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Generative Template-based Approach to the Automated Detection of Small Craters

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Abstract

In this study we present a generative template matching based approach to the automatic detection of small craters (<10 km diameter) in spacecraft images. The templates are synthetically generated based on LOLA track data and knowledge about the reflectance behavior of the surface as well as the known illumination and viewing geometry. Our first results on Chandrayaan-1 M³ imagery indicate successful crater detection down to <1 km diameter.

1. Introduction

In planetary science, craters are of interest in many scenarios, i.e. age estimation or spacecraft navigation. Automatic crater detection is desirable due to the reproducibility and speed of automatic algorithms.

An overview of current algorithms for automatic crater detection is given in [2]. Two groups of algorithms exist, namely image-based or DEM-based ones. DEM-based algorithms, however, are not suitable for small craters due to the commonly low lateral resolution of DEM data [3].

We propose a method to detect small craters in images using template matching (TM). Generally, a huge amount of templates is necessary to cover changing illumination and geometric distortions. While [3] relies on ellipse fitting to limit the number of necessary templates, we make use of the known directions of the sun and the spacecraft and render templates based on crater models.

2. Generation of Crater Models

We limit our search to craters with diameters less than 10 km. According to [4], most craters with diameters below 15 km are simple bowl-shaped craters. We analyzed the LOLA tracks running through 23 satellite craters of the lunar crater Plato and found three distinct shapes: the simple bowl shape, a transient shape with a flat floor, and a complex shape with a central mound (cf. Fig. 1). We selected the three craters presented in Fig. 1 and divided the cross-sections in half at the zero mark of the *x* axis. Both the left and the right profile are rotated to form a rotationally symmetric 3D crater model.

3. Online Template Generation

The crater models are rendered using the full Hapke model [4, 5] based on the directions towards the sun and the viewer. Optionally, additional elliptical shapes due to an inclined viewing angle may be produced using an appropriate projection model, e.g. the pinhole camera model. A set of sample templates is shown in Fig. 2. The rendered templates are then resized to fit the radius of the desired craters in image pixels. Within this work, we use an orthographic projection of the images. Furthermore, for images in simple cylindrical projection the *x* axis of the template has to be stretched depending on the selenographic latitude.

4. First Results and Outlook

The normalized cross-correlation is computed for each template and each image pixel, and the maximum value over all templates is assigned to each pixel. A crater is detected if that value exceeds a predefined threshold. To cover the full diameter range up to 10 km, we compute the normalized cross-correlation for template sets at multiple radii (cf. results in Fig. 3). The cross-correlation based approach commonly provides a large number of crater candidates. Similar to [3], a second stage classifier will be applied to increase the accuracy of the template matching algorithm. In this context, we will examine the possibility of multimodal classification, e.g. based on spectral data and derived features.

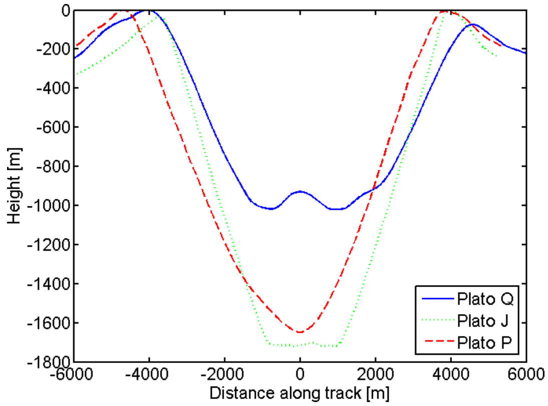

Figure 1: Cross-sections of the selected Plato satellite craters. The diameter of all craters is approx. 8 km. The selected crater shapes range from simple bowl-shaped to slightly complex with central mound.

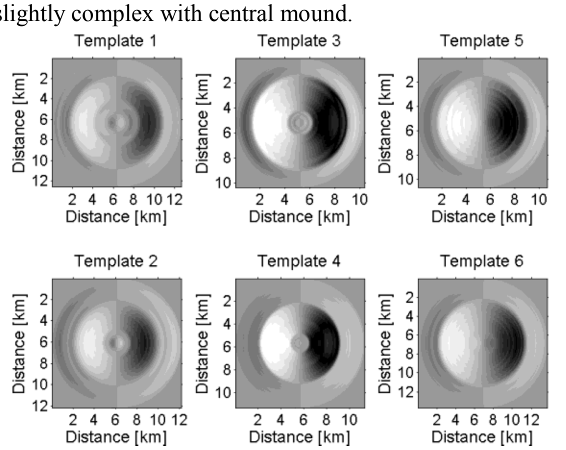

Figure 2: Crater models. Templates 1 and 2 show a small central mound, flat craters are represented by templates 3 and 4, and templates 5 and 6 are simple bowl-shaped craters.

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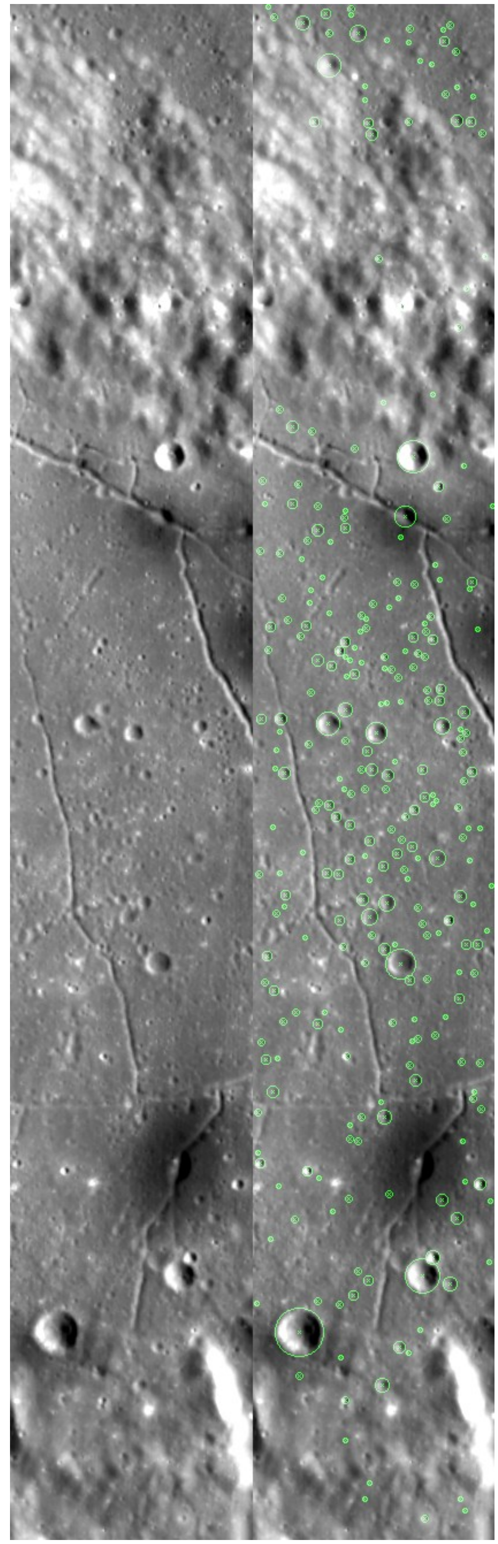

Figure 3: Craters detected based on a M³ 1579 nm image showing the crater Alphonsus. Threshold of normalized cross-correlation: 0.75.