A NEW GLOBAL CATALOG OF LUNAR IMPACT CRATERS (≥1 KM) WITH 3D MORPHOLOGICAL INFORMATION. Yiran Wang and Bo Wu*. Department of Land Surveying and Geo-Informatics, The Hong Kong Polytechnic University, Hung Hom, Hong Kong (yiran.wang@connect.polyu.hk; bo.wu@polyu.edu.hk).

Introduction: Caters are dominant geomorphological features on lunar surface. The investigation of lunar crater populations, distributions and their morphometric parameters provides valuable information on impact cratering processes, as well as the physics and geology of planetary processes. In the past, various efforts have been dedicated to generate global lunar crater catalogs. The first well-known global crater catalog for the Moon was developed by Head et al. [1]. Their catalog contains 5,185 craters with diameters larger than 20 km. Later work extended this catalog to contain craters larger than 10 km [2], 8 km [3] [4], 5 km [5] and 3 km [6] in diameter. Among these crater catalogs, only the one by Krüger, et al. [6] contains 3D morphological information. Recently, Robbins [7] developed a lunar crater catalog with 1.3 million craters ≥ 1-2 km. This catalog is the most updated one regarding the size and number of craters, but no 3D morphological information of craters is provided.

The higher-resolution remote sensing datasets collected by recent lunar missions enable the investigation of impact craters of a relatively smaller size and provide more accurate and detailed 3D information. Based on the 3D datasets, an automatic crater detection method and an automatic method for extracting 3D morphological information of craters are developed, and the preliminary results are summarized in this abstract. Based on the developed methods, a new global catalog of lunar impact craters (≥ 1 km) with 3D morphological information is developed.

Datasets: The automatic crater detection and morphological information extraction are based on digital elevation models (DEMs) of the lunar surface. For the regions in latitudes of [−60º, 60º], the Lunar Reconnaissance Orbiter (LRO) Laser Altimeter (LOLA) and SELENE Terrain Camera (TC) [8] merged DEM (SLDEM) was used. The SLDEM has a spatial resolution of 512 pixels per degree (about 60 m at the equator) [9]. The LOLA DEMs (LDEMs) were used for the regions in latitudes of [-90º, -60º] and [60º, 90º]. The LDEM has the best resolution of 1,024 pixels per degree and has a relatively better resolution on polar regions. The SELENE TC images with a spatial resolution of 10 m/pixel were used for assisting the manual checking and digitization after the automatic crater detection. The SLDEM, LDEM and SELENE TC images were manually co-registered to remove the geometric inconsistencies among them before use.

Crater Detection: The automatic crater detection method is based on machine learning. Firstly, a feature descriptor based on the histogram of oriented gradient (HOG) [10] was designed for describing the elevation changes of crater areas and used to extract features for machine learning. Then, a support vector machine (SVM) classifier was trained and optimized using the HOG features from positive samples (crater regions) and negative samples (non-crater regions). The trained classifier was then applied to detect craters using adaptive moving windows, which can return both the center coordinate and the diameter of each crater. The method was trained at one site and validated independently at four other sites, including the most challenging regions with craters densely distributed. These tests confirm the effectiveness and high efficiency of the proposed method, which allows the crater detection globally.

To ensure the reliability of the detected craters, a manual checking process was further performed by two independent operators with the assistance of a grid with a cell size of 1 km× 1 km overlaid on the SELENE TC images, to remove artifacts and digitize missing craters.

Morphological Information Extraction: In addition to the geographic coordinates of the crater centers, the crater catalog is enriched by 3D morphological information, including crater depth, wall slope, bottom width, rim height, central peak height and central peak width of the craters based on the 3D information from the SLDEM and LDEM. For each detected craters, four profiles were derived, including a vertical profile, a horizontal profile, and two diagonal profiles. The 3D morphological characteristics of craters are automatically calculated by a two-term Gaussian fitting model based on the extracted profiles. The definition and calculation of the morphological parameters are illustrated in Figure 1. Evaluations show that the morphological information derived from this automatic method is comparable to those measured manually.

Results: The automatic crater detection and morphological information extraction methods were performed throughout the datasets covering the entire lunar surface to generate the new crater catalog. The catalog is overlapped with the newly released catalog of craters ≥ 1~2 km [7] to compare the completeness. For the discrepancies of those two catalogs, craters in our catalog were revised with further confirmation from the image and DEM data. Ultimately, the resulting new catalog contains more than 1 million craters (as shown in Figure 2) with the diameters reach to 1 km. Additionally, each crater has the record of not only the position and diameter information, but also the 3D morphological information.

Conclusions: This study presents a new global crater catalog of lunar surface. It extends the existing global catalog to all craters with diameters ≥ 1 km. Furthermore, the crater catalog was enriched by 3D morphological information, owing to the 3D information extracted from the DEMs. This new catalog is the most complete one than any previously published efforts. This new crater catalog will be useful for researchers in lunar geology and other related fields.

References: [1] Head, et al. (2010) Science, 329, 1504. [2] Luo, et al. (2013) Front Earth Sci, 7(4), 456-464. [3] Salamunićcar, et al. (2012) PSS, 60(1), 236-247. [4] Salamunićcar, et al. (2014) Adv. Space Res., 53(12), 1783-1797. [5] Povilaitis, et al. (2017) PSS, 162, 41-51 [6] Krüger, et al. (2018) JGR: Planets 123-10. [7] Robbins, 48th LPSC, pp. 20-24 [8] Kato, et al. (2008) Adv. Space Res., 42, 294-300. [9] Haruyama, et al. (2012) 43rd LPSC, vol 43. [10] Dalal, et al. (2005) CVPR 2005, pp. 886-893.

