APPLICATION OF AIRBORNE PHOTOGRAPHY IN THE McDOWELL SONORAN PRESERVE

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INTRODUCTION

Field research requires collecting observations and recording them on a basemap. A good basemap can significantly enhance data collection. We present an easy, cost-effective approach for producing high-resolution aerial photography at three research sites in the McDowell Sonoran Preserve. Aerial photographs are collected by a digital camera attached to a tethered helium-filled balloon, and the photographs then are processed using software to produce mapping products. Quality can be comparable to LIDAR at a fraction of the cost. This technique of mapping 3D features from overlapping photos, called Structure from Motion (SfM), can be applied to landscapes, objects, etc.

Figure 1. Geologist Brian Gootee (left) and citizen scientist Dan Gruber with the SfM field apparatus, a digital camera (in Gootee's hand) and large helium-filled balloon on a tether reel (held by Gruber) to loft it. Photo by Melanie Tluczek.

OBJECTIVES and BACKGROUND

The objectives of this project were to:
- Demonstrate whether this approach can produce high resolution aerial photos and topographic models at low cost and with reasonable effort.
- Determine whether this method can be used successfully in the field by trained volunteers with expert support.
- Establish general guidelines and parameters for planning future use.

The McDowell Sonoran Preserve, owned by the City of Scottsdale, AZ, is the largest urban preserve in the United States. The Preserve permanently protects the natural and cultural resources within its more than 30,000 acres.

The Preserve is jointly managed by Scottsdale and the McDowell Sonoran Conservancy, a leader in urban preserve management. This volunteer organization connects the community to the Preserve through education, research, advocacy, partnerships and appropriate access. Citizen scientists of the McDowell Sonoran Field Institute (MSFI), the research center of the Conservancy, work with experts to conduct research in the Preserve.

Software using Structure from Motion (SfM) analytic techniques:
- Creates seamless aerial photography and topographic models using overlapping photos as input.
- Uses photos taken with ordinary cameras carried by hand, on poles, by low-altitude balloons, unmanned aerial vehicles, etc.
- Works by identifying the same features in overlapping photos and calculating the spatial relationships between them.
- Produces highly accurate outputs based on the number, overlap, and resolution of the input photos.

Figure 2. From left Dan Gruber, Melanie Tluczek (McDowell Sonoran Field Institute Manager), and Brian Gootee launch the balloon apparatus at the Fraesfield site. Picture taken by camera mounted below the balloon.

MATERIALS and METHODS

Materials consisted of software and hardware to produce images for input to the software. The software used for these projects was Agisoft PhotoScan provided through Arizona State University and ESRI ArcMap from MSFI. Hardware lent by the Active Tectonics Lab at Arizona State University included:
- Balloon ~2 meters in diameter.
- Tether (250 meters of strong line, marked every 10 meters) on a reel.
- 16 megapixel digital camera capable of taking pictures at defined intervals, field of view ≈ distance from object in focus, and battery/memory card sufficient to collect up to 1000 images.
- Suspension mount to point the camera downward under the balloon.
- Helium to fill balloon (purchased locally).

Significant planning and volunteer training were done before deployment:
- The area to be surveyed was identified and the perimeter marked. This approach can photograph 5+ hectares (12+ acres) of moderate terrain per hour of balloon flight.
- The paths to be followed by the "balloon wrangler" holding the tether were marked on the ground.
- All participants were trained beforehand using a checklist for preparation, a small balloon, and a "course" to practice navigation on the ground.

Figure 3. Google Earth survey area delineation and path grid for Brown's Ranch archeological survey.

In the field:
- Time of day and day of week were selected to minimize wind and people who might interfere with the survey or show up in the photos.
- Using the checklist made sure all steps were completed.
- The camera was started and the balloon unreeled to the desired altitude.
- A person with a compass accompanying the wrangler and people stationed at path end points kept the balloon on the planned paths.
- Other assistants kept the tether clear of overhanging vegetation, etc.
- The survey exceeded 90 minutes, so the balloon was reeled in to check the battery and memory card status.

