National Aeronautics and Space Administration

FY23 Innovative Spontaneous Concepts Research and Technology Development (ISC)

Denoising low light imagery from diverse sources, enabling quality 3D maps in lunar shadowed regions

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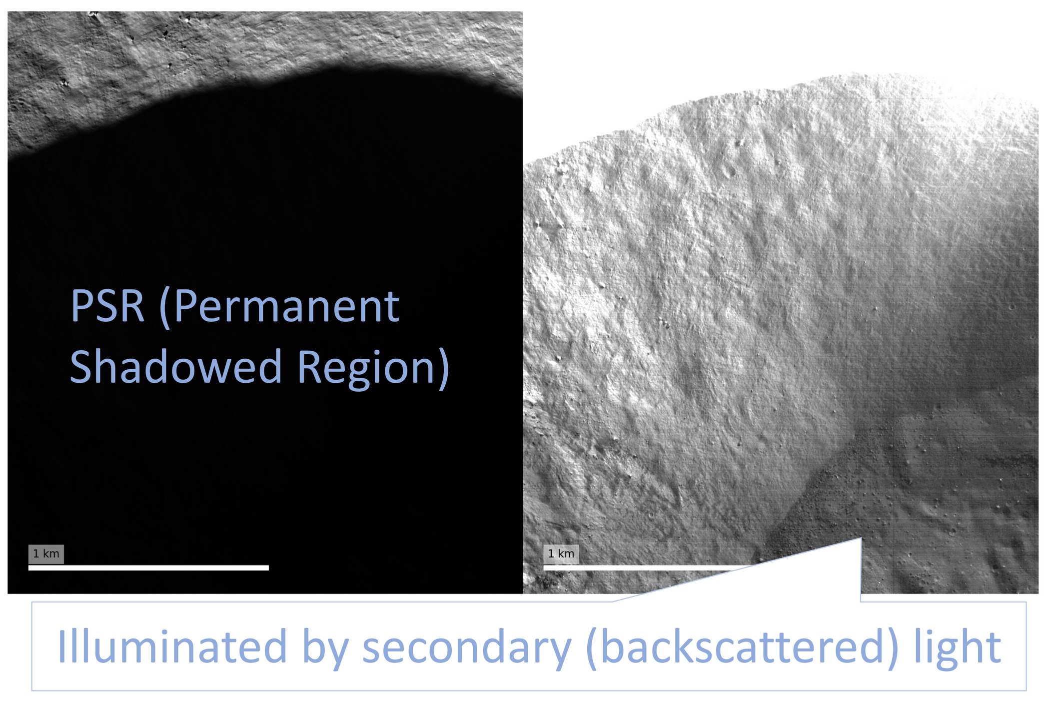
Objectives

The objectives were: (i) to evaluate a deep-learning approach to denoising low imagery in poorly illuminated areas, from any imaging sensor, to achieve sufficient low noise levels that one can use feature matching to create 3D maps, and (ii) to use GAN (generative adversarial network) to generate separate estimates of denoised image and noise image and adapt GAN parameters.

