Detection of Dark Regions on the Lunar Surface with Shadow Masked Multiband Imager Data

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The lunar low-reflectance regions, such as Dark Mantle Deposits (DMDs), iron or titanium rich regions, or weathered older mare, have important information for clarifying the process of lunar evolution. To locate the global distribution of the low-reflectance (dark) region is one of important studies for lunar geological science. Since even small dark regions can be detected based on high-resolution lunar images such as Kaguya’s Multiband Imager (MI) images, a goal of this research is to identify candidates of the darkest region with various spatial scale on the global lunar surface. However, a simple automatic identification of small dark regions from Kaguya’s MI images, such as using a threshold value, may be hindered by shadows. Therefore, in this research, dark regions other than shadows were identified after removing the shadow regions from the MI images.

The areas that have relatively lower reflectance than the surrounding area due to the difference in the local solar incidence angle are treated as same as actual shadows cast by being hidden from sunshine because the areas often show abnormal spectrum patterns. In the first step, to detect shadow regions, we employed conditional generative adversarial networks (cGAN) which is deep learning method. The cGAN is composed of the generator neatwork and the discriminator network. The Generator is trained to generate realistic fake images that cannot be distinguished from real images by the Discriminator, whereas the Discriminator is trained to detect the fake images generated by the Generator. We prepared supervised data which are pair of MI images and correct shadow masks for training the cGAN networks. In this step, Generator was trained for generating a realistic shadow mask as much as possible according to an input MI image. After the training, our Generator successfully provide a shadow mask in which we can detect high contrast shadows and shadows by craters or other land features. On the other hand, we found that our network had low accuracy for smaller shadows and surround regions of invalid values, and these detected shadow masks included many noises.

In the next step, we employed simple thresholding to detect candidates of DMD from the MI images with shadow masks generated by the trained Generator. Since the results of shadow detection are not stable when an image has many invalid values., regions higher than ±60 °including relatively many invalid values were excluded from target regions. The threshold value was determined from a histogram of the reflectance which calculated from the band 2 (750 nm) of the MI image after the shadow removal, and regions where the reflectance was lower than the threshold were detected as candidate of the dark region. In this study, because dark regions with a small size in the detected candidates may be mis-detection of the small shadow regions that could not be distinguished and removed by the trained network, dark regions which area are smaller than 900 pixels (0.36 km^2) were excluded from candidates. Though this process may exclude candidates for actual small dark regions that are not shadows, we decided to focus on locating candidates that can be more reliably determined as dark regions. As threshold processing and noise removal method are important factors greatly affecting the detection of the final candidate points, we will consider the improvements for detecting smaller dark regions in the future work.

In the result of applying this method, although some noise remained, some known DMDs, in the Sinus Aestuum, Taurus-Littrow, Sulpicius-Gallus and Mare Vaporum, were detected as candidates of dark regions. Most of the other detected points were also located in the region of high titanium. In this work, analysis results of detected dark regions and utility of the detection methods will be reported and

discussed.

Keywords: deep learning, shadow detection, Multiband Imager, Dark Mantle Deposit

