ESTIMATING VOLUME OF MARTIAN VALLEYS USING AXELSSON ALGORITHM

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Introduction: Fluvial landforms such as valley networks (VN), outflow channels [1] and delta deposits [2] found on Mars offer the best evidence for past water activities on the red planet [3]. The volume of excavation by fluvial processes is of significant importance for understanding both the source of water and its evolution and cycling on Mars. There have been extensive studies on the outflow channels and the volume of water needed to excavate them. However, previous attempts at estimating the amount of water needed to erode the VN were limited to selected local sites based on simple morphometric measurements of the valleys, volume of deltas deposited in closed basins, and hydrologic modeling [1, 4, 5]. Here we adapt a new method that was originally designed to generate bare earth DEM from Lidar data to estimate the volume of excavation of Martian valleys. The preliminary result is consistent with previous studies [6] and offers an alternative that is directly based on original MOLA point data (as opposed to the interpolated DEM).

Methodology: Many algorithms have been developed to generate bare earth DEM from intensive Lidar point cloud data in terrestrial studies [7-9]. We can adapt such algorithm to estimate the volume of Martian valley excavation by first inverting the topography so that valleys become positive features and then using these algorithms to detect the valleys (the inverted positive features); the difference between the surface with valleys and the one without valleys is the volume of valleys.

The Axelsson algorithm based on progressive Triangular Irregular Network (TIN) densification is applied to detect VN in the current study. This algorithm commences with defining virtual grid while considering the size of the largest structure. Sparse TIN is derived from minima points in the virtual grid at the first stage. A point of interest is added to the TIN if it meets the following criteria in relation to the triangle that contains it: (a) angles that the point makes to the nodes of the triangle and (b) the distance from the point to the triangle facet plane must be below data-derived thresholds. At the end of each iteration, the TIN is updated and the thresholds are re-computed based on the derived angles and distances according to the updated TIN. The process is repeated until no more points can be added according to the above criteria. Further details can be found in [7].

Results: We applied the Axelsson algorithm to the valleys flowing into Tuscaloosa Crater (center coordinates longitude = 28.75°, latitude = 0°, see Figure 1) so that we can have independent constraint on the volume through crater infill calculation. The results for the small valley and large valley draining into the crater are shown in Figures 2 and 3. The total estimated volume of the valleys is $1.41 \times 10^{11}\,\mathrm{m}^3$. This is consistent, at least in order of magnitude, with the crater infill volume based on the difference between the current topography and a fresh crater topography modeled by a power law function [6, 10], which is $1.26 \times 10^{11}\,\mathrm{m}^3$. This is also consistent with another estimate using Black Top Hat (BTH) transformation method, an image processing technique originally designed to extract dark features from a variable background, with the result of $1.22 \times 10^{11}\,\mathrm{m}^3$ [11, 12].

Discussion and Summary: The advantage of the Axelsson Algorithm is that it is directly based on original MOLA point data, thus eliminating the uncertainty in gridded DEM that may be introduced by interpolation. Another advantage is that the thresholds used in this method are derived automatically and objectively from data. This is in great contrast with BTH method, which may require trial and error. The slight overestimate compared with crater infill volume and BTH method may be attributed to the small secondary crater at the mouth of the small valley.

The Axelsson algorithm shows great potential in estimating valley excavation volume. After more testing, our ultimate goal is to apply it to estimate the global water inventory associated with valley networks on Mars and evaluate its implications on nature of hydrologic cycle and paleoclimate on early Mars.