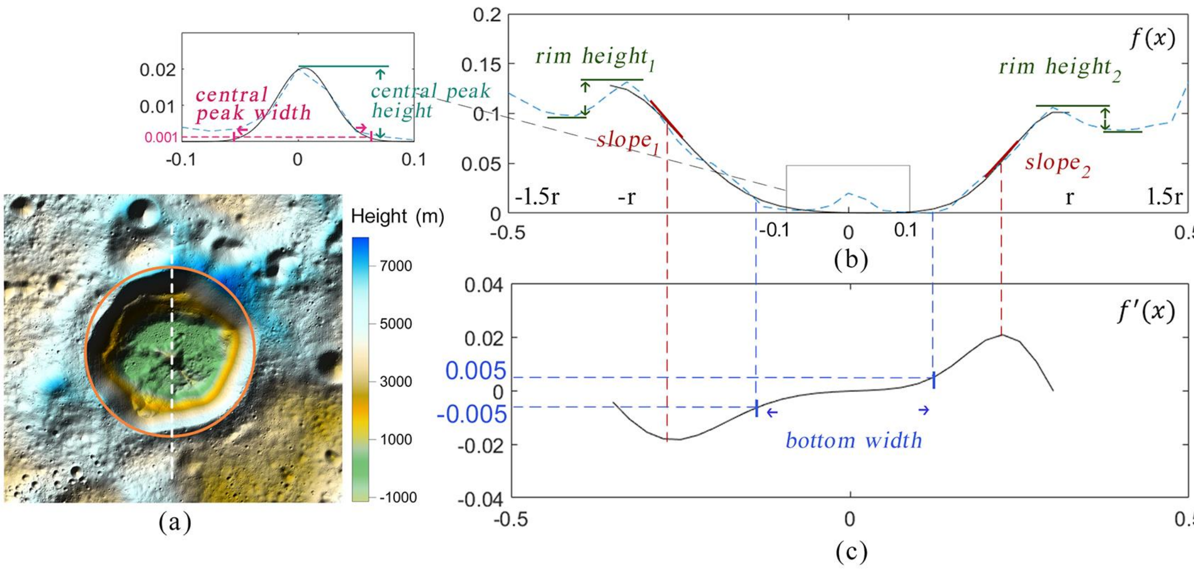

Figure 1. Automatic extraction of the 3D morphological information of craters. (a) The circle shows the boundary of the detected crater and the dash line illustrates where the crater profile is extracted. (b) The light blue dash line displays the extracted profile, and the black line is the fitted two-term Gaussian function. For the sake of fitting, the horizontal distances (x-axis) were normalized, and the elevation (y-axis) were zoomed accordingly. (c) The black line is the first-order derivative of the fitted Gaussian function, used for the calculation of morphological information.

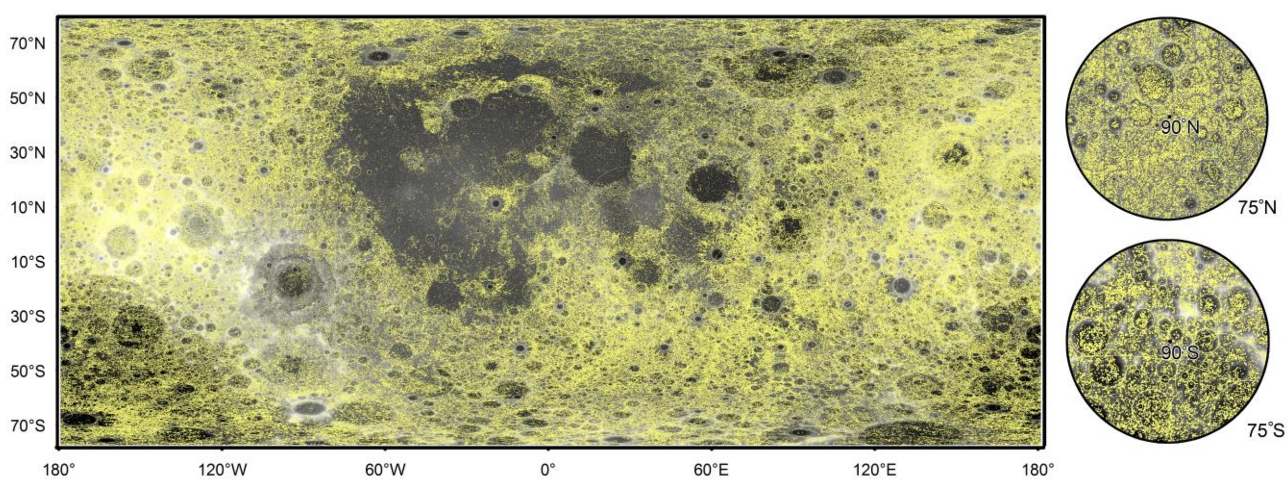

Figure 2: The new global catalog of lunar impact craters (≥1 km) overlaid on the SLDEM and LDEM.