AUTOMATIC MAPPING OF LANDFORMS FROM DEM ON MOON

Jiao Wang[1,2,3], Chenghu Zhou[1], Weiming Cheng[1], and Wei Luo[3], [1] State Key Laboratory of Resources and Environmental Information System, Beijing, China 100101, [2] University of Chinese Academy of Sciences, Beijing, China 100049, [3] Northern Illinois University, Dekalb, IL 60115. (wjiao@lreis.ac.cn)

Introduction: Landforms are the result of geologic and geomorphologic processes that occur on planets' surface. Mapping of landforms on planetary surfaces at broad spatial scales are becoming increasingly important and eligible with abundant availability of Digital Elevation Model (DEM). A pixel in the DEM carries a vector of elevation value and other basic attributes of terrain. It is expected that pixels constituting a particular landform carry similar terrain vectors. So classification of landforms can be achieved by applying a clustering algorithm over all attribute vectors for their exclusive similarity in a given site. The digital computer and Geographic Information System (GIS) have removed many obstacles to the classification of terrain from surface geometry, for areas of any size or spatial resolution. The purpose of this paper is to report a methodology for the automatic mapping of lunar landforms based on DEM within a GIS environment. Iterative self-organizing (ISO) cluster unsupervised classification performs landforms mapping of Moon on a series of input raster bands of six morphologic parameters. Limitations of automatic classification are presented. The method can be extended to other Moon-like landforms with DEM.

Data: The DEM is constructed from the Lunar Orbiter Laser Altimeter (LOLA), an instrument on NASA's Lunar Reconnaissance Orbiter (LRO) spacecraft representing more than 6.5 billion measurements that were converted into a DEM [1] using Generic Mapping Tools software [2], with a resolution of 256 pixels per degree. In projection, the pixels are 118 meters in size at the equator. The grid size of LOLA-derived DEM is 11248 by 7867. The area selected as test site for our algorithm is located on the portion of Lunar surface that has been dated from an early period in Moon history and exhibits abundant types of landforms. According to United States Geological Survey's lunar geologic mapping program, the Moon was divided into 30 quadrangles [3] and our tested area in quadrangle LQ-20 between 0° and 30°S latitude, 0° and 45°E longitude. The sites' size is almost 10^5km^2.

Methodology: Our classification algorithm consists of several major modules: (1) DEM preprocessing; (2) morphologic parametrization; (3) ISO cluster unsupervised classification; (4) the final construction of mapped landforms. DEM usually contain errors that should be minimized prior to their use in extracting terrain parameters. After a number of routine check of DEM, the filling progress is executed to address the issue of the topographic craters, and the difference between the filled and original elevation fields has non-zero values only for pixels located inside topographic craters [4]. Considering lunar surface's dichotomy (highland and mare) and widely distributed impact crates, we used six morphologic parameters derived from original and filled elevation fields to implement our classification. They are: elevation, filled elevation, slope, filled slope, relief amplitude, and filled relief amplitude. ISO cluster unsupervised classification performs unsupervised classification on a series of input raster bands (six terrain parameters) using the ISO Cluster and Maximum Likelihood Classification tools [5]. The ISO cluster algorithm computes the minimum Euclidean distance when assigning each candidate cell to a cluster. The number of iterations is a free parameter, we have experimented with N=12, 15, 20, and 40 clusters. We found that the clusters display landforms in reasonable classification consistent with visual interpretation when N=20. Clusters merge with neighboring clusters when the statistical values are similar after the clusters become stable. The final merging is performed using Jenks Natural Breaks algorithm that is a kind of variance-minimization classification [6]. Finally, the result of our classification is automated as a thematic map of landforms by reviewing statistical properties of topographic attributes in each cluster and studying spatial relations between different clusters, which pertain to landform classes that the clusters represent..

Results: We have applied our method to the LQ-20 test site on Moon. Each pixel in continuous topography represented by square-grid DEM is classified automatically based on ISO cluster unsupervised classification into 20 undefined landform types by a terrain parameters comprising elevation, filled elevation, slope, filled slope, relief amplitude, filled relief amplitude. We have divided the 20 landform classes into five larger groups: mare, craters, lowlands, highrelief and highlands following the rules of similarity relations between different classes. This division, which takes spatial relation into account, follows closely an algorithmic grouping based exclusively on Euclidean distances between average attribute vectors. We assess the quality of the automated classification that produced a better accurate result in classification. The classifying quality in different levels of confidence and 1,093,015 cells have a 100% chance of being correct classified whereas only 0.42% cells that have a 0.005 percent chance of being correct classified. Although a visual inspection of topography with the thematic map of landforms reveals that our classification is, overall, in good agreement with what one would expect, the automatic classifier misclassified pixels in some places due to interaction of aggradation (effusion, deposition) and degradation (erosion, deformation). For the misclassification, we have selected three craters for closer examination. Most of the misclassifications are for low flat floor inside the craters and lowlands for a similarity measure between attribute vectors does not correspond to actual similarity of landforms. The ghosted craters without clear boundary are not filled at all and their pixels are severely misclassified as other types of landscape.

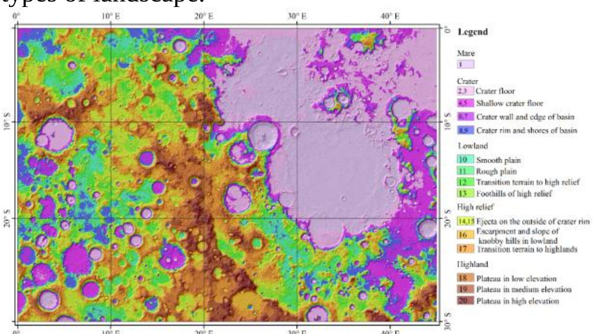

Figure 1. Thematic map of automatically identified landforms for LQ-20 region. Legend represents geographical meaning to numbered landform classes.

References: [1] Smith D. E. et al. (2010) *Space Science Reviews*, 150(1-4), 209-241. [2] Wessel P. and Smith W. H. (2001) 2013-01-01, http://gmt. soest. hawaii. edu. [3] Gaddis L. R. et al. (2006) *LPS*, Absrtact #2135. [4] O'Callaghan J. F. and Mark D. M. (1984) *Computer vision, graphics, and image processing*, 28(3), 323-344. [5] Esri. (1995) 2014-02-01,http://resources.arcgis.com/en/help/main/10.2/index.html#/Iso_Cluster_Unsupervised_Classification/009z000000pn000000/. [6] Jenks G. F. and Caspall F. C. (1971) *Annals of the Association of American Geographers*, 61(2), 217-244.