Structure from Motion in Sedimentary Geology, Geomorphology, and Paleontology: High resolution three dimensional models easily extracted from oblique digital photographs

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Structure from Motion (Sfm)

That reliable source, Wikipedia, defines *structure from motion* as "a range imaging technique; it refers to the process of estimating three-dimensional structures from two-dimensional image sequences which may be coupled with local motion signals." For our purposes, it is creating detailed three dimensional digital models from digital photography. We like to think of it as a 'poor person's LiDAR.

Some uses of High Resolution 3D digital models

- Detailed characterization of pseudo 3D facies architecture (old-school pan mapping with total station control points).
- Visualization of complex three dimensional structures in the field.
- Precise digital measurment of three dimensional objects (fossils, clasts, bedforms, fracture orientations, etc.).
- Precise temporal change measurement and visualization (fault scarp degradation, knick point migration, bed state changes in a stream, etc.).
- Improved communication of three dimensional features to our students.
- Geomorphic mapping of subtle topography (vegetated dunes)

Data acquisition and processing: really easy!!

In many respects, data acquisition is as easy as pointing a digital camera at the feature of interest and taking photos of it from all angles. Ideally, every point on the object you are imaging should be viewed from at least three angles. You can also video the the entire feature and extract overlapping frames from the video. The field notes below show how we acquired the data in example 1, the Anniversary Mine dataset. We set up the camera in three positions (on a tripod), took the GPS coordinates of each position, and shot overlapping images upward from horizontal.

We used Agisoft's Photoscan Pro software to process the images. If we did not want to make measurements or georeference the image, and we only wanted to create a 3D model for visualization, the software uses pattern recognition to reconstruct the camera positions relative to the photos, then uses photogrammetry to extract an elevation model. Initial processing is relatively fast, but processing time increases depending on the desired quality of the output.

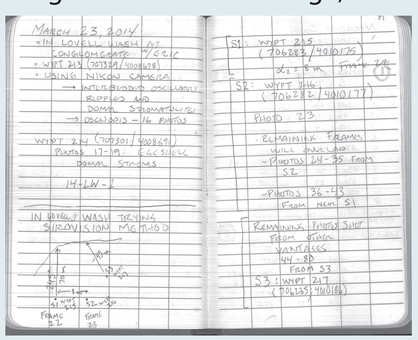

Figure 1. Field notes from first data acquisition attempt. S1 through S3 are camera positions. Lower left is a sketch map of the locale

Example 1: Outcrop scale features

We acquired about 57 photos of an outcrop in the Lake Mead region of Southern Nevada. The camera was set up on a tripod and leveled for the first photo only and only at the first camera position. We then shot overlapping images vertically upward from each camera position (see Fig. 1). There were three camera positions. We noted the GPS coordinates of each camera position, which we will use later to integrate these data into ArcGIS.

Figures 2 and 3 are screen shots from Photoscan Pro that show the computed positions of each of the photographic frames used to construct the 3D model. Figure 4 is a high resolution image of the outcrop. Three dimensional models can be output as .pdf files and can be rotated and visualized in Acrobat Viewer (see laptop display).

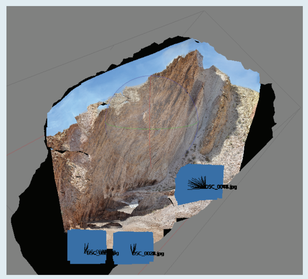

Figure 2. Screen shot of outcrop showing computed camera positions.

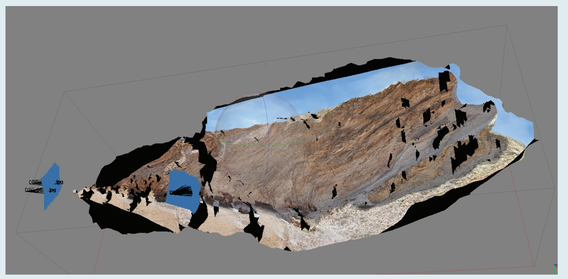

Figure 3. Rotated view of figure 2. Black patches are places that the camera did not 'see' from multiple look angles.

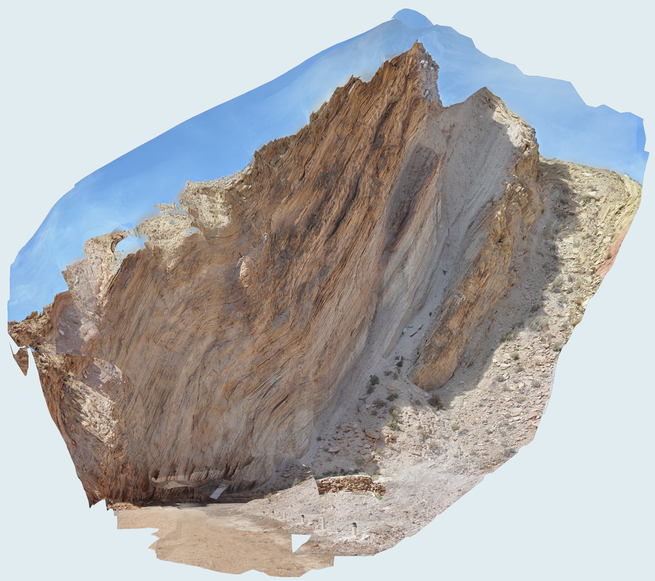

Figure 4. Fully rendered outcrop image from a perspective somewhat higher the camera stations.

Example 2: Hand samples

Below is an example of a small, ~15 cm hand sample of a conglomerate encrusted by microbial carbonate and tufa. The sample was placed on a table top and imaged from the positions shown in figure 5. See laptop display for full 3D model representation.

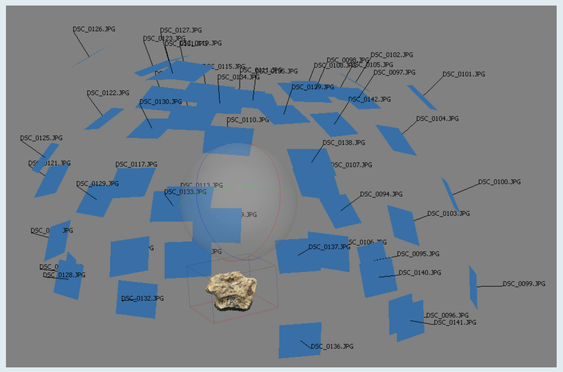

Figure 5. Screen shot showing our hand sample and the computed camera positions that we used to make the rendered images below.