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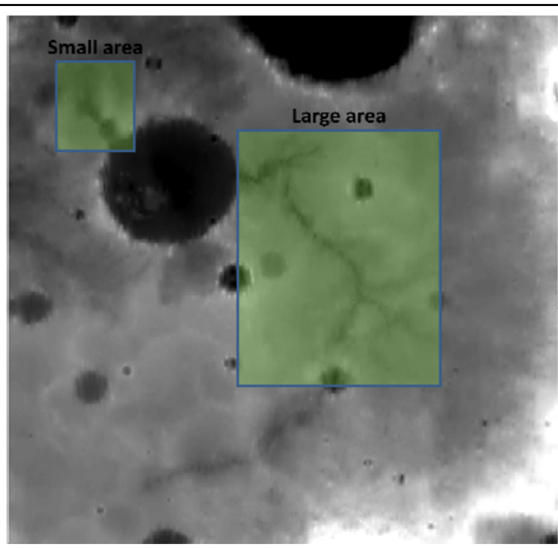
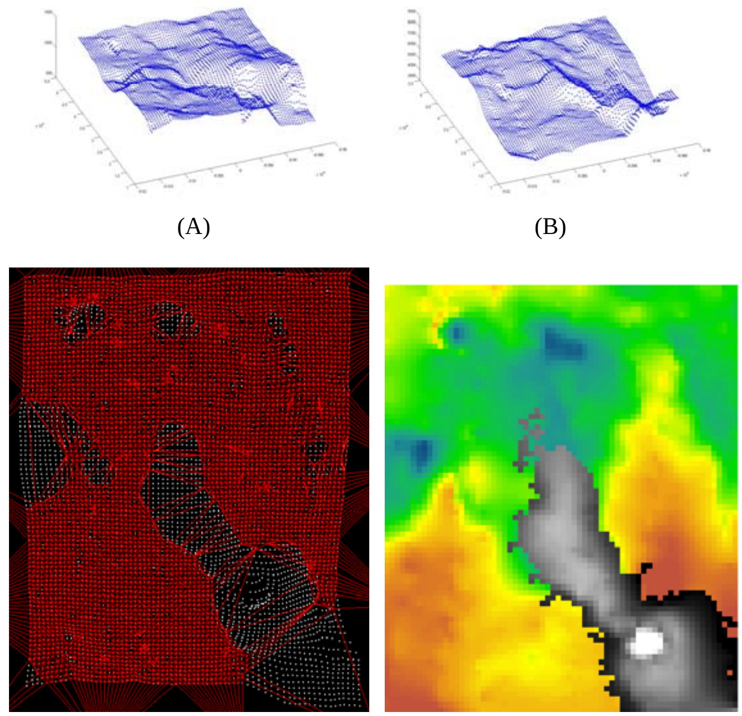
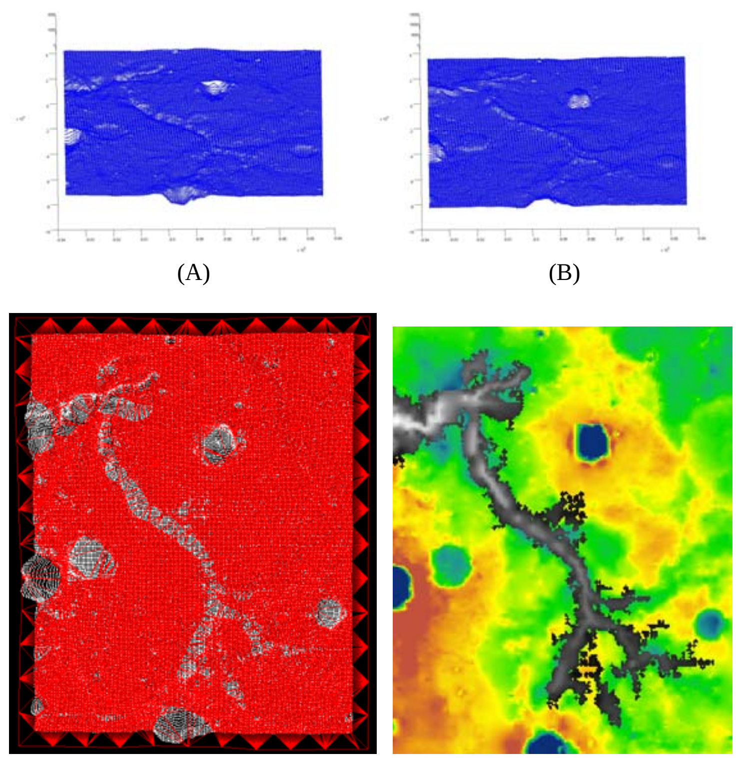


Figure 1. Study area: valleys draining into Tuscaloosa Crater (center coordinates longitude = 28.75°, latitude = 0°) The image is about 170 km across.



(C) (D)

Figure 2. (A) Original point view of small area in Figure 1; (B) Inverted point view of small area in Fig; 1. (C) Axelsson algorithm result; (D) Valley volume extraction.



(C) (D)

Figure 3. (A) Original point view of large area in Figure 1; (B) Inverted point view of large area in Fig; 1. (C) Axelsson algorithm result; (D) Valley volume extraction.