CRATER DETECTION BASED ON MARKET POINT PROCESSES

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1. INTRODUCTION

Identification of features on planetary surfaces by human experts can be very time consuming. Therefore, a reliable automatic approach is needed to detect the position, structure, and dimension of each feature is highly desirable. This is difficult for several reasons: Limited data are usually available, the quality of the images is generally low (i.e., it depends on illumination, surface properties and atmospheric state), and the features that are present in the images can be barely visible due to erosion and exhibit different structures and variable sizes.

Among typical features in planet-surface imagery, craters play a primary role. Detection of craters has been widely addressed and different approaches have been proposed in the literature. The image-based approaches for crater detection can be divided into two main categories: supervised and unsupervised. The supervised methods require the input of an expert and generally use machine learning concepts to train the algorithm to feature extraction. Unsupervised methods are completely automatic and are generally based on pattern recognition techniques. Different approaches have been proposed, based on template matching [1], texture analysis [2], neural networks [3], or a combination of these techniques [4], [5].

Here, a novel approach based on a Marked Point Process (MPP) [6] for the extraction of planetary craters is proposed. In a pre-processing stage, the boundaries of the regions of interest are extracted by using a Canny edge detector. The extracted contours are considered as the realization of a MPP of ellipses: The optimum configuration of objects x^* has to be estimated. An energy $U(x)$, which takes into account the interactions between the geometric

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objects and the way they fit in the image, is minimized by using a Markov chain coupled with a simulated annealing scheme.

The proposed approach is described in Section 2. The presentation and analysis of the results is included in Section 3. Finally, the conclusions and ideas for future improvements are presented in Section 4.

2. APPROACH

Planetary images show the surface of the analyzed planet and its structures. The aim of this study is to automatically detect the structures that are present in the represented planetary surface by using image analysis techniques.

The features to be extracted are rocks (i.e., objects of small elliptical or circular shape) and craters (objects of approximately elliptical shape with shadows). Their extraction is a difficult task, because planetary images are blurry, quite noisy, present lack of contrast and uneven illumination, and the represented objects are not well defined.

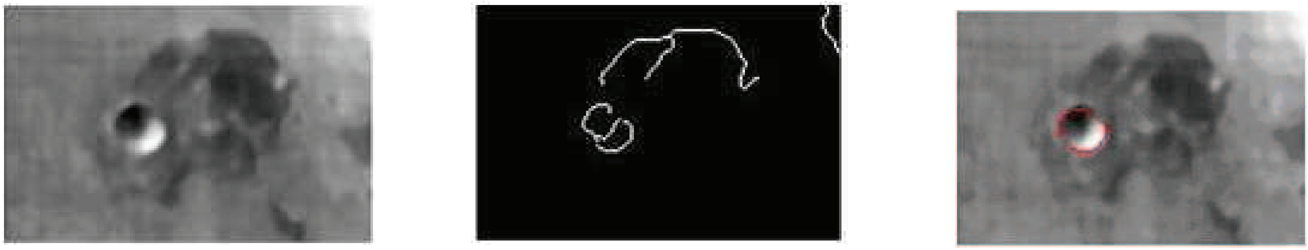
A marked point process has been chosen in order to address such problem (i.e., the detection of round and elliptical objects). Before applying any feature extraction, the images need to be preprocessed. First, the noise is smoothed by applying a Gaussian filtering and a median filtering operation in cascade [7]. Then, in order to detect the edges, the image gradient I_g, showing the contours of the objects represented in the original image, is computed by using the Canny edge detector [8]. I_g is modeled as a configuration of ellipses whose positions and attributes are a realization X of a MPP [9]. X is a random variable whose realizations are random configurations of objects belonging to a set space $S = P \times K$, where P is the position space, and K the space of the marks. The probability distribution $P_X(\cdot)$ of the stochastic process is uniformly continuous with respect to the Poisson measure $\mu(\cdot)$ of intensity $\lambda(\cdot)$ on S. Then, by using the Gibbs energy formulation of the density of the process, we define an energy $U(x)$ as:

$$P_X(dx) = \frac{1}{Z} \exp\{-U(x)\}\mu(dx) \tag{1}$$

where Z is a normalizing constant. $U(x)$ will be minimized on the space of all configurations in the feature extraction process.

The 2D model, used to extract the features of interest, consists of a MPP of ellipses. The associated set space S_2 is $S_2 = P \times K = [0, M] \times [0, N] \times [a_m, a_M] \times [b_m, b_M] \times [0, \pi]$, being M and N the width and the height of the image I, $a \in [a_m, a_M]$ and $b \in [b_m, b_M]$ the semimajor and semiminor axes, respectively, and $\theta \in [0, \pi]$ the orientation angle.

A Monte-Carlo Markov Chain algorithm [10], coupled with a Simulated Annealing, is used in order to find the configuration x which minimizes $U(x)$. It is an iterative algorithm where at each iteration k a perturbation is proposed to the current configuration at temperature T_k. This perturbation is accepted or rejected with a probability



(a) Original image (b) Canny gradient (c) Crater contours

Fig. 1. Original image (a), Canny gradient I_g (b), and detected crater contours in red (c), transparently superimposed to the original image.

which insures that the probability distribution of the Markov chain ergodically converges to $f(x)^{\frac{1}{T_k}}\mu(dx)$. In practice, the decrease of the temperature is not logarithmic and also does not imply the ergodic convergence to some Dirac distribution located at the minima of $U(x)$, but is adaptive [11]. This cooling schedule based on an heuristic gives better results in a fixed number of iterations scheme than the geometric schedule by spending more time around the critical temperature.

3. EXPERIMENTAL RESULTS

Experiments were carried out using Mars images, collected during the 2001 Mars Odissey mission (MO), by the Thermal Emission Imaging System (TEMIS), an instrument on board the Mars Odyssey spacecraft. Such an instrument combines 5-wavelenght visual imaging system with a 10-wavelenght infrared imaging system [12]. Both 5-bands visible TEMIS images, with a resolution of 18 meters per pixel, and 10-bands infrared TEMIS images, with resolution of 100 meters per pixel, were used to test the proposed approach. Results of the feature extraction are shown for a partition of the first band of an visible image (Fig. 1-a). The image is first preprocessed, in order to smooth the noise. Canny gradient is applied to the smoothed image and results are shown in Fig. 1-b. Subsequently, the extracted rock and crater boundaries are shown in Fig. 1-c, transparently superimposed to the original image.

4. CONCLUSIONS

The proposed approach represents the first important step for many applications dealing with all the various data that will be collected during the current and future space missions, among which image analysis, with the aim of selecting safe landing sites, identifying planetary resources, and preparing for subsequent planetary exploration by humans and robots. A novel approach has been proposed for feature extraction as applied to planetary data. For such data, the features to be extracted are not as well contrasted nor defined as for Earth data. Nevertheless, it is shown here that their identification can be achieved. In future work the use of an illumination correction will be investigated, in order to improve the reliability of the detection for all craters and large rocks, when shadows are present. Once the feature extraction will be optimized, the approach will be applied to the registration of multisensor and multitemporal images, by feature matching.

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