Straightforward reconstruction of 3D surfaces or DEMs from photos

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1. Introduction

Digital elevation models (DEMs) and 3D surfaces have been generated from aerial images for many years, but traditional techniques based on conventional photogrammetry usually require specialist software, expertise, and extensive measurement of control points or features .

Using a computer vision approach which combines structure-from-motion[1] and multi-view stereo[2] (**SfM-MVS**), 3D models can be automatically constructed using images from consumer cameras with the following advantages:

- flexible image capture and free software
- significantly reduced control-point requirements

SfM-MVS has been previously used with ground-based images of lava[3]; here, we explore the error magnitudes involved and use the technique to derive DEMs of the Volcán de Colima lava dome.

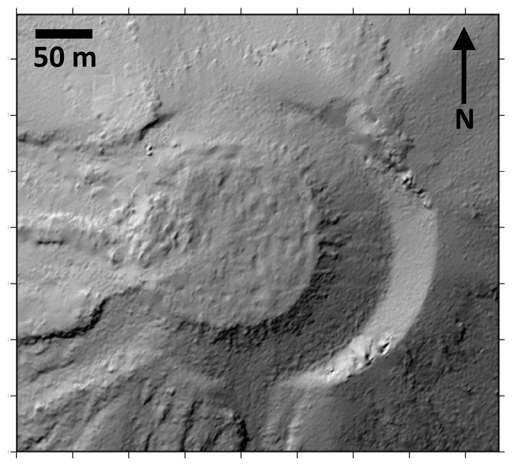
2. SfM-MVS method

image collection using a consumer camera from different positions

run the automatic reconstruction[a]

3D coloured point cloud (without scale or orientation)

define scale and georeference[b]



interpolate point cloud into DEM surface

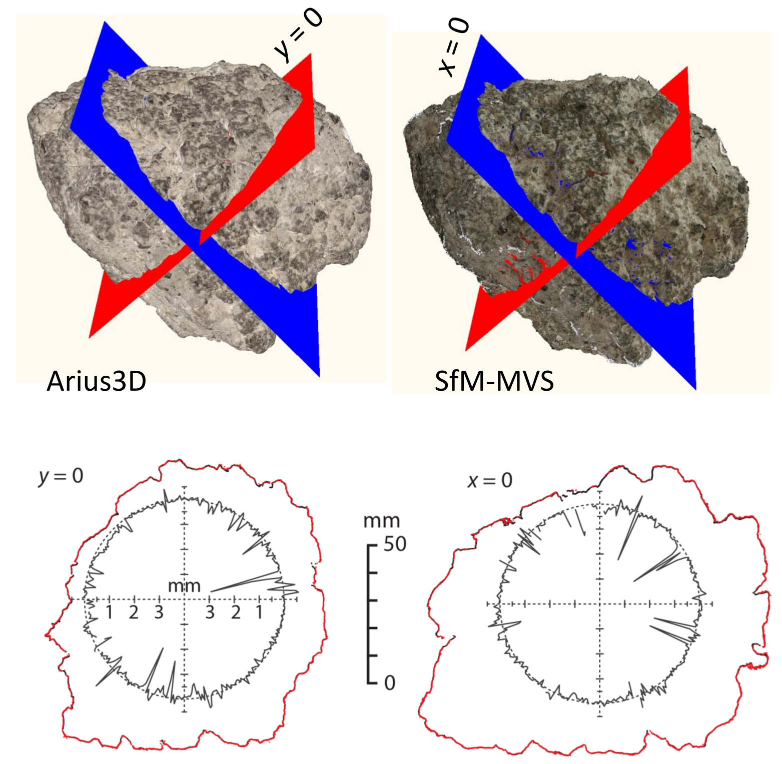
3. Error assessment

How accurate is SfM-MVS for surface reconstruction?

Two contrasting examples[4] are used to assess error magnitudes.

