Application of Structure-from-Motion Multi-View-Stereo Photogrammetry to the extraction of vertical deformation caused by an inflated magma chamber in an analogue experiment

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In recent years, SfM MVS (Structure-from-Motion Multi-View-Stereo) photogrammetry has become widespread in the Earth sciences. Although this technique has been applied mainly to topography measurement, it has been expected to have applications in the analysis of data from analogue experiments (model experiments).

In this study, we attempted to verify whether or not the SfM MVS technique could extract displacement of a sub-millimeter order when applied to a small analogue experiment. We employed an analogue experiment on surface deformation caused by inflation of a magma chamber, because this type of experiment has often been conducted and discussed for the purpose of understanding caldera formation, and excellent results have been obtained. In addition, the requisite knowledge for obtaining a good result has been accumulated.

We made an experimental apparatus using an aluminum tube (diameter 60 cm), a small balloon, a bicycle pump, and rice powder. We conducted experiments and analysis according to the following procedures. (1) We fixed the balloon (radius 2.0 cm) at the center of the base of the tube, and covered it with rice powder. The base is 19 cm below the top of the tube. The scale of this model experiment was 1/20,000, and the fracture strength of the material was estimated using the Coulomb-Mohr criterion for model experiments. (2) We took photos (80 pictures) of the non-deformed surface as an initial state, from various directions and distances. We employed a RICOH GR II digital camera to take the photos. (3) We inflated the balloon radius from 2.0 cm to 4.5 cm in 0.5 cm increments, and we took photos (80 pictures) of the deformed surface caused by the inflated balloon at each stage. (4) We analyzed these photos using PhotoScan software, and constructed a DEM (Digital Elevation Model). (5) We detected net surface deformations caused by inflations of the balloon by subtracting the DEM data obtained at an arbitrary stage from the DEM data obtained at the other stages, using QGIS software.

We repeated this experiment more than ten times, and found that vertical deformations of more than 1 mm could be extracted without conspicuous noise. In addition, we found that inhomogeneity of illumination affected the extraction of the net deformation field, when we attempted to extract vertical deformations of less than 1 mm. The effects of this inhomogeneity appeared as systematic noise or error, appearing like a shadow in the results. This systematic noise appeared in the results even if we illuminated the experimental apparatus using strong LED lights. From the occurrence pattern of the noise, we found that the ceiling lights were causing inhomogeneity of illumination. When we conducted the experiments without the ceiling lights, we were able to detect vertical deformation of 0.2 mm without conspicuous noise.

From these results, we can conclude that the SfM MVS technique can extract vertical deformations of 0.2 mm when the technique is applied to model experiments of the scale of 1/20,000.

Keywords: Structure-from-Motion Multi-View-Stereo Photogrammetry, analogue experiment, inflated magma chamber