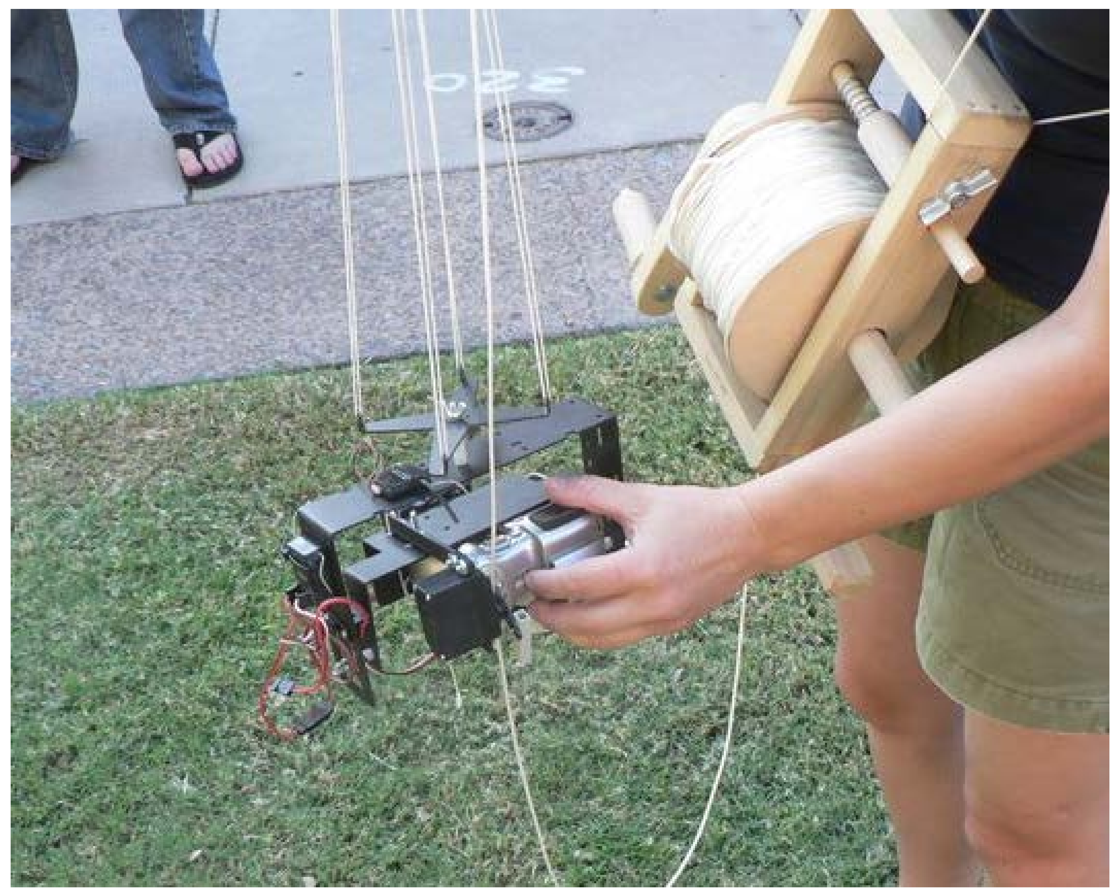
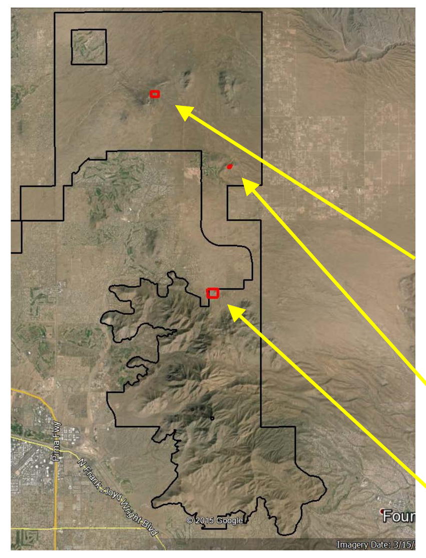


Figure 4. Digital camera suspended in mount. Balloon tether reel at right. GPS mounted with camera; not needed with ground control points. Photo courtesy of Dr. Ramon Arrowsmith, ASU.

RESULTS

Balloon-borne photography was used at three sites in the Preserve with the following parameters and resolution results:



Site	Area (Hectares)	Balloon Max Height (meters)	Photos	Res. (cm/ pixel)
Brown's Ranch	9	50	934	1.4
Fraesfield	1	75	276	2.0
Paraiso	18	100	609	2.5

Figure 5. Three aerial survey sites in Preserve

Table 1. Summary statistics from three Preserve survey sites.

