [1]

Databases Used

- Secondary crater catalogue provided by Guo et al.,2018 is used for identifying secondaries at the investigation area
- Head et al.,2010 provided with a database consisting of craters with diameters ≥ 20 km. The study shows that secondaries in this region do not contribute significantly in ≥ 20 km crater population
- Robbins et al.,2019 and Wang et al.,2021 are used for extraction of morphological parameters listed in this study

Chart 1. Bar plot showing distribution of primaries and secondaries in train and test dataset



Methodology

Manually selecting crater samples

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Extracting crater features from published databases and preparing the dataset

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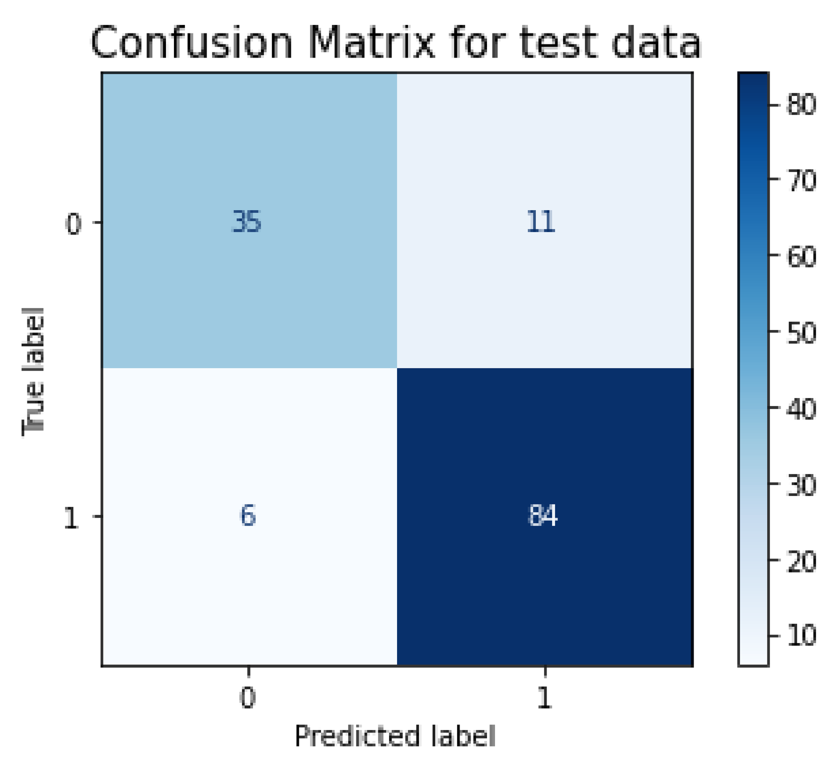
Random Forest Classifier with fivefold Cross Validation

Results and Conclusion



	Accuracy	F1- score
Primary	0.88	0.80
Secondary		0.91

Table 1. Accuracy and F1-score on test data

- A machine learning approach has been implemented for distinguishing between primary and secondary craters automatically
- The developed approach is evaluated with the already established crater databases of Moon
- The proposed machine learning model shows good performance with an accuracy of 88% on the testing dataset

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References

1. Q. Liu, W. Cheng, G. Yan, Y. Zhao, and J. Liu, 'A Machine Learning Approach to Crater Classification from Topographic Data', *Remote Sens (Basel)*, vol. 11, no. 21, p. 2594, Nov. 2019, doi: 10.3390/rs11212594.
2. D. Guo, J. Liu, J. W. Head, and M. A. Kreslavsky, 'Lunar Orientale Impact Basin Secondary Craters: Spatial Distribution, Size-Frequency Distribution, and Estimation of Fragment Size', *J Geophys Res Planets*, vol. 123, no. 6, pp. 1344–1367, Jun. 2018, doi: 10.1029/2017JE005446.
3. James W. Head, III et al. ,Global Distribution of Large Lunar Craters: Implications for Resurfacing and Impactor Populations.Science329,1504-1507(2010).DOI:10.1126/science.1195050.
4. Robbins, S. J. (2019). A new global database of lunar impact craters >1– 2 km: 1. Crater locations and sizes, comparisons with published databases, and global analysis. Journal of Geophysical Research: Planets, 124, 871–892. https://doi.org/10.1029/ 2018JE005592.
5. Wang, Y., Wu, B., Xue, H., Li, X., & Ma, J. (2021). An improved global catalog of lunar impact craters (≥1 km) with 3D morphometric information and updates on global crater analysis. Journal of Geophysical Research: Planets, 126, e2020JE006728.https://doi.org/10.1029/2020JE006728

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