Volcanic bomb hand sample, ~10 cm across

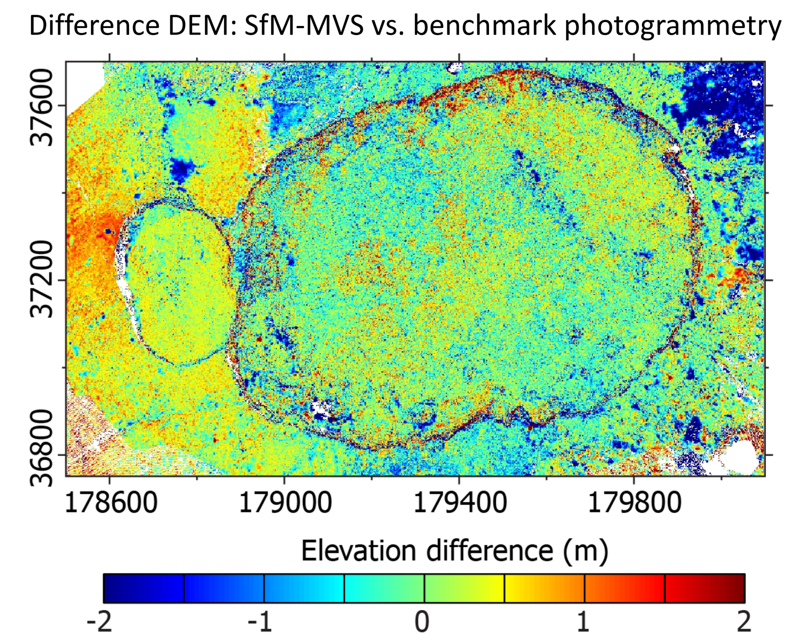
- SfM-MVS: 210 photos, viewing distance 0.7 m, scaled by length measurements with steel rule
- Benchmark data from Arius3D scanner (25 µm accuracy)
- RMS difference ≈300 µm



Cross sections: red = SfM-MVS, black = scanner; inset circular graph gives radial difference

Piton de la Fournaise summit craters, ~1.6 km across

- SfM-MVS: 133 photos taken from micro-light aircraft, viewing distance ~1000 m, model georeferenced by control points
- Benchmark DEM from oblique photogrammetry
- RMS difference ≈1.0 m

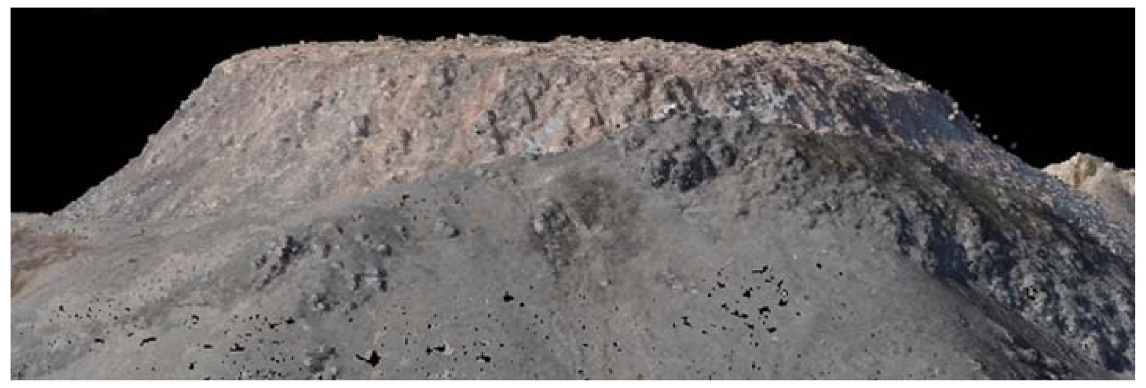


- good accuracy relies on a high quality, convergent image set
- relative precision ratio can exceed 1:1000 [4]
  i.e. a precision of ±1 mm for each metre of viewing distance

4. Colima datasets

- overflights with light aircraft (~30 -160 photos per flight)
- images taken using Nikon D90 with 18-105 mm lens
- example images shown in box 2, here we reconstruct DEMs for two dates: 26th Dec. 2010 & 27th May, 2011

5. Colima dome



Example 3D point cloud model (26th Dec. 2010)

Georeferencing: use features identified in web-sourced aerial imagery (and estimated elevation differences)

