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A voxel-based technique to estimate volume and volumetric error of terrestrial photogrammetry-derived digital terrain models (DTM) of topographic depressions

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It is a common task in geoscience to determine the volume of a topographic depression (e.g., a valley, a crater, a gully, etc.) based on a digital terrain model (DTM). In case of DTMs based on laser scanned data this task can be fulfilled with a relatively high accuracy.
However, if the DTM is generated using terrestrial photogrammetric methods, the limitations of the technology often makes geodetically inaccurate/biased models at forested or purely visible areas or if the landform has an ill-posed geometry (e.g. it is elongated).
In these cases the inaccuracies may hamper the generation of a proper DTM.
On the other hand if we are interested rather in the determination of the volume of the feature with a certain accuracy or we intend to carry out an order of magnitude volumetric estimation, a DTM having larger inaccuracies is tolerable. In this case the volume calculation can be still done by setting realistic assumptions about the errors of the DTM.
In our approach two DTMs are generated to create top and bottom envelope surfaces that confine the "true" but unknown DTM. The varying accuracy of the photogrammetric DTM is considered via the varying deviation of these two surfaces: at problematic corners of the feature the deviation of the two surfaces will be larger, whereas at well-renderable domains the deviation of the surfaces remain minimal.
Since such topographic depressions may have a complicated geometry, the error-prone areas may complicate the geometry of the aforementioned envelopes even more. The proper calculation of the volume may turn to be difficult. To reduce this difficulty, a voxel-based approach is used. The volumetric error is calculated based on the gridded envelopes using an appropriate voxel resolution.
The method is applied for gully features termed lavakas existing in large numbers in Madagascar. These landforms are typically characterised by a complex shape, steep walls, they are often elongated, and have internal crests. All these geometric properties make the photogrammetric reconstruction of the surface of these teardrop- or amphitheatre-shaped features challenging.
The studied lavaka has been photographed by a digital camera with overlaps and the position and azimuth of the images have also been registered. The DTM has been calculated based on the series of digital images, however, due to the poor geometry and to the visibility problems (vegetation) the DTM at places has a larger error. Despite of these relatively erroneous geometry, the aforementioned approach allowed the approximation of the volume and the estimation of its error.

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