Small Area Stream Mapping with Directly Georeferenced Pole Aerial Photography

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Abstract

The collection of high-resolution data is helping researchers better understand form, process, and change in river systems and, especially, stream restoration projects. In the last 10 years it has become apparent that there is no “one-size-fits-all” approach to collecting high-resolution data for fluvial studies. The approach we demonstrate here is a self-contained pole aerial photography (PAP) system capable of collecting data for directly georeferenced structure from motion photogrammetry. PAP can produce higher-spatial resolution data than remotely piloted aerial system collected data and is one option where RPAS are restricted, like in parks and protected places. Another advantage of PAP is that it makes 3D data collection possible in parts of rivers, like under riparian canopies, that can elude capture with RPAS methods. Direct georeferencing removes the necessity for ground control points, which can greatly decrease the amount of time needed for a survey. The system that we developed combines a low-cost, dual-frequency GPS receiver capable of Real-time and Post-Processed Kinematic surveying with an off-the-shelf digital SLR camera, an inertial measurement unit, and 3D printed mounts and housings. The open-source control/survey software runs on an inexpensive Raspberry Pi computer with a 7-inch (18 cm) touch screen display. We highlight the accuracy of the system along with the high spatial resolution 3D data, ortho imagery, as well as other data that can be derived from these datasets such as sediment size measurements.

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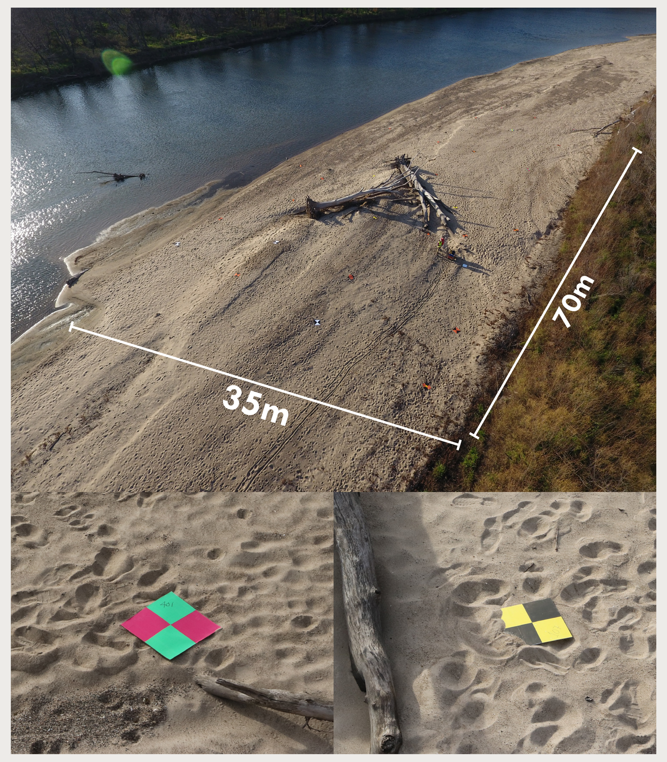
ABSTRACT

The collection of high-resolution data is helping researchers better understand form, process, and change in river systems and, especially, stream restoration projects. In the last 10 years it has become apparent that there is no "one-size-fits-all" approach to collecting high-resolution data for fluvial studies. The approach we demonstrate here is a self-contained pole aerial photography (PAP) system capable of collecting data for directly georeferenced structure from motion photogrammetry. PAP can produce higher-spatial resolution data than remotely piloted aerial system collected data and is one option where RPAS/UAS are restricted, like in parks and protected places. Another advantage of PAP is that it makes 3D data collection possible in parts of rivers, like under riparian canopies, that can elude capture with RPAS methods. Direct georeferencing removes the necessity for ground control points, which can greatly decrease the amount of time needed for a survey. The system that we developed combines a low-cost, dual-frequency GPS receiver capable of Real-time and Post-processed Kinematic surveying with an off-the-shelf digital SLR camera, an inertial measurement unit, and 3D printed mounts and housings. The open-source control/survey software runs on an inexpensive Raspberry Pi computer with a 7-inch (18 cm) touch screen display. We highlight the accuracy of the system along with the high spatial resolution 3D data, ortho imagery, as well as other data that can be derived from these datasets such as sediment size measurements.