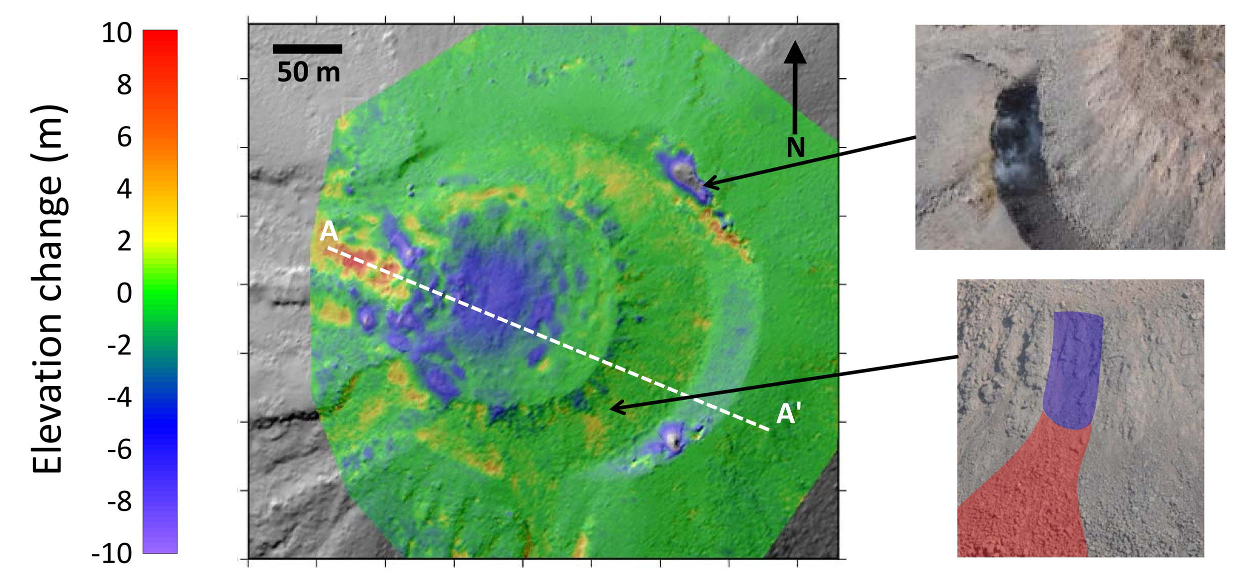
RMS error to control features ≈1 m

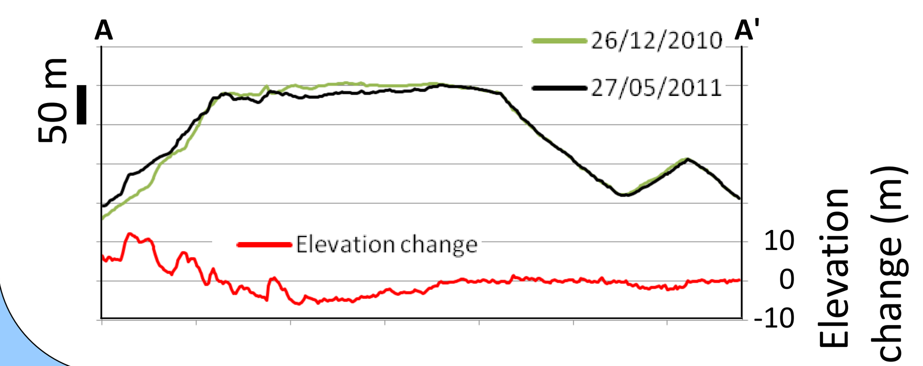
(shaded relief DEM shown in box 2)

Two models constructed: 26th Dec. 2010 & 27th May, 2011

Both independently geo-referenced, then compared by subtraction

Difference DEM





SfM-MVS provides an efficient and effective technique for DEM generation

Software and References

[a] **Reconstruction pipeline:** http://blog.neonascent.net/archives/bundler-photogrammetry-package
[b] **Georeferencing:** http://www.lancs.ac.uk/staff/jamesm/software/sfm_georef.htm

[1] Snavely et al (2006), Photo tourism: Exploring photo collections in 3D, *ACM Trans. Graphics*, 25, 835-846, doi: 10.1145/1141911.1141964.

[2] Furukawa & Ponce (2010), Accurate, dense, and robust multiview stereopsis, *IEEE Trans. Pattern Anal. Mach. Intell.*, 32, 1362-1376, doi: 10.1109/TPAMI.2009.161.

[3] James et al (2011), Lava channel roofing, overflows, breaches and switching: insights from the 2008-2009 eruption of Mt. Etna, *Bull. Volcanol.*, doi: 10.1007/s00445-011-0513-9.

[4] James & Robson (submitted to *J.Geophys. Res.*) Straightforward reconstruction of 3D surfaces and topography with a camera: Accuracy and geoscience applications

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