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Segment Anything Model (SAM) for Automatic Crater Detection

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Impact craters, resulting from the collision of meteorites, asteroids, or comets with planetary surfaces, manifest as circular-elliptical depressions with diverse sizes and shapes influenced by various factors. These morphological features play a crucial role in planetary exploration, offering insights into the geological composition and structure of celestial bodies. Beyond their scientific importance, craters may also hold valuable natural resources, such as frozen water in the Moon's permanently shadowed craters. Furthermore, understanding craters' spatial distribution is pivotal for terrain-relative navigation and for selecting future landing sites.

Manual crater mapping through visual inspection is an impractical and laborious process, often unattainable for large-scale investigations. Moreover, manual crater mapping is susceptible to human errors and biases, leading to potential disagreements of up to 40%. In order to tackle these issues, semi-automatic crater detection algorithms (CDA) have been developed to mitigate human biases, and to enable large-scale and real-time crater detection and mapping.

The majority of CDAs' are based on machine learning (ML) and data-driven methods. ML-based CDAs' are trained in a supervised manner using specific datasets that were manually labelled. Because of that, existing ML-based CDAs' are constrained to specific data types according to the type of their training data. This makes current ML-based CDAs' unstable and un-practical, since applying an ML scheme to a different type of data requires acquiring and labelling a new training set, and subsequently use it to train a new ML scheme, or fine-tune an already existing one.

In this study, we describe a universal approach [1] for crater identification based on Segment Anything Model (SAM), a foundational computer vision and image segmentation model developed by META [2]. SAM was trained with over 1 billion masks, and is capable to segment various data types (e.g., photos, DEM, spectra, gravity) from different celestial bodies (e.g., Moon, Mars) and measurement setups. The segmentation output undergoes further classification into crater and no-crater based on geometric indices assessing circular and elliptical attributes of the investigated mask. The proposed framework is proven effective across different datasets from various planetary bodies and measurement configurations. The outcomes of this study underlines the potential of foundational segmentation models in planetary science. Foundational models tuned for planetary data can provide universal classifiers contributing towards an automatic scheme for identifying, detecting and mapping various morphological and geological targets in different celestial bodies.

References

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