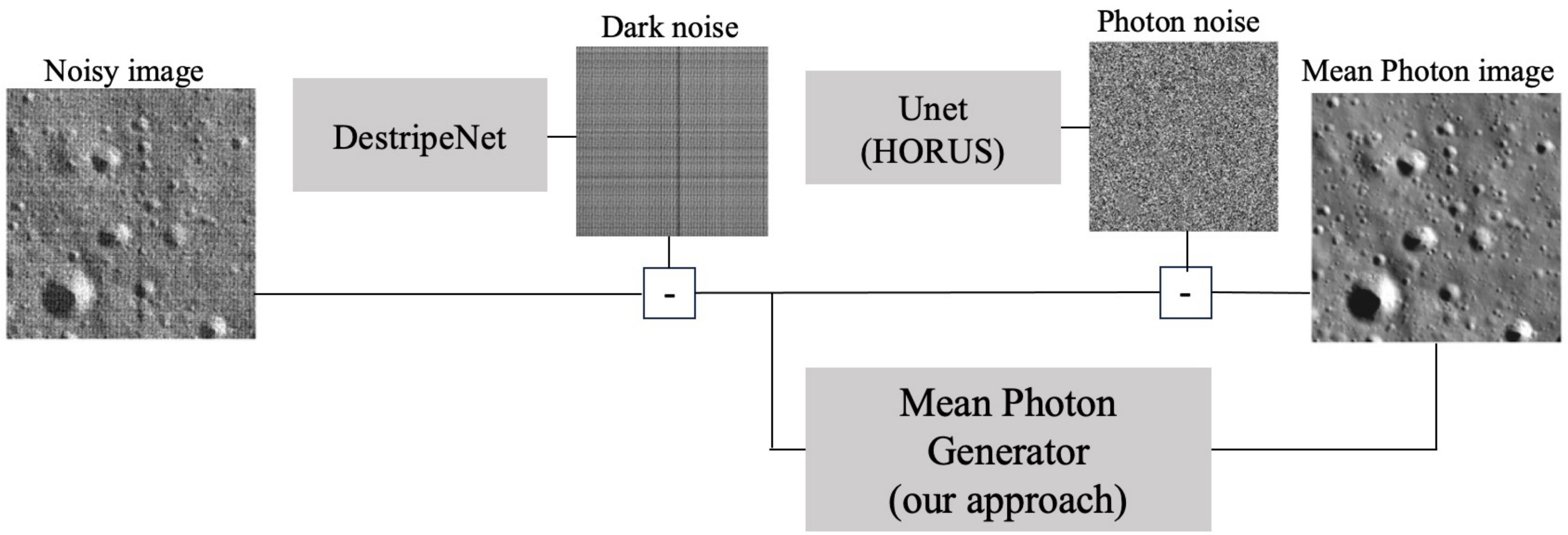


Background

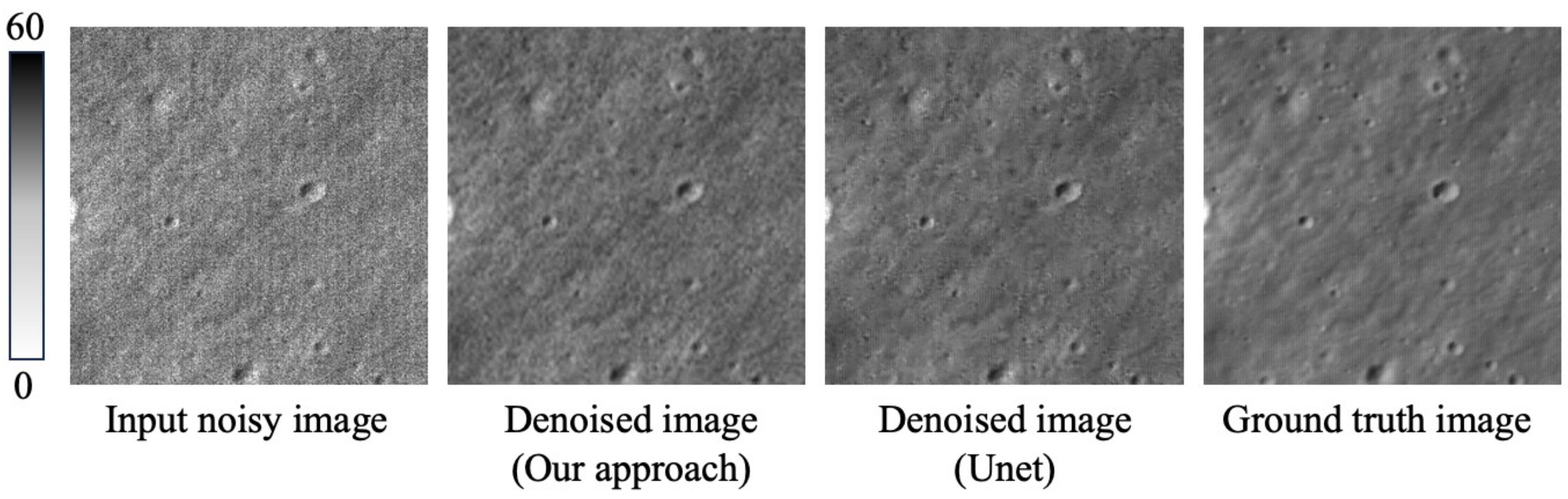
High-quality 3D maps are critical for in-situ planetary exploration. In particular, maps of the lunar south pole (SP) are of the highest interest to the ARTEMIS program. With the SP sun always at a low angle above the horizon, permanently shadowed regions (PSRs) exist at low elevations, especially in craters. PSRs have high relevance for potentially harboring water ice and most volatiles. To denoise low-light images, Hyper-effective nOise Removal U-net Software (HORUS) [1] uses a physics model of CCD-related and photon noise. HORUS utilizes a convolutional neural network, which can estimate noise in the training data. In other words, the noise model needs to be known in HORUS, without which it can't operate.

