Feature extraction and automatic detection of Martian impact craters from 3D meshes

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***Abstract*—In this paper, we propose a novel feature extraction algorithm based on curvature analysis over the 3D data and the grayscale information extracted from the images. The performance of the method is tested on 3D mesh data, provided by Mars Orbiter Laser Altimeter (MOLA) and compared to benchmark research work. The experimental results demonstrate that the proposed method can achieve less computational complexity and better accuracy in comparison with other crater detection methods.**

Keywords— **MOLA data, 3D mesh, automated extraction of features, machine learning, craters, Mars.**

I. INTRODUCTION

In recent years, several research groups have tried to build an automatic method to estimate the age of different celestial bodies. In planetary science, the only way to estimate the age of planets, satellites and asteroids is by measuring the density of the impact craters on their surface. Impact craters are ubiquitous features due to collisions with other celestial bodies such as meteorites and small asteroids, experienced since their formation. The topography of impact craters ranges from small, simple and bowl-shaped depressions to large, complex and multi-ringed impact basins [1]. The crater is a subject to several erosion processes after its formation, which gradually modifies its initial topography.

Several methods have been used in the past to detect craters: manually [2] or automatically using 2D [3], 2.5D [4] or 3D [5], [6] information. One of the most popular automatic methods is called Crater Detection Algorithm (hereafter CDA). It has a 2D and 2.5D variation. The method employs the image of Digital Elevation Model (DEM). Unfortunately, the 3D methods are not very popular because there are too few 3D processing data and few methods for crater detection.

The rest of the paper is organized as follows: in Section II, some of existing approaches related to automatic crater detection are briefly described. In Section III, we describe the environmental data, and then we focus on extraction of features in Section IV. Section V is dedicated to a brief description of the used classifiers. We present our experimental results in Section VI. Conclusions and the direction of future research are given in Section VII.

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II. RELATED WORK

The most popular 2D or 2.5D crater-detection approaches could be divided into two general categories: unsupervised (fully autonomous) and supervised (which require the input labelled training data).

The unsupervised methods use pattern recognition techniques to identify crater rims as circular or elliptical features, such as described in [7], [8] and [9]. To enhance the edges of the rims, the original image is pre-processed and the actual detection is achieved using Hough Transform (HT) [9], [8]. In [7] as pre-processing step an edge-detecting algorithm is applied, the authors of [10] calculate texture measures; and in [11] and a combination of texture measurement, edge detection and edge direction analysis is performed but for all the cited papers HT is used as a detection method.

The supervised methods [12], [13], [14] use machine learning concepts to train an algorithm into detecting crater forms. During the learning phase, the training set of images containing craters labeled by astrophysics experts is fed to a machine learning algorithm. During the detection phase, the chosen and trained algorithm detects craters in a dataset of new and unlabeled images. To achieve the detection, authors in [12] and [13] use a continuously scalable template-model technique. In [14] are tested a number of algorithms and the support vector machines achieve the best rate of crater detection.

But none of these proposed crater detection algorithms can be directly applied on 3D meshes.

III. DATA AND DATA PRE-PROCESSING

For this research, we use 3D mesh data, provided by MOLA that has a resolution of 1/128 degree, or ~500 m at the equator. It is centered at (0°, 0°) and represents the equidistant cylindrical projection. The test site file contains 5 328 000 vertices and 10 646 272 faces, and represent a piece of land on Mars. The following coordinates bound our sample: Top: 13° N, Bottom: 0° N, Left: 25° W, Right: 0° W.

In our research, we introduce the idea of using curvature estimation on 3D meshes.

The curvature is a differential descriptor of the local appearance of a curve or a surface. This indicator is used extensively in mesh processing because it offers information on the concavity or convexity of a surface along its principal directions. This can be used in order to get a classification of the vertices lying on the discrete surface.

Let us respectively denote k_1 and k_2 (see Fig. 1) the maximal and minimal curvatures of a point P on a smooth surface.