Geophysical Research Abstracts
Vol. 19, EGU2017-8549, 2017
EGU General Assembly 2017

Discrete curvatures combined with machine learning for automated extraction of impact craters on 3D topographic meshes

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One of the challenges of Planetary Science is to estimate as accurately as possible the age of the geological units that crop out on the different space objects in the Solar system. This dating relies on the counting of the impact craters that cover the given outcrop surface. Using this technique, a chronology of the geological events can be determined and their formation and evolution processes can be understood.

Over the last decade, several missions to asteroids and planets, such as Dawn to Vesta and Ceres, Messenger to Mercury, Mars Orbiter and Mars Express, produced a huge amount of images, from which equally huge DEMs have been generated. Planned missions, such as BepiColombo, will produce an even larger set of images. This rapidly growing amount of visible images and DEMs makes it more and more fastidious to manually identify craters. Acquisition data will become bigger and this will then require more accurate planetary surface analysis. Because of the importance of the problem, many Crater Detection Algorithm (CDA) were developed and applied onto either image data (2D) or DEM (2D1/5), and rarely onto full 3D data such as 3D topographic meshes.

We propose a new approach, based on the detection of crater rim, which form a characteristic round shape. The proposed approach contains two main steps: 1) each vertex is labelled with the values of the mean curvature and minimal curvatures; 2) this curvature map is injected into a Neural Network (NN) to automatically process the region of interest. As a NN approach, it requires a training set of manually detected craters to estimate the optimal weights of the NN. Once trained, the NN can be applied onto the regions of interest for automatically extracting all the craters.

As a result, it was observed that detecting forms using a two-dimensional map based on the computation of discrete differential estimators on the 3D mesh is more efficient than using a simple elevation map. This approach significantly reduces the number of false negative detections compared to previous approaches based on 2.5D data processing. The proposed method was validated on a Mars dataset, including a numerical topography acquired by the Mars Orbiter Laser Altimeter (MOLA) instrument and combined with Barlow et al. (2000) crater database.

Keywords: geometric modeling, mesh processing, neural network, discrete curvatures, crater detection, planetary science.