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Mapping Surface Winds on Mars from the Global Distribution of Barchan Dunes Employing an Instance Segmentation Neural Network

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The surface of Mars is riddled with dunes that form by accumulating sand particles that are carried by the wind. Since dune geometry and orientation adjust in response to prevailing wind conditions, the morphometrics of dunes can reveal information about the winds that formed them.

Previous studies inferred the prevailing local wind direction from the orientation of dunes by manually analyzing spacecraft imagery. However, building a global map remained challenging, as manual detection of individual dunes over the entire Martian surface is impractical. Here, we employ Mask R-CNN, a state-of-the-art instance segmentation neural network, to detect and analyze isolated barchan dunes on a global scale.

We prepared a training dataset by extracting Mars Context Camera (CTX) scenes of dune fields from a global CTX mosaic, as identified in the global dune-fields catalog. Images were cropped and standardized to a resolution of 832x832 pixels, and labeled using Labelbox's online instance segmentation platform. Image augmentation and weight decay were employed to prevent overfitting during training. By inspecting 100 sample images from the validation database, we find that the network correctly identified ~86% of the isolated dunes, falsely identifying one feature as a barchan dune in a single image.

After dune outlines are detected, they are automatically analyzed to extract the dominant-wind and net sand-flux directions using traditional computer vision techniques. We expect our future surface-wind dataset to serve as a constraint for atmospheric global circulation models to help predict weather events for upcoming in situ mission as well as shed new light on the recent climate history of Mars.