Airplane-based photography conducted for Scottsdale currently provides 10 cm/pixel resolution. Compare photos of the Fraesfield site from conventional aerial photography and the balloon aerial survey, both done in 2014:

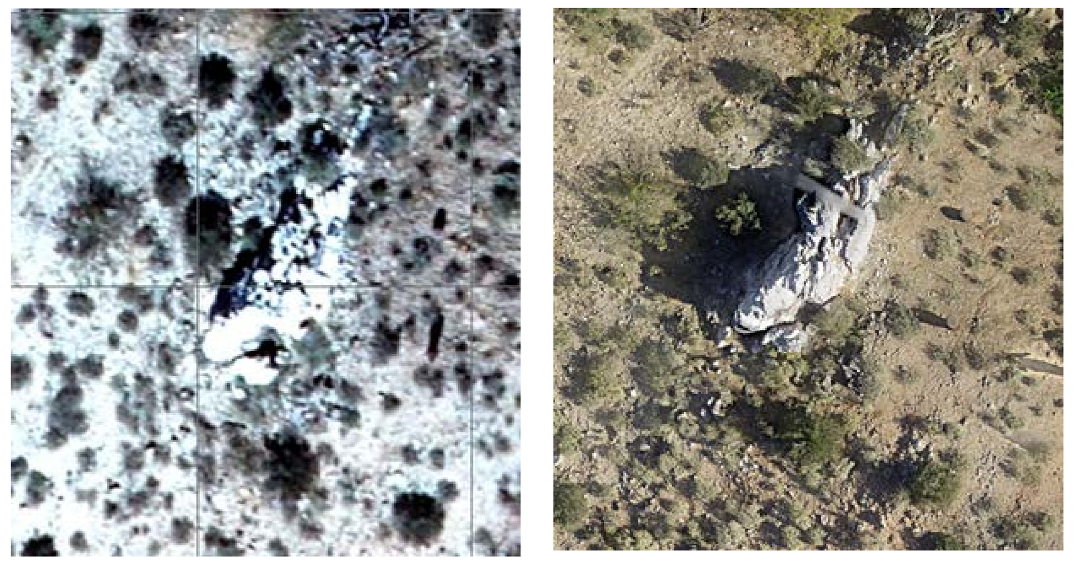


Figure 6. Comparison of conventional aerial photo (10 cm/pixel) of quartz outcrop at Fraesfield site (left) with result from balloon apparatus and SfM software processing (1.4 cm/pixel).

The balloon apparatus and associated processing also produce digital elevation models (DEMs) and contour maps. DEMs are calibrated using ground locations with known position and elevation. The three locations achieved vertical resolution as low as 8 cm/pixel, depending on photos per unit area covered.

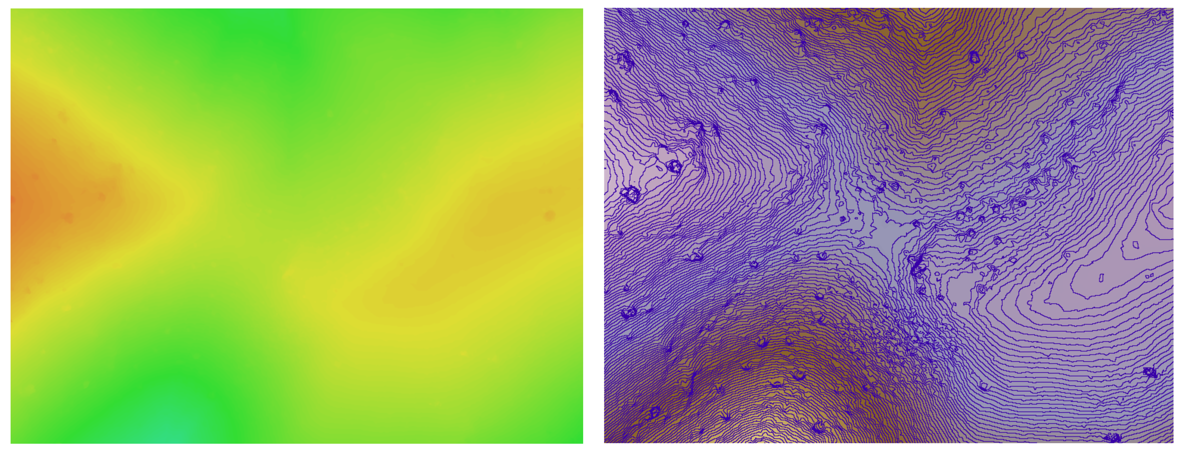


Figure 7. (Left) DEM of center of Fraesfield site produced by Agisoft processing. (Right) 1-foot contour map produced by ESRI ArcMap from DEM. Note vegetation as isolated raised contours. Area shown is slightly larger than that in Fig. 6.