STUDY SITE

The testing site for the accuracy assessment was a sand bar on the Cedar River in Black Hawk Park in Cedar Falls, IA. The bed of the Cedar River is primarily sand and fine gravel and the bar is only visible/accessible at lower flows (~1500cfs/42.5cms). The study section was 35 x 70 meters.



METHODS

Pole Camera - The pole camera was extended to its maximum height of 4.7m and the camera was tilted down 30° from the horizon (60° off nadir). 183 photos were taken at intervals of "3 paces" (~3.5 meters) in a lawnmower pattern to cover the site. Positions were calculated by IMU corrected PPK GNSS.

UAS Survey - Using a DJI Phantom 4, 54 nadir photos were collected in a grid at 50m AGL with 80% side- and end-lap (calculated in DJI Ground Station Pro). An additional 16 oblique photos (30° off-nadir) were added to the photo set in a circular flight path at 30-35m AGL.

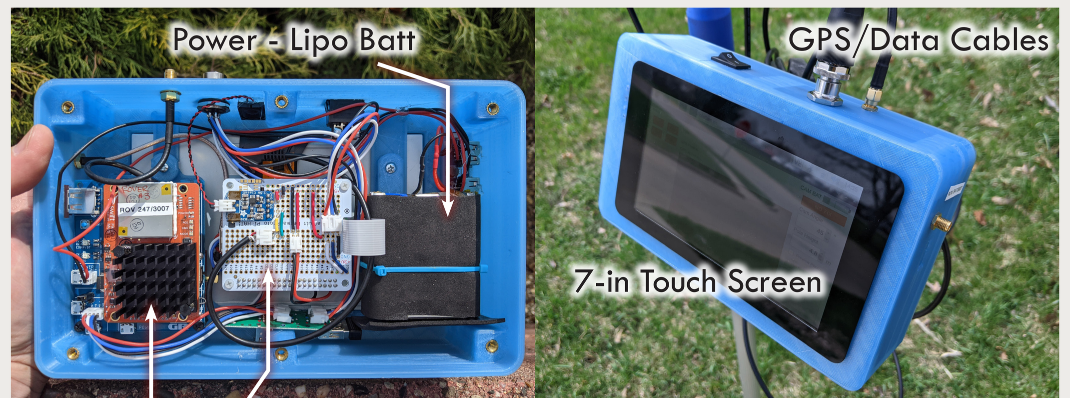
Ground Control/Validation Survey - Thirty-one (31) ground control targets (GCPs) were placed throughout the survey area for X,Y, and Z validation. An additional 60 points (z-points) were collected for only Z validation. The positions were collected with a Topcon HiperVR RTK GNSS.

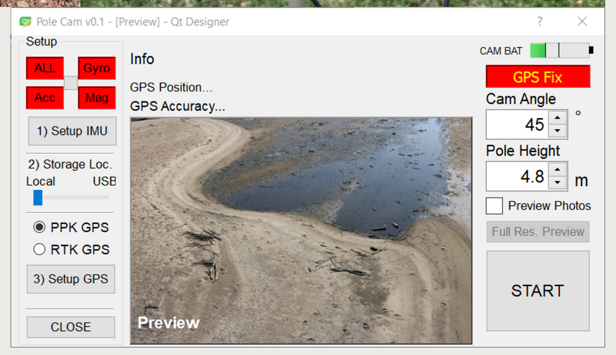
- Pole Cam: 31 GCPs and 60 z-points were used for validation.
- UAS: 6 GCPs were used for georeferencing. 25 GCPs and 60 z-points were used for validation.

Photogrammetry/SfM - High quality settings in Agisoft Metashape 1.7.2

POLE CAMERA SYSTEM

The Pole Cam is built with 3D printed components and centers around a Raspberry Pi 3a single board computer running a custom Python GUI for data logging and camera control.

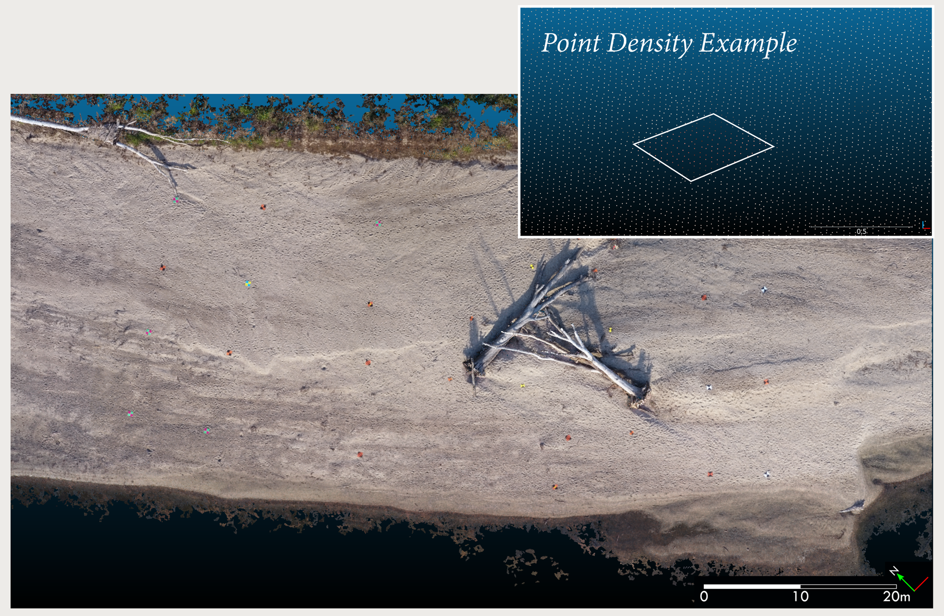




Python GUI for PPK GPS logging & camera control

Results

Pole Cam
183 photos
355,454,320 points
(135,411 points/m²)



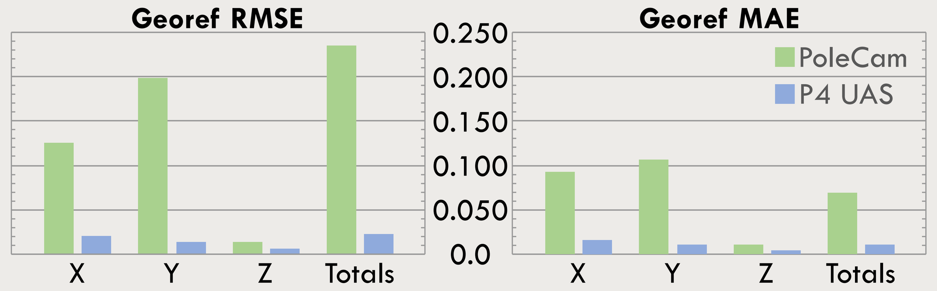
Phantom 4 UAS
70 photos
6,016,775 points
(1,252 points/m²)

Accuracy Assessment

Georeferencing accuracy

Pole Cam (Direct Georef)	165 Cameras X	Y	Z	Totals
Mean Error	0.000	0.000	0.000	
St. Dev Error	0.150	0.129	0.008	
95% Conf.	0.295	0.252	0.016	
Root Mean Sq. Error	0.126	0.198	0.014	0.235
Mean Abs. Error	0.092	0.106	0.011	0.069

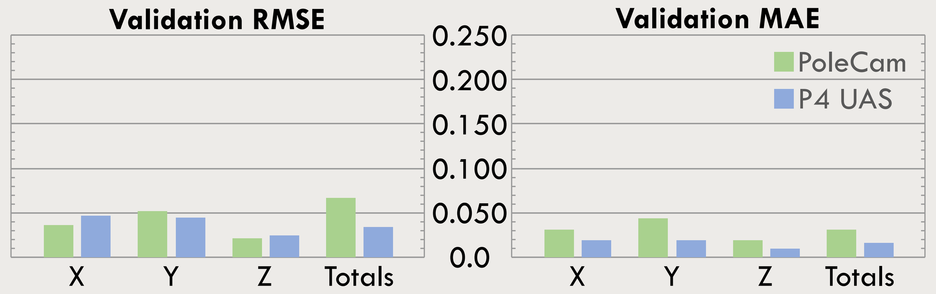
Phantom 4 (Ground Control)	7 GCPs X	Y	Z	Totals
Mean Error	0.000	0.000	0.000	
St. Dev Error	0.020	0.013	0.005	
95% Conf.	0.040	0.026	0.011	
Root Mean Sq. Error	0.020	0.013	0.005	0.023
Mean Abs. Error	0.016	0.010	0.004	0.010

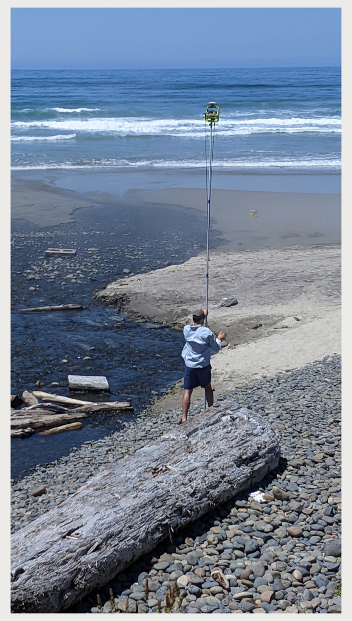


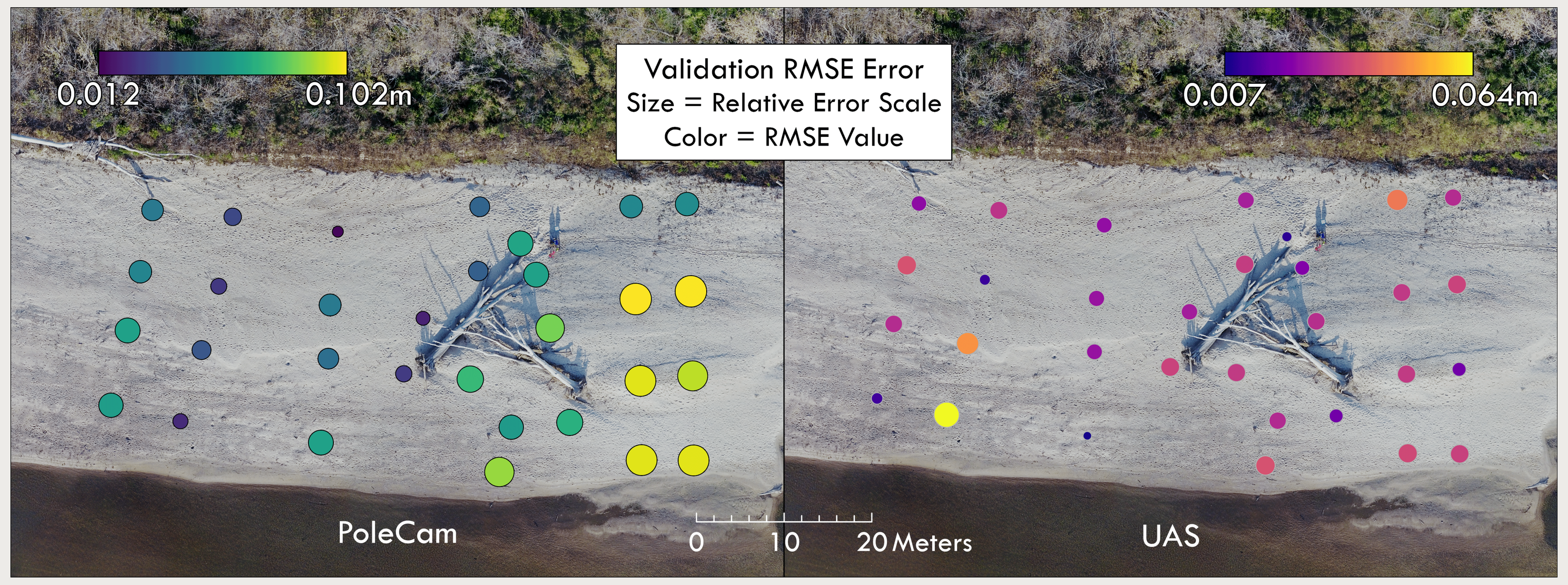
Validation Accuracy

Pole Cam (Direct Georef)	31 GCPs X	Y	Z	Totals
Mean Error	-0.024	-0.038	0.018	
St. Dev Error	0.027	0.037	0.009	
95% Conf.	0.053	0.072	0.017	
Root Mean Sq. Error	0.036	0.052	0.020	0.067
Mean Abs. Error	0.031	0.044	0.018	0.030

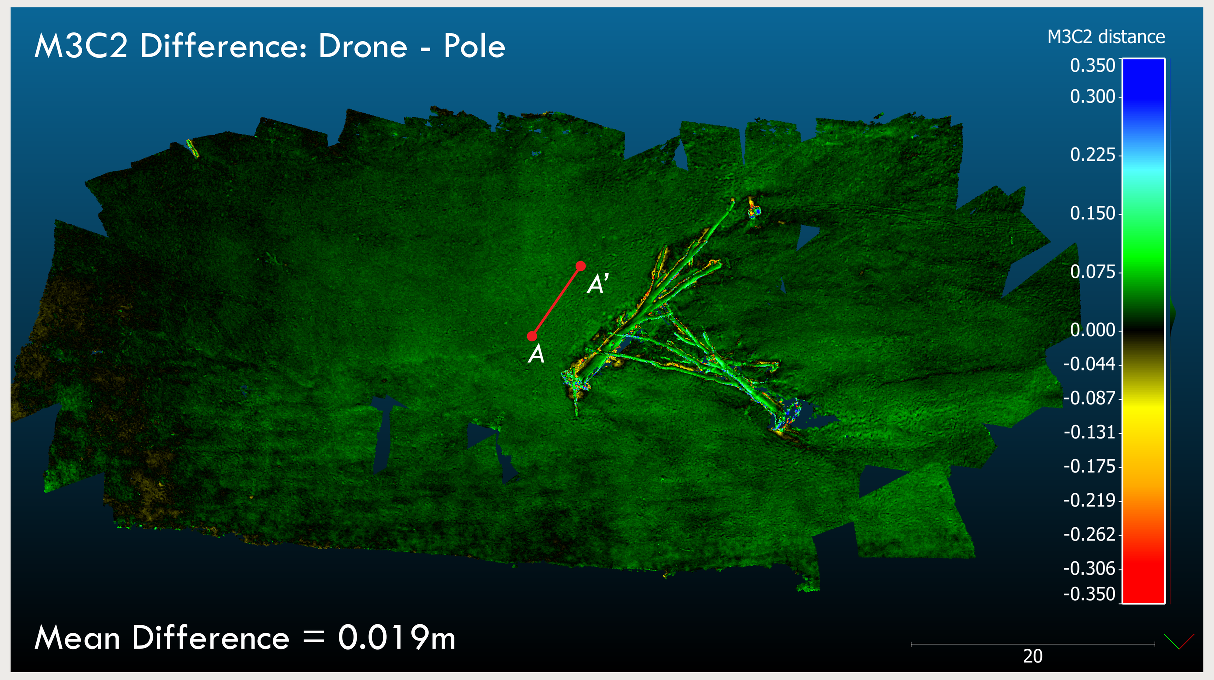
Phantom 4 (Ground Control)	24 GCPs X	Y	Z	Totals
Mean Error	0.001	-0.002	-0.005	
St. Dev Error	0.024	0.022	0.011	
95% Conf.	0.047	0.044	0.022	
Root Mean Sq. Error	0.047	0.044	0.024	0.034
Mean Abs. Error	0.019	0.019	0.009	0.016



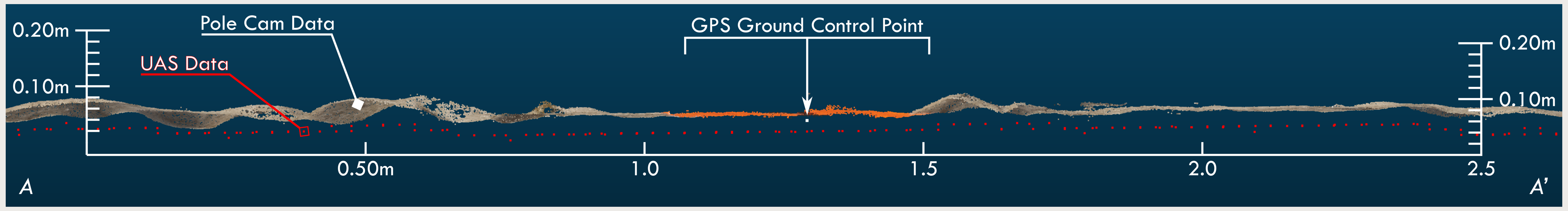




Spatial Error distribution



10cm X-Section showing Pole Cam and Drone point cloud height differences



Conclusions

- PPK positioning on the PoleCam provides high accuracy 3D mapping results for most small area mapping needs.
- Point cloud/DEM/Ortho photo resolutions are very high. Could be useful for sediment size mapping or measuring ultra-high resolution change.
- Survey time is slightly longer than a comparable UAS survey with GCPs, without the need to layout and collect GCP targets.
- Survey patterns and photo spacing are critical for any SfM survey - the oblique nature of the photography from a PAP platform requires more careful planning and monitoring to ensure proper photo coverage of the site.

GitHub

Acknowledgments

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