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A Deep Neural Network for Automated Detection and Mapping of lunar Rockfalls

Valentin Bickel (1,2), Charis Lanaras (3), Andrea Manconi (2), Simon Loew (2), and Urs Mall (1)

(1) Max Planck Institute for Solar System Research, Planets and Comets, Goettingen, Germany (bickel@mps.mpg.de), (2) ETH Zurich, Engineering Geology, Zurich, Switzerland, (3) ETH Zurich, Photogrammetry and Remote Sensing, Zurich, Switzerland

Since its launch in 2009, NASA's Lunar Reconnaissance Orbiter Narrow Angle Camera (NAC) has taken more than 1.6 million high-resolution images of the lunar surface. This dataset contains a wealth of potentially significant geomorphological information, including features related to rockfalls. The investigation of lunar rockfalls, in particular their spatial distribution and magnitude, would provide insights into past and recent lunar seismic activity, the geomorphological evolution of the surface, and the mechanical properties of regolith, among others. However, the vast majority of this data stack remains unused and the required information has not yet been exploited, due to limitations of current data processing and information extraction capabilities.

To cope with these limitations, we implemented a single-stage dense object detector (RetinaNet) to automatically detect and map rockfalls in high-resolution NAC images. The deep neural network (DNN) has been trained with $\sim$3000 original rockfall images that have been augmented to $\sim$240000 images during training using image rotation, flipping, and up- and downsampling. DNN performance has been assessed by using labelled testing images. The evaluation shows that the DNN is capable to reach recall values between 0.98 and 0.39, precision values between 1 and 0.25, and average precisions (AP) ranging from 0.89 to 0.69, depending on the used confidence threshold and Intersection-over-Union values. In addition, the trained network provides an estimate of the rockfall boulder dimensions based on the size of the placed bounding boxes. Average processing time of a single NAC image in RetinaNet is around 10 seconds using a GeForce GTX 1080 Ti and GeForce Titan Xp, being orders of magnitudes faster than a human operator. The combination of speed and detection performance can be used to exploit the entire NAC archive and to produce lunar rockfall distribution maps on large or even global scales. Preliminary results of such a map are presented and compared to locally existing rockfall distribution maps that have been produced by human operators.

The trained DNN is currently being implemented as a tool in NASA's Moon Trek platform hosted by JPL. Moon Trek is part of the Solar System Treks Project (trek.nasa.gov/) and is a sophisticated web-based platform that provides tools and datasets for scientific inquiry as well as public outreach and education. This cloud-based approach allows an on-demand operation, i.e. brings the user to the data, not the data to the user, thus, avoiding data download and storage limitations. The DNN Rockfall Detector tool will eventually be available on NASA JPL's Moon Trek for utilization by the scientific and engineering community.