Approach and Results

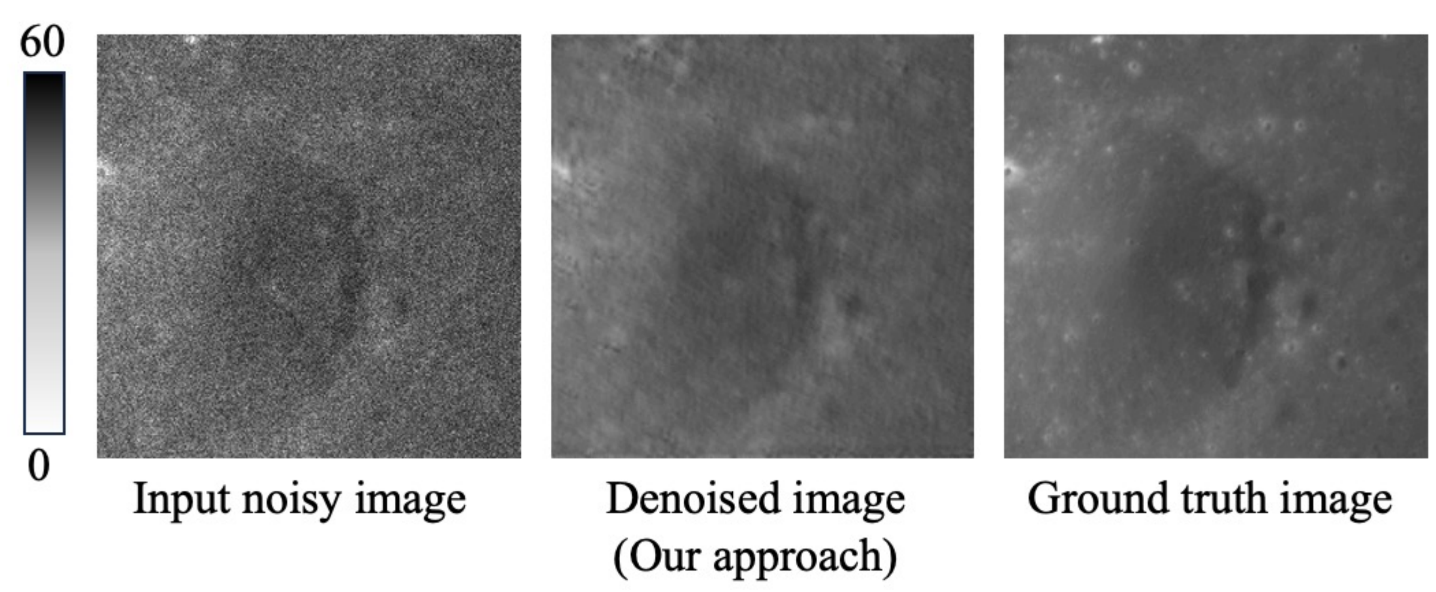
We developed a deep learning approach using a generative adversarial network (GAN) and demonstrated denoising of depth images from a LiDAR sensor [2]. It has promise to extend this to other imaging sensors. Our network architecture has 2 components as shown in Fig. 1; (a) DestripeNet to estimate sensor-related noise [1] and (b) Mean Photon Generator to estimate denoised images. The difference between our approach and HORUS is that we use images as they are *without requiring a model of the photon noise* (which HORUS uses for training). In other words, we do not need to know photon noise in advance, which HORUS needs to. Thus we can deal with noise of unknown type, which is closer to reality.



In experiments, we collected LRO NAC images from the same areas on the lunar surface as HORUS used. We used a total of 500 images, which were divided into a training, validation and test sets (72:18:10). The mean absolute errors (MAE) of our approach, at 6.06, are lower than Unet's at 6.78 [DN]. This shows that our approach is slightly better than Unet. We applied our approach to JAXA's Kaguya images, and an example result is shown in a figure.



An example results using NAC images



An example results using Kaguya images

Significance/Benefits to JPL and NASA

Our method resulted in about 10% improvement in lowering the mean absolute errors compared with HORUS, and without using a noise model. This is promising in obtaining 3D maps of the moon from further imagery. Furthermore, beyond the Moon, denoising low light imagery and 3D mapping directly apply to PSRs on Mercury and Ceres and potentially to other solar system destinations with soft illumination.

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