AUTOMATED DETECTION AND EXTRACTION OF LUNAR IMPACT CRATERS FROM DIGITAL TOPOGRAPHY DATA. F. Zhang1,2, Y. L. Zou1, Y. C. Zheng1, X. H. Fu1, and Y.C. Zhu1,2 1National Astronomical Observatories, CAS, Beijing, A20 Datun Road, Chaoyang District, Beijing 100012, P.R. China, 2 University of CAS, Beijing, A19 Yuquan Road, Shijingshan District, Beijing, 100049. (zfzhang@bao.ac.cn)

Introduction: Craters are studied extensively since they provide us with the relative age of the surface unit [1, 2] and more information on the lunar surface geology [3]. There are three important aspects for the detailed analysis of their distributions, morphology and numbers: (1) they display an important role in defining the present character [4, 5] of the surface of the Moon, the study of craters’ distributions and morphology can also improve our knowledge of the cratering mechanism itself [6, 7]; (2) evaluating their number density on different areas has led to the establishment of a large-scale stratigraphy for the Moon, especially in the lack of samples returned in most surfaces of the Moon; and (3) to some extent, craters are eroded or damaged partially by a series of later interior and exterior processes (slumping owing to gravity, other impacts, temperature changes, and moonquakes), and thus we can search for clues about these processes which once caused the degradation [8, 9] of craters. However, crater detection and measurement is important and a crucial prerequisite for a further application research. Owing to all of the image-based crater-detection approaches involving complicated, multistep algorithms to combat inherent limitations of imagery data, digital elevation model (DEM) data are available and several versions obtained from different remote sensors (e.g., China’s Chang’E-1 and current NASA’s LRO) can be used to establish three-dimensional forms of lunar craters. They are suitable for a quantitative geomorphic analysis and are well suited for automated identification of craters [10]. Here we present a new approach using DEM data to detect and extract craters on the moon with GIS technique, and it realized quantitatively automated extraction.

Data: In our study, the lunar global image [11] and the digital elevation model (DEM, ~500 m spatial resolution) data [12] obtained by CE-1’s three-line-array CCD stereo camera, and the DEM data acquired by the Lunar Obiter Laser Altimeter [13], an instrument on the Lunar Reconnaissance Orbiter (LRO) are used. For the result to show, the released LRO USGS global mosaic (LRO_WAC_Mosaic_Global_303ppd.jp2; downloaded from: ftp://pdsimage2.wr.usgs.gov/) was also used as the basemap for exhibiting our result extracted.

Method: In this study, firstly, crater inner wall detection performed from topography data. Individual primary-impact craters resemble one another more than they differ [14]. The rims of these craters are nearly circular. Their floors lie below the level of the adjacent terrain. Their inner walls slope steeply, and the flank outside the raised rim crest slopes more gently. Inner wall polygons were obtained by calculating slope gradient index from DEM data on the basis of the characteristics of crater's shape and structure. These crater inner wall polygons have the biggest slopes from the gradient index map. These steps are performed based on the vector type data in the ArcGIS software.

Figure 1: The DEM profile map along one direction from one outer rim point to the opposite one. A and B are two crater rim crest points identified in this paper.

The minimum bounding rectangle (MBR), also known as bounding box or envelope, is an expression of the maximum extents of a 2-dimensional object (e.g. point, line, and polygon) within its 2-D (x, y) coordinate system, in other words a rectangle ranging from min(x), max(x), min(y), and max(y) of a 2-dimensional object. In this step, an inner point, which located within the interior of the crater, will be identified by positioning the center of the MBR of these crater inner wall polygons obtained in the first step. Then take the inner point as the center to search all crater rim crest points along different directions outside. The highest point of the crater rim have the biggest DEM value (For example, A and B in Figure 1 are two crater rim crest points along one direction across the whole crater) from the inner point to outer rim part. After all crater rim crest points were identified according to the approach referred above. Finally, the crater rim circle is obtained by fitting at least squares principle.

Results: In order to test the potential capability to detect craters using different DEM data acquired by various lunar orbiter probes, we applied the DEM data obtained by China’s CE-1 satellite and the DEM data obtained in the NASA’s LRO mission to the detection algorithm in this study. The image covers approximately 26650.9
km$^2$. The crater detection results and the differences of using different DEM data can be verified by comparing the extracted results (Fig. 2). Crater detection results using algorithm proposed in this paper are as follows: (a) CE-1 image (Fig. 2a), 7 craters are identified, the resolution of DEM is ~500 m/pixel, the minimum diameter is about 5.2 km; (b) LRO WAC image (Fig. 2b), 22 craters is identified, the resolution of LOLA DEM is 60 m/pixel, the minimum diameter is 1.75 km, a crater (marked by the blue rectangle), the diameter of which is about 2.5 km, is not detected.

Generally, Figure 2 illustrates our crater detection results after that we have applied our approach to two pairs of images (the same study area) captured by the China’s Chang’E-1 probe and the NASA’s LRO mission respectively. The result suggests that the coarse resolution (~500 m) of the present Chang’E-1 DEM limits the size of craters that can be detected to more than ~5 km in diameter. However, the recent LRO’s LOLA DEM data, of which the resolution is ~60 m, allow for detection of smaller craters, such as the size of craters about ~2 km in diameter. A crater of 2.5 km in diameter is not detected from the LOLA DEM data (the blue rectangle in Fig. 2b), which is caused by the lower inner-wall slope value (lower than 10 degree) compared to others detected successfully.

![Figure 2](image)

**Figure 2:** Crater detection results using algorithm proposed in this paper. The coarse resolution (~500 m) of the Chang’E-1 DEM (left) and the recent LRO’s LOLA DEM data (the resolution is ~60 m, right) are used.

In order to check the capacity of our approach to extract craters of different size. We selected diameters extracted of 20 craters distributed in the low latitude region in Oceanus Procellarum and Imbrium to compare with the diameter values in Lunar Impact Crater Database (2011, http://www.lpi.usra.edu/lunar/surface/) released by Lunar and Planetary Institute. Figure 3 shows the comparing result. Bowl-shaped craters are the simple craters (most $D < 20$ km) and obtained the highest extraction accuracy [Fig. 3] in our study. Lunar mare surface retained a record of many bowl-shaped craters, which are important in age measurements of mare units in previous researches [e.g., 15, 16]. Because of the lack of lunar samples and radiometric ages for lunar basalts are available only for spatially very limited areas, the ages of mare units are mainly measured by the crater size-frequency distribution measurements technique [e.g., 17, 18]. The craters (D $\geq$ 1 km) are often measured on the geologic unit to be dated. The errors in determination of crater frequencies would cause model age errors. Therefore, our results suggest that the studies on the automated method based on the topography data with high resolution to detect craters are needed in the future work.

![Figure 3](image)

**Figure 3:** The scatter chart of crater diameters extracted in this study as opposed to the values in Lunar Impact Crater Database (2011) released by LPI.

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