



Identifying control point features in Venus-like radar imagery for VERITAS calibration purposes

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One of the goals of the NASA-led VERITAS mission to Venus is to produce a global, high-resolution digital elevation map (DEM). Its X-band radar instrument, VISAR (Venus Interferometric Synthetic Aperture Radar), will enable imagery and topographic mapping at resolutions two orders of magnitude higher than previously achieved by the Magellan mission. However, it will face fundamental challenges concerning the calibration of the initial DEMs due to limited orbital position accuracy and severe atmospheric path delay (hundreds of meters compared to meters on Earth). These challenges cannot be approached as for Earth-orbiting missions given the lack of precisely-calibrated ground reference targets and the absence of GNSS-like systems. Therefore, the VERITAS mission will instead exploit VISAR imagery to improve our knowledge of the orbital position and attitude of the spacecraft by incorporating repeated observations of the same ground features from different viewing geometries into the orbit determination routine and to calibrate the DEM.

Extracting calibration points from images that can subsequently be localized and used as references, however, requires a robust feature matching algorithm. Although there already exist several matching algorithms which have demonstrated strong performance with optical imagery, their effectiveness can degrade significantly when applied to SAR data. This degradation is due to inherent differences in the measuring principle of optical and radar systems (depending on angle of incoming light versus travel time of radar pulses, respectively), and different noise processes.

This work evaluates the performance of existing feature matching algorithms on SAR imagery with the goal of identifying the most suitable approach for VERITAS data. To conduct these tests, TerraSAR-X spaceborne X-band SAR imagery was acquired over a Venus analog site in the Askja region of Iceland. Importantly, we use a postprocessed version of this dataset which mimics the resolution of different VISAR products to enable a meaningful interpretation of our results. Furthermore, we test both radar-coordinate and geocoded imagery, as the latter is expected to offer better performance for classic feature matchers, but the former is less sensitive to errors in the assumed topography of Venus (which still relies on low-resolution Magellan data).

Our study offers a comparative performance baseline for feature matching algorithms on SAR data in the Venus exploration context. The results enable an evidence-based decision on the optimal approach for the development of algorithms suitable for VERITAS data, and showcase remaining challenges and opportunities for the entire VISAR DEM calibration pipeline.