Exploring the Use of Commercial Off-the-Shelf (COTS) Unmanned Quadcopters to Identify and Characterize Ice Surface Features

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Abstract

Recent advances in the capabilities of small, affordable, commercial off-the-shelf (COTS) unmanned aerial systems (UASs), such as "drone" quadcopters, have opened up a wide range of possibilities for using COTS UASs to perform missions and provide data products traditionally reserved for larger, more expensive UAS platforms. Additionally, open source and/or affordable image processing software tools have simplified data post-processing. Small UAS quadcopters have great potential for use in mapping and data collection in polar environments, especially at scales below the resolution of satellite or aircraft remote sensing systems. In this study, processed imagery collected by COTS UAS quadcopters during test and field surveys will be presented to evaluate the current potential for using COTS UASs to identify and describe surface features over ice in polar environments. Results suggest future potential for COTS UAV deployment in polar research/operations as these platforms become more advanced in terms of control systems, power sources, sensor system integration, increased payload, and more ruggedized designs for employment in harsh environments.

Study Area and Methods

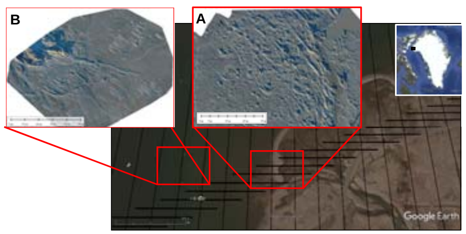
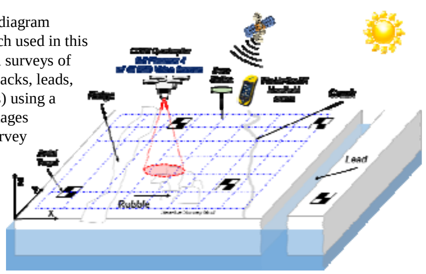


Figure 1. Study area southwest of Thule Air Base, Greenland. Highlighted areas show orthomosaics of two ice fields surveyed in this study using a COTS quadcopter: (A) Land-to-sea ice rubble field; and (B) Ridge feature on offshore (fast) sea-ice. The black hash-marks indicate the NASA OIB airborne survey line.

A DJI Phantom 4 quadcopter with a 4K UHD video camera was used to survey two areas (0.0255 km^2 and 0.0094 km^2) of fast sea-ice near Thule AB, Greenland (**Fig.1**) in March 2017 during the USNA Polar Science & Technology Program (PS&TP) ice experiment with the National Aeronautics and Space Administration (NASA) Operation IceBridge (OIB) utilizing the approach outlined in **Figure 2**. Post-processing was performed using Pix4Dmapper Pro v. 3.4 drone-based mapping software with high-resolution geo-referenced control points collected using a Trimble Geo7X handheld GNSS system.

Figure 2. Conceptual diagram illustrating the approach used in this study to conduct aerial surveys of sea-ice features (i.e. cracks, leads, rubble, pressure ridges) using a COