Recognition and classification of Martian chaos terrains using imagery machine learning

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Chaos terrains on Mars are irregular to circular fractured areas that consist of jumbled knobs and polygonal flat-topped blocks (e.g. Pedersen et al., 2014) . The blocks of the chaos terrains vary in size (kilometers to tens of kilometers) and shape depending on locations (e.g. Pedersen et al., 2014) . The blocks are surrounded by depressions with altitude difference of typically 1–2 km (e.g. Warner et al., 2011) . Chaos terrains locate primarily in Valles Marineris, with the numbers of ~470 individual terrains, on Mars. Based on the preservation of the original surface structures on the fractured blocks, some chaos terrains are interpreted to be collapsed terrains due to discharge of groundwater upon melting of ice (e.g. Zegers et al., 2010) . This can be supported by the fact that chaotic terrains are often associated with outflow channels (e.g. Pedersen et al., 2014) . On the other hand, others propose that based on the geomorphologic features, other chaos terrains may have been formed through different formation processes, including magma excavation (Sharp, 1973) , degradation of ground ice (e.g. Zegers et al., 2010) , and clathrate destabilization (e.g. Rodriguez et al., 2006) . Owing to high resolution images on Mars, a number of chaos terrains have been found thus far. However, only limited numbers of chaos terrains are investigated to interpret the formation mechanisms. In addition, the interpretations of the observations vary depending on the locations. This implies that there are significant differences in the morphology and possibly formation mechanisms among the chaos terrains.

In the present study, we perform imagery machine learning for the chaos terrains on Mars with aims at for recognition and classification. We used the fine-tuning VGG19 model, which was constructed by Visual Geometry Group with convolutional layer depth of 19. We prepare total 3300 images of chaotic terrains on Mars, including 1100 visible images taken with the Context Camera, CTX, in grayscale, 1100 images of thermal inertia map taken with the Thermal Emission Imaging System, THEMIS, and colored 1100 images of Mars Orbiter Laser Altimeter (MOLA) High-Resolution Stereo Camera (HRSC) blended digital elevation model (DEM) taken by Mars Global Surveyor, MGS and Mars Express, MEX. Among the chaos terrains, we define two types of chaos terrains: Ones were probably formed through the discharge of groundwater based on the previous studies (e.g. Zegers et al., 2010; Roda et al., 2014; Rodriguez et al., 2005) (221 images) , and the others were probably generated in association with magma excavation and tectonic tiles based on the previous studies (Sharp, 1973; Bamberg et al., 2014) (151 images) . We also collect 200 images of non-chaotic features, such as valley networks and impact craters, on Mars to construct the classifier.

Our preliminary results show that using THEMIS images, we can classify chaotic terrains with 83% accuracy. The constructed classifier is useful to find new chaos terrains on Mars and other planets, such as Earth. However, the accuracy to recognize whether they formed through discharge of groundwater or magma excavation is low. This means that the formation mechanisms may not be able to suggest based on only the morphology.

Keywords: Mars, Chaotic terrains, Machine learning

