INTRODUCTION

Field research requires collecting observations and recording them on a map. A good baseline 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 is 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.

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.

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-meter 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.

RESULTS

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.

The balloon apparatus includes:

- Photosphere atmospheric pressure balloon (4.2 m diameter) and helium balloon filled by electrically driven compressor.
- Digital camera (16 megapixels) capable of taking pictures at defined interval.
- Suspension mount to point camera downward.
- GPS unit to record balloon coordinates.
- Software using Structure from Motion (SfM) analytic techniques.
- DEMs are calibrated using ground control points. Photo courtesy of Dr. Ramon Arrowsmith, ASU.

The balloon apparatus was used at three sites in the Preserve with the following parameters and resolution results:

<table>
<thead>
<tr>
<th>Site</th>
<th>Area (Hectares)</th>
<th>Balloon Max Height (meters)</th>
<th>Photos</th>
<th>Res. (cm/pixel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown’s Ranch</td>
<td>9.7</td>
<td>50</td>
<td>434</td>
<td>1.4</td>
</tr>
<tr>
<td>Finn Farm</td>
<td>1.7</td>
<td>75</td>
<td>276</td>
<td>2.0</td>
</tr>
<tr>
<td>Fronesfield</td>
<td>18</td>
<td>100</td>
<td>609</td>
<td>1.5</td>
</tr>
</tbody>
</table>

The balloon apparatus was used at three sites in the Preserve with the following parameters and resolution results:

- Photosphere atmospheric pressure balloon (4.2 m diameter) and helium balloon filled by electrically driven compressor.
- Digital camera (16 megapixels) capable of taking pictures at defined interval.
- Suspension mount to point camera downward.
- GPS unit to record balloon coordinates.
- Software using Structure from Motion (SfM) analytic techniques.
- DEMs are calibrated using ground control points.

The balloon apparatus includes:

- Photosphere atmospheric pressure balloon (4.2 m diameter) and helium balloon filled by electrically driven compressor.
- Digital camera (16 megapixels) capable of taking pictures at defined interval.
- Suspension mount to point camera downward.
- GPS unit to record balloon coordinates.
- Software using Structure from Motion (SfM) analytic techniques.
- DEMs are calibrated using ground control points.

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 than 10 cm high.

CONCLUSIONS and MANAGEMENT IMPLICATIONS

Low-altitude photography using a helium-filled balloon combined with SfM and DEM algorithms can produce detailed aerial photographs (DEMs) and contour maps, and shaded relief maps with LiDAR-like accuracy. Applications include geological and archeological surveys and site documentation, non-traditional plant monitoring, restoration monitoring, vegetation 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.
- Defining 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 close to 1.5 cm/pixel at ≤50 m balloon altitude. Larger areas require higher altitude and wider path separation.

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 a small balloon to produce low overlap.
- 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.

REFERENCES and SOURCES


ACKNOWLEDGEMENTS

This work was supported by the McDowell Sonoran Field Institute, the Arizona Geological Survey, the Active Tectonics Lab at Arizona State University, and the City of Scottsdale.

Thanks to:

1. Ramon Arrowsmith, Department of Geology, Arizona State University.
2. Melanie Tluczek, Manager, McDowell Sonoran Field Institute.
3. John Loleit, Preserve Coordinator, City of Scottsdale.