Shaded relief maps can be generated from DEMs, which can be valuable in identifying features too subtle to be seen in photos or by casual field exploration. Some of the features seen below are less then 10 cm high.

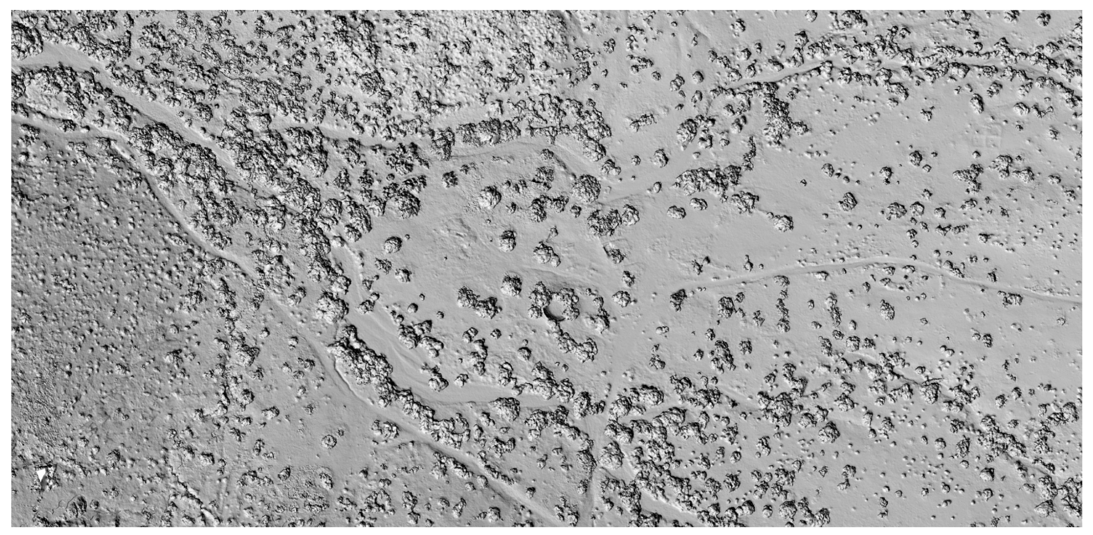


Figure 8. Shaded relief map of Brown's Ranch site (see Fig. 3) produced by Brian Gootee using ESRI ArcMap software.

CONCLUSIONS and MANAGEMENT IMPLICATIONS

Low-altitude photography using a helium-filled balloon combined with SfM and GIS software can produce aerial photography, DEMs/contour maps, and shaded relief maps with Lidar-like accuracy. Applications include geological and archeological surveys and site documentation, non-native plant monitoring, restoration monitoring, topographic map production, and many others.

Advantages of this technique include:
- Easy to use.
- Volunteers can collect good data successfully, leveraging scientist time.
- Not time-consuming – only a few hours of field work is needed.
- Relatively inexpensive – total cost of the apparatus is less than $1000 including helium. The Agisoft software costs $500 for an academic license.
- Hardware/software can be shared among users.

The basic planning decisions are:
- Site selection and field marking.
- Deciding balloon altitude for pictures.
- Defining ground paths to follow.
- Determining team needed and training.

Density of photos per unit area determines resolution. Resolutions approaching 1 cm/pixel and DEMs with resolution of <10 cm/pixel require:
- 15+ megapixel camera photos
- ≤ 50 m balloon altitude
- ≤ 20 m path separation

Larger areas require higher altitude and wider path separation.

Figure 8. Brian Gootee launching the balloon with suspended camera. The tether reel is in his left hand. Photo by Dan Gruber.

Special care is needed in these areas:
- This approach is not appropriate for sites with challenging terrain, dense vegetation, or material that should not be disturbed.
- Mitigate the effect of irregular paths caused by terrain and vegetation by using lower flight height and closer path spacing to produce big overlaps.
- Minimize blur by flying when it's light enough for the camera to use fast shutter speeds. Blurred photos should not be input to the software.

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5. http://activetectonics.blogspot.com/2015/06/black-canyon-city-structure-from-motion.html.

Software: Agisoft Photoscan, Agisoft LLC, St. Petersburg, Russia. www.Agisoft.com. ArcGIS, ESRI, Redlands, CA. www.esri.com.

Balloon: Arizona Balloon Company, Glendale, AZ. www.arizonaballoon.com.

Camera Mount: Brooxes, www.brooxes.com

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