TEXTURE ANALYSIS OF LUNAR SURFACE USING DEM AND IMAGE DATASET. Bo Li[1], Zongcheng Ling[1], Jiang Zhang[1], Zhongchen Wu[1], Yuheng Ni[1], Jian Chen[1]. 1 Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment; Insitute of Space Sciences, Shandong University, Weihai 264209, China, (libralibo@sdu.edu.cn)

Introduction: Generally speaking, textures are complex visual patterns composed of entities, or subpatterns, that have characteristic brightness, color, slope, elevation, size, etc. Thus texture can be regarded as a similarity grouping in an image [1]. The local subpattern properties give rise to the perceived lightness, uniformity, density, roughness, regularity, linearity, frequency, phase, directionality, coarseness, randomness, fineness, smoothness, granulation, etc., of the texture as a whole [2]. Lunar morphologic information is important for lunar scientific investigations and exploration missions. Lunar orbiter imagery and digital elevation model data are two primary data sources for lunar morphology modeling.

lunar exploration missions in recent years have collected a vast amount of lunar surface images and elevation measurements from the cameras and laser altimeters onboard the spacecraft. There are two cameras onboard the LRO spacecraft: a wide-angle camera(LROC WAC) and the narrow-angle camera(LROC NAC). The cameras have collected lunar images with spatial resolutions of 100m and 50cm [3]. The LOLA onboard the LRO measure the distance to the lunar surface, and the LOLA Digital Elevation Models (LDEM) are built which has the best spatial resolution about 30m [4]. The every cell' value of lunar images and the DEM data can also be regarded as the texture of lunar surfaces' brightness and elevations. An important approach to region description is to quantify its texture content. The three principal methods used to analyze the texture of a region are statistical, structural, and spectral. statistical approaches yield characterizations of textures as smooth, coarse, uniformity, average entropy, and so on [5].

In this paper, we use statistical moments of gray-level histogram of lunar images or DEM data to describe lunar surface morphology. Let z be a random variable denoting gray levels and let $p(z_i)$, $i = 0, 1, 2, \ldots, L-1$, be the corresponding histogram, where L is the number of distinct gray levels. The *nth* moment of z about the mean is:

$$\mu_n(z) = \sum_{i=0}^{L-1} (z_i - m)^n p(z_i),$$

where m is the mean value of z:

$$m = \sum_{i=0}^{L-1} z_i p(z_i).$$

The second moment is an important factor of texture description, because the variance $\sigma^2(z) = \mu_2(z)$. So we can establish descriptors of relative smoothness of lunar surface as:

$$R = 1 - \frac{1}{1+\sigma^2(z)}.$$

The R in the areas of constant intensity is 0, and is 1 in areas of large values of $\sigma^2(z)$. The third moment and fourth moment are measures of the skewness and flatness of the area's gray-level histogram. Other useful additional texture measures based on histograms include of uniformity, given by

$$U = \sum_{i=0}^{L-1} p^2(z_i),$$

and an average entropy measure is defined as

$$e = -\sum_{i=0}^{L-1} p(z_i) log_2 p(z_i).$$

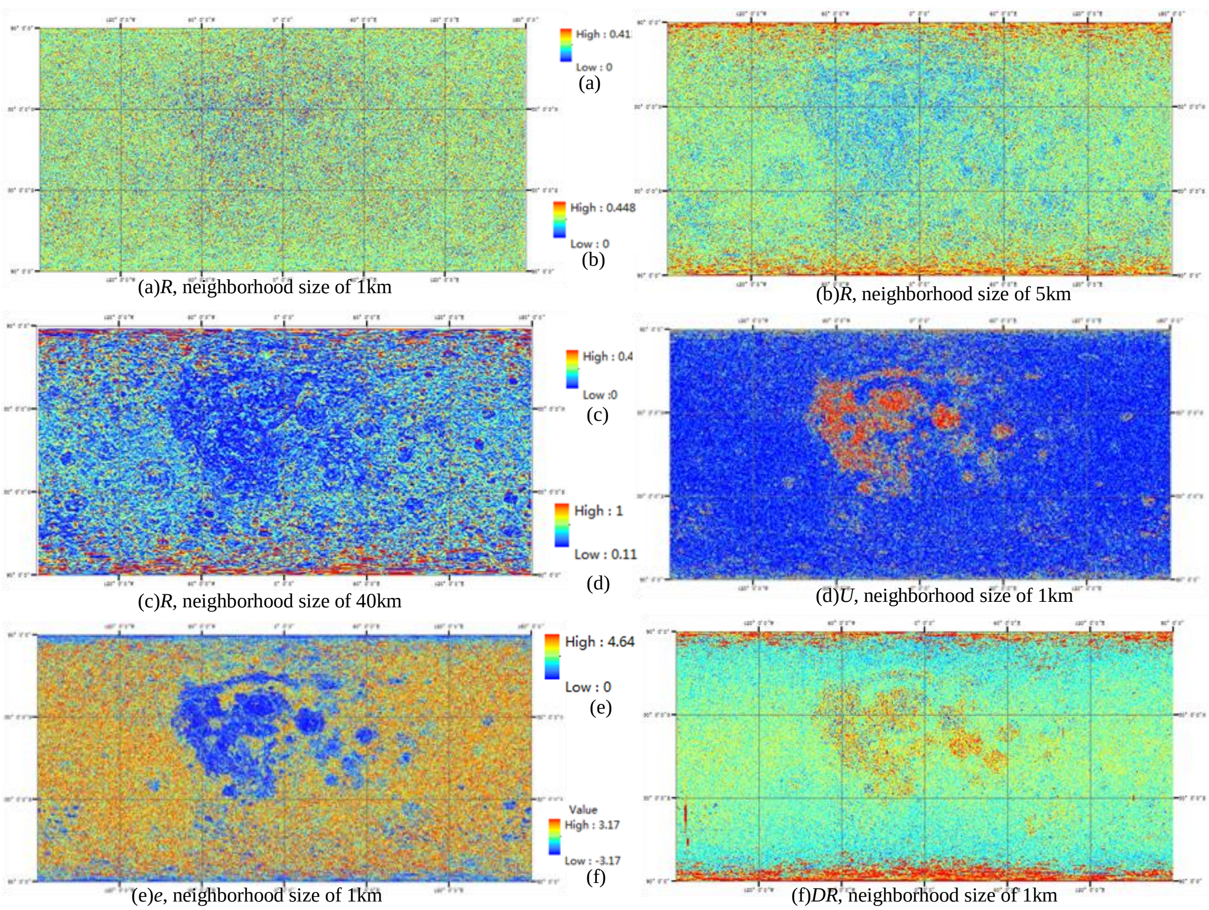
Entropy is a measure of variability and is 0 for a constant image.

Results and Discussions: We use LDEM data with spatial resolution of about 500m (18432×9216) and global WAC images with spatial resolution of 100m (http://wms.lroc.asu.edu/lroc/). Taking every cell of images or DEM data as an input, we generate a regular neighborhood, generally a rectangle. Then all values in this neighborhood were classified as distinct gray levels and the number of every level were counted. Last, a normalized gray-level histogram was created, and every above-mentioned texture measurements were calculated as output results. The results are shown in Fig. 1.

The results of texture analysis are depend on three factors including spatial resolution, neighborhood size and the number of gray levels of normalized histogram. According to previous studies [6], the roughness of lunar surface has obvious spatial scaled effects. Mikhail employed orbits data obtained by LOLA to calculated the roughness based on different baselines which are 2, 8, 16 and 32 shot to shot steps, which are with spatial resolutions of 115m, 0.46km, 0.92km, and 1.8km respectively. He found that there were great differences between kilometer-scaled roughness and hectometer-scaled roughness. The former has apparent boundaries between mare and highland, but the latter has no such boundaries. The spatial scaled effects can also been seen in our results, Fig. 1 (a), (b) and (c). With the size of neighborhood increasing, the recognized features are from craters, basins to boundaries between mare and highland. The roughness variations in a crater region are small-scale, however in impact basin are middle-scale, and between mare and highland are the largest. Thus the different scaled roughness resulting from crater, basin, mare and highland boundaries stand for different resurfacing processing of lunar surface. The high roughness values often show in the rims of craters, especially fresh craters, edges of impact basins and highland areas.

In this paper, from lunar surface images and DEM data, we obtained five texture measurements which are roughness (R), 3th moment (μ_3), 4th moment (μ_4), uniformity (U) and average entropy (e). In information theory, entropy is the average amount of information contained in each message received [7]. Here, message stands for a character drawn from a distribution of brightness and elevation. Entropy thus characterizes uncertainty about source of information. From the Fig.1(e), we can see the largest entropy appears on the highland region, while in mare the entropy is close to 0. This indicates the lunar highland has more geomorphic information than in mare region, in other word, the highland has more variations and details in topographic relief. This is because of the different resurfacing process in highland and mare, and there are well correlations between the *R* and the entropy. We can use values of entropy to divide lunar surface into two kind of geological units: mare and highland because of the visible difference of entropy.

Lastly, we calculated all kinds of texture measurements of the image (basemap_warp_mosaic100m, which was resized to spatial resolution of 500m). The roughness difference (*DR*) in the same location of DEM data and image was computed by *D(R) = DEM(R)-IMG(R)*, in which *DEM(R)* and *IMG(R)* stood for the same cell roughness in the DEM data and image respectively. From Fig.1 (f), we can see the high difference are situated in mare and polar regions, while for highland regions the roughness difference is relatively small. The value of every cell in the image stands for the brightness of lunar surface, whose variations on images depend on the spatial distributions of local topographic slopes, albedo (that is, a characteristic of the surface material composition), and the global illumination / observation geometry. Although in the mare, the relief and entropy are flat and small, but there are some discrepancies in composition of regolith and bedrock or illumination/observation geometry.



(a)*R*, neighborhood size of 1km
(b)*R*, neighborhood size of 5km
(c)*R*, neighborhood size of 40km
(d)*U*, neighborhood size of 1km
(e)*e*, neighborhood size of 1km
(f)*DR*, neighborhood size of 1km

Fig.1 The texture measurements of different neighborhood size.

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