

State of the Art

In 2019, a lunar crater database based on Lunar Reconnaissance Orbiter data was introduced, which documents craters with a diameter of at least 1 km [4]. When analysing the data, various studies have already shown clear differences between the lunar nearside and farside. The nearside has more maria (basaltic plains) and fewer visible craters per unit area, while the farside is more heavily cratered [5]. These differences have been linked to variations in geological activity. The crust of the nearside likely enabled extensive volcanic resurfacing due to being comparably thinner, which covered or erased many older craters [3]. Contrary to that, the crust of the farside is significantly thicker and less geologically active, which may have enhanced the preservation of the older and more densely cratered surface [3]. Another theory is that the differences in the subsurface temperature are an additional cause of these asymmetries [2]. An explanation for these factors might be that the nearside was hit by a very large and slow-moving impactor. This led to a melting of the crust and allowed a higher KREEP concentration (a combination of potassium, rare earth elements, phosphorus) on the impact surface, which ultimately raised the temperatures drastically, thus allowing more volcanism [1]. These patterns are supported by satellite observations and crater distribution analyses, and they form the basis for many current models of lunar geological evolution [4,3].

Problem Statement

Most of the existing knowledge remains in static literature or is based on closed-source workflows. There are very few accessible and reproducible tools that use modern geospatial methods to explore and visualize crater distributions across the Moon in a more flexible way. This leads to a limitation of the exploration and extension of lunar geological analysis. There is a gap in visual workflows that quantify and represent crater densities across the lunar hemispheres. These comparisons often rely on subjective assessments or inaccessible scripts. Furthermore, automated spatial binning, normalization by surface area, and scalable visualizations are not commonly provided.

Objective/Question

This investigation aims to quantify and visualize differences in crater distribution between the lunar near- and farside. The main goal is to determine whether modern geospatial tools in R can effectively quantify and visually represent lunar crater distributions, and what geological insights regarding the lunar near- and farside's histories can be derived from the result of these spatial analyses. The result of a remarkably lower crater density on the nearside would support the hypothesis that extensive volcanic activities on the nearside have erased and/or covered older craters, which would be in line with established models of lunar geological evolution.

Method

The analysis utilized the publicly available moon crater database published by the USGS Astrogeology Science Center in 2019, which includes approximately 1.300.000 lunar craters. The dataset was imported into R and processed using modern spatial and statistical libraries, including “sf”, “tidyverse”, and “spdep”. The data was reprojected into a consistent coordinate system to ensure accurate spatial analysis.

The lunar surface was divided into two hemispheres for comparison purposes. The nearside hemisphere was defined by longitude ranges between -90° and $+90^{\circ}$, while the farside hemisphere got the remaining longitude ranges from -180° to -90° and from $+90^{\circ}$ to $+180^{\circ}$.

For morphometric analysis, several crater shape and measurement quality metrics such as diameter, elongation ratio, eccentricity, ellipticity, diameter standard deviation, rim arc length, and the number of rim points were calculated. These parameters should enable a good comparison of crater formation between hemispheres.

Crater densities were then computed separately for the nearside and farside, normalized by each hemisphere's surface area. Additionally, crater size-frequency distributions were analysed using descriptive statistics (mean, median, standard deviation), and visualized with histograms and boxplots using ggplot2.

In addition, a 10x10 grid was created by dividing to spatially visualize crater counts. These maps help identify patterns and regional clustering of craters.

To check spatial autocorrelation in crater distribution, Moran's I was calculated on the binned crater counts. This provides a statistical measure of whether crater densities are clustered, dispersed, or randomly distributed across the lunar surface.

Results of the analysis

The result of the analysis confirms clear differences in crater distribution between both hemispheres. The farside consistently shows a higher crater density. This supports the expectation that the farside surface has been less geologically modified over time.

Morphometric analysis reveals only slight differences in crater shapes and similar measurement quality metrics between the hemispheres. The average crater diameter on the farside is slightly larger and the number of larger craters is higher. Distributions of elongation ratio, ellipticity, and eccentricity are quite similar between both sides, indicating that craters on both hemispheres tend to be circular. Measurement quality metrics such as diameter standard deviation and number of rim points show similar distributions, suggesting consistent data quality across the dataset.

Crater size-frequency histograms and boxplots confirm these findings. The farside distribution is slightly skewed towards larger craters, while the nearside is more concentrated in the 0-5 km diameter range. Both hemispheres show a strong dominance of small craters with frequency decreasing as crater size increase.

The spatial visualization using the 10x10 global grid shows several regions on the farside with crater clusters, while the nearside shows lower crater counts.

At last, the Local Moran's I was used to check the spatial autocorrelation. The strongest clusters could be found on the nearside. The farside also has clusters, but they are less densely populated. This would support the theory that the moon's asymmetry is a factor for these distributions, as the nearside has more mare regions (the biggest hotspot found is very likely the Mare Imbrium).

After this project it is realistic that the nearside experienced more extensive volcanic activities and resurfacing, which likely erased a portion of its older craters, as hypothesized in other studies. The farside, which has undergone fewer resurfacing

events and has a thicker, less geologically active crust, has preserved more of its original craters.

Literaturverzeichnis:

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