Quantifying Dissipative Beach and Vegetated Dune Morphology With Multiple Aerial Photography Systems

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EP11A-0973

Background and Questions

Structure from Motion (SfM) is the technique that allows for the creation of a 3-d surface from a set of overlapping 2-d photographs[1]. This technique has been shown to be viable in collecting morphological datasets in diverse environments, however has not been applied to the coastal zone until relatively recently[2,3]. This project aims to better constrain the efficacy of this technology in low-sloping coastal environments utilizing multiple data-collection platforms.

Specifically we aim to address:

1) How viable is aerial photography-based SfM technology in low-gradient coastal environments?
2) What are important factors to consider in data collection platforms? For example, what kinds of cameras should be used?
3) What is an optimal data collection platform for use in coastal environments?

Image Collection Platforms and Structure from Motion (SfM) Methods

Setting: In summer 2016, a six-week field campaign called the **S**andbar-a**E**olian **D**une **Ex**change **Ex**periment (**SEDEX2**) took place on the Long Beach Peninsula in southwest Washington with the goal of collecting a suite of datasets fundamental to improving understanding of progradational morphodynamics. Data presented here were collected as part of this experiment.

Kite: Three Mobius Actioncams (3 MP) were mounted on a 8 foot Delta Conyne kite via a 3-d printed hemisphere. Each camera took a downward facing picture of the beach every 2 seconds, and cameras were pointed so that each set of three pictures overlaps. The kite was flown at ~15m elevation, and mapped ~.02 km² utilizing 11 Ground Control Points (GCPs)[4].

Figure 1. Kite data collection system and an example set of two overlapping images acquired with this system

UAV: A Phantom 3 Professional (P3P) quadcopter was used to take oblique photographs of the upper beach and dunes. The UAV includes a 12.4 MP camera mounted on a gimbal system. The UAV was flown at ~25m elevation, and mapped ~.1 km² utilizing 20 GCPs.

Figures 2. P3P UAV and example images acquired with this system

SfM: Agisoft Photoscan Professional Edition (Version 1.2.6, build 2834) was used to run collected pictures through an SfM algorithm. Point clouds are generated in 3 stages[5,6]:

1) Unique features are matched across images using custom tracking algorithms similar to the SIFT system.
2) Intrinsic and extrinsic camera parameters are computed using greedy algorithms, and scene geometry is reconstructed to generate a sparse point cloud.
3) A dense point cloud is generated from the sparse cloud using a dense multi-view stereo reconstruction. This dense cloud is then georeferenced using GCPs, and can be re-created into a DEM.

RTK: Cross-shore profiles were collected using an RTK DGPS system. These profiles are accurate to ~5 cm in the vertical[7], and are therefore used as a tool to quantify errors of SfM generated results.

Results: RTK DGPS

RTK DGPS data reveals a thickly vegetated multiple-dune system, with dune heights of ~10m elevation relative to NAVD88. Data also shows significant temporal evolution, with intertidal sandbars propagating onshore and eventually welding to the shoreline throughout the experiment.

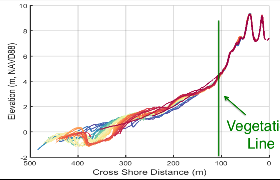


Figure 3. An example RTK DGPS profile, showing temporal morphologic evolution. Lines progress through time from blue to red.

Results: Kite and UAV Imagery Systems

Results indicate quality differences between platoforms. The kite-data exhibits inaccurate spikes in elevation that the UAV data does not. Additionally, the accuracy of the UAV data is higher than that of the kite, with significantly lower errors along each transect. The fordunes at this site are heavily vegetated primarily with Ammophila breviligulata, and our results clearly show that this vegetation is impacting DEMs derived from both platforms. Tiller heights of A. breviligulata have been estimated (in the lab) to be ~70 cm[8], however initial analysis of Terrestrial Laser Scanner data collected during SEDEX[9] indicate that vegetation in this natural dune setting is only ~50-60cm tall. Below we apply a 50cm vegetation correction (UAV Modified DEM) to attempt to derive bare-earth DEMs from our data.

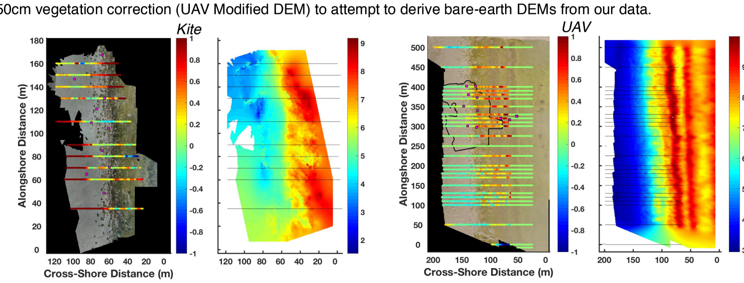


Figure 5. Orthophoto and DEMs from kite-based (left) and UAV-based (right) imagery systems. Left two panels show an orthophoto overlain with modeled elevation difference from RTK DGPS data (m) along cross-shore profiles, and SfM generated DEM (respectively) for the kite platform. Right two panels show the same for the UAV platform

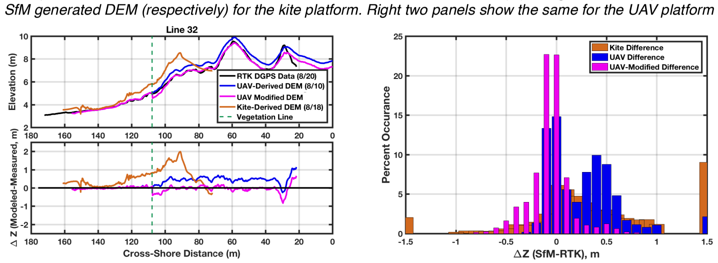
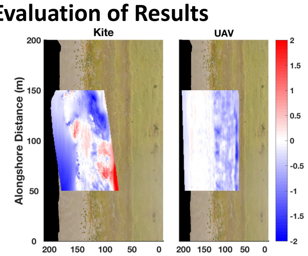


Figure 6. (left) RTK cross-shore profile plotted with the same profile from the UAV and kite-derived DEMs, as well as the UAV modified DEM. (right) Histogram showing distribution of difference from RTK collected profiles for each DEM

Evaluation of Results



- The UAV platform performed well, attaining a model RMS error 28 cm less than that of the kite-system.
- There is relatively uniform increase in error of the UAV-model backshore of the vegetation line. Various methods can be applied to filter out this vegetation, discussed more in "Implications and Future Research."
- The kite was able to create a higher resolution model due to its lower flying elevation than the UAV platform.
- The kite model shows many inaccurate spikes in elevation. Various factors could be contributing to this, including pitch and roll of the platform while images are acquired, poor camera quality, and insufficient GCP dispersal. To investigate causes of poor kite results, lab tests were performed to determine the importance of camera quality on SfM output.

Figure 7 (top) and Table 1 (right). Figure 7 shows DEMs of difference for both imagery platforms as compared with RTK DGPS data. Table 1 gives important parameters of the final models. Reprojection error is defined as the difference between any one point's first detected location and it's final projected location.

Table 1.

	Kite	UAV
Model RMS error	.66 m	.38 m
Model Resolution	112 pts/m²	14 pts/m²
Model RMS Reprojection Error	2.13 m	.19 m

Camera Quality Controls on SfM Output

Controlled lab tests were performed to evaluate the effects that different camera parameters have on the quality of SfM-created DEMs. The same 9 pictures of a controlled mock-landscape were taken using 4 smartphones and 2 action cameras, each with slightly different camera specifications. Each set of pictures was processed using identical processing parameters in Agisoft Photoscan, and final DEMs were created from each. These DEMs were then evaluated for accuracy, and this accuracy was correlated with camera specifications.

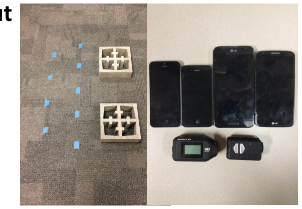


Figure 8. (Left) Setup of lab tests. Pictures were taken from above while standing on each of the marks. (Right) Cameras used in the test

Results:

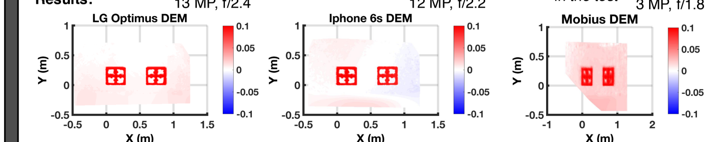


Figure 9. DEMs created from pictures taken with (from left to right): LG Optimus G Pro, Iphone 6s, and Mobius ActionCam

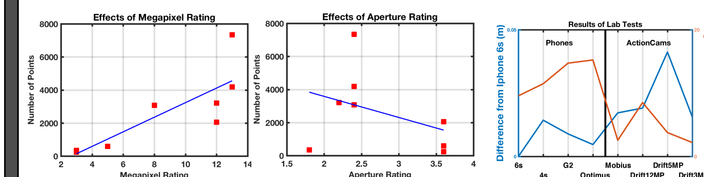


Figure 10. (left) Camera megapixel rating effects on model resolution. (center) Camera aperture rating effects on model resolution. (right) For the DEM generated for each camera: RMS difference from the Iphone 6s DEM, and DEM resolution.

Results indicate a decrease in accuracy, sharpness, and spatial coverage with the action camera as compared to the smartphones. Additionally, results indicate a positive correlation between megapixel rating and model resolution, and a negative correlation between aperture rating and model resolution.

Implications and Future Research

Figure 11. Photograph taken with a fixed-wing aircraft

- Based on our final laboratory tests, **we suggest utilizing a camera with a megapixel rating no less than 8, and an aperture value no greater than 2.4** for optimal SfM results. Additionally, if the data collection system will be relatively transient (e.g. kite-based), **shutter speed must be fast** (~1/500 sec). Finally, elevation of flight must be considered, as higher flying elevation will lead to greater model spatial coverage at the cost of model resolution. Our kite platform did not follow these recommendations, helping to explain the poor results of this system. A logical next step is therefore to utilize a smartphone on the kite-platform.
- Both data collection platforms used here have unique environmental conditions in which they are optimal[4]. Many more platforms are available for this purpose: fixed wing aircraft (figure 11)[3], telescoping poles, and balloons could all be utilized as well. Our results, as well as others [2,3,4], show that **aerial photography-based SfM can be a low-cost, effective means of attaining low-gradient coastal morphology data. Provided suggested camera parameters are taken into account, this technique can be applied through many different data collection platforms, each optimal in unique environmental conditions.**
- **Techniques to filter vegetation from models will be an important focus of this project moving forward.** Specifically, Terrestrial Laser Scanner data also acquired during SEDEX2[9] will be utilized to create DEMs of vegetation, allowing for the removal of these areas from SfM results. Techniques to filter vegetation through color detection algorithms will also be explored.

Acknowledgements

This work is supported by the National Science Foundation under EAR award number: 1561847. The author would additionally like to thank Dylan Anderson for always providing valuable input, and every other member of the CIL for continued support and guidance.

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