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Short Communication

Investigation and remediation of false topographic perception phenomena observed on Chang'E-1 lunar imagery

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ABSTRACT

False topographic perception phenomenon (FTPP) is a relief inversion phenomenon in remote sensing images and causes false perception problems. Such images of the Moon suffer from serious FTPP problems. Correctly observing and understanding the terrain features on the Moon from lunar surface images is important for lunar exploration missions and various lunar scientific investigations. This paper presents a systematic investigation of the FTPP problem associated with lunar craters, by using the Chang'E-1 lunar imagery covering the major areas of the lunar surface. Results reveal that the FTPP problem is positively correlated with crater latitudes in the north hemisphere of the Moon. For craters within a similar latitude range, the FTPP level is positively correlated with the depth–diameter ratio of the crater. A wavelet-transform based approach is proposed for FTPP remediation on Chang'E-1 imagery. Experimental analysis using three different types of craters revealed that the approach is able to effectively correct the FTPP problem.

1. Introduction

False topographic perception phenomenon (FTPP) is a relief inversion problem firstly identified by Saraf et al. (1996) in Earth remote sensing images. FTPP is commonly observed in Earth images of rugged terrain surfaces acquired from Sun-synchronous satellites (e.g., Landsat, IKONOS), and it causes topographic perception problems, i.e., mountains appear as valleys, craters appear as hillocks, and vice versa (Saraf et al., 1996; Rudnicki, 2000; Patterson and Kelso, 2004). The FTPP problem has also been noticed on lunar images (Saraf et al., 2011). Remote sensing images of the Moon surface, in fact, suffer from more serious FTPP problems. This is mainly due to the highly rugged and dust grayout surface, the absence of atmosphere eliminates the scattering effects, and the lack of familiar landmarks on the Moon, to supply visual cues (Colby, 1991; Rieser et al., 1995).

Fig. 1 illustrates typical examples of lunar images suffering from FTPP problems. Fig. 1(a) shows a crater in the Chinese Chang'E-1 image recognized as a hillock as a result of the FTPP problem. After the image is rotated by 180°, it appears as a crater free of FTPP as shown in Fig. 1(b). Fig. 1(c) and (d) illustrate a similar example on the India Chandrayaan-1 image. Fig. 1(e) and (f) show other similar examples as observed in NASA's Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) image. These images were taken by different sensors at different time slots, and have different spatial resolutions, such as 120 m/pixel for the Chang'E-1 imagery (Ouyang et al., 2010), 5 m/pixel for the Chandrayaan-1 imagery (Kumar and Chowdhury, 2005), and 0.5 m/pixel for the LRO NAC imagery (Robinson et al., 2010). This indicates that the FTPP problem is quite common in lunar surface images from different sources with different resolutions.

Many factors lead to the FTPP problem such as topographic relief, object locations, Sun elevation and azimuth angles, viewing angle, and hatching or engraving features presented on the valley slopes (Saraf et al., 2005). Liu and Todd (2004) and Saraf et al. (2005, 2007) provide several solutions for FTPP remediation on Earth surface images. However, this problem has not been investigated systematically, in particular for lunar surface imagery.

The lunar terrain is highly irregular and rugged. There are about half a million craters on the Moon with diameters greater than 1 km (Ivanov, 2001). Correctly observing and understanding the terrain features from lunar surface images is important. Lunar images with FTPP problems inhibit accurate scientific study of the Moon. During the planning of lunar robotic or human exploration missions, any wrong interpretation of the lunar surface because of FTPP must be avoided. Systematic investigation of the FTPP problem in lunar surface imagery and the remediation methods for the FTPP problem are vital to support future lunar exploration missions and various lunar scientific investigations.

This paper presents a systematic investigation of the FTPP problems observed in the Chang'E-1 imagery and an effective

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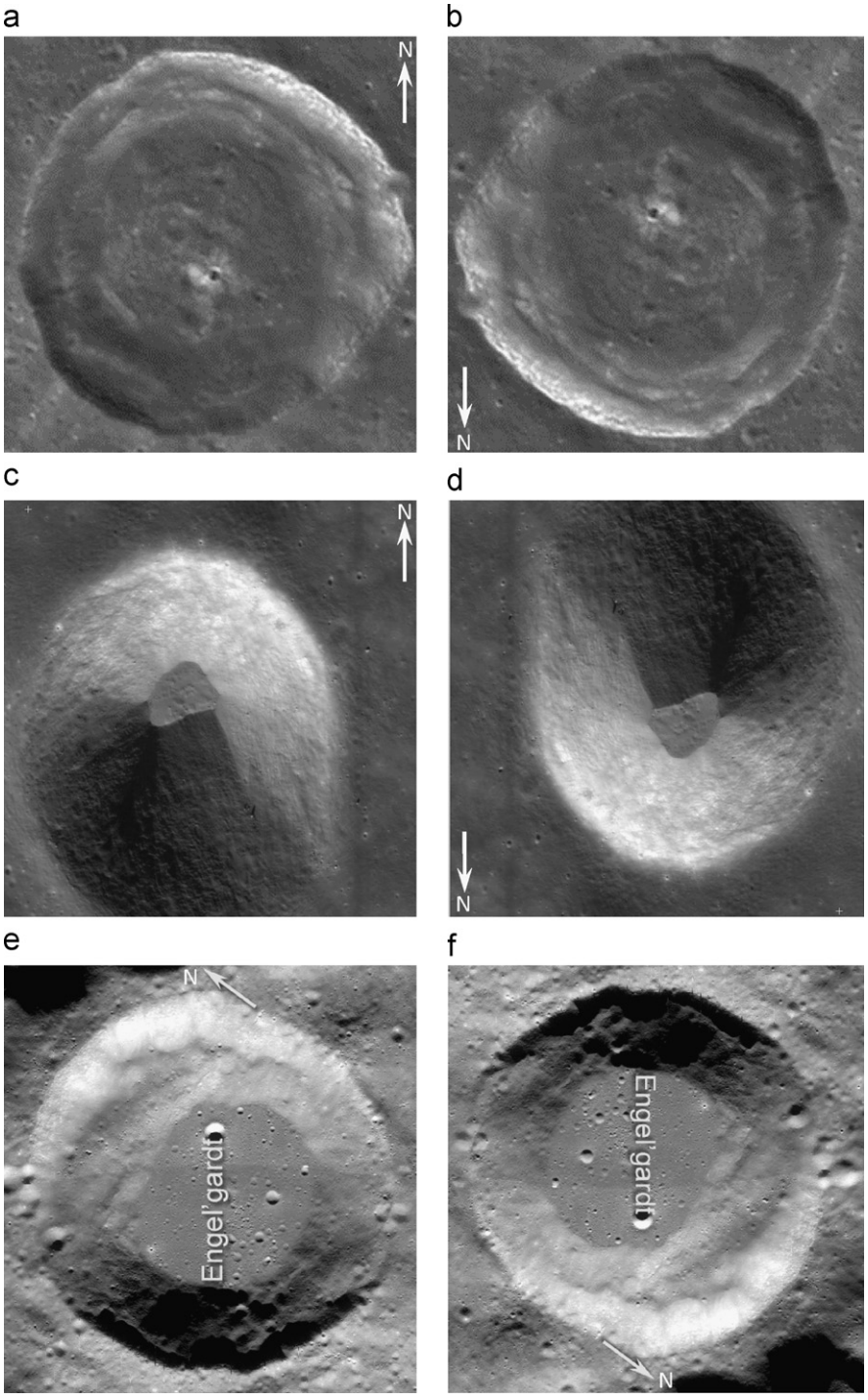

Fig. 1. Examples of FTPP observed on lunar orbit imagery: (a) An original Chang'E-1 image with FTPP, (b) the Chang'E-1 image rotated by 180° free of FTPP, (c) an original Chandrayaan-1 image with FTPP, (d) the Chandrayaan-1 image rotated by 180° free of FTPP, (e) an original LRO image with FTPP, and (f) the LRO image rotated by 180° free of FTPP.

method alleviating the FTPP problems. The paper is organized as follows. A literature review of existing studies of FTPP problems and FTPP correction methods is given in the second section. A systematic statistical analysis of the FTPP problem discovered in Chang'E-1 imagery is presented in the third section. A wavelet-transform based approach for FTPP remediation is presented in the fourth section and the detailed experimental results and analysis are also given in the fourth section. Finally, conclusions are presented and discussed.

2. Related work

It is generally recognized that vision perception plays a major role in remote sensing image cognition (Toutin, 1998). The FTPP problem in remote sensing imagery is mainly due to human perception. Human brain perceives that light illuminating source is from northern hemisphere (front) rather than from southern hemisphere (behind). Human vision relies heavily on lighting cues to recover 3D shape (Morgenstern et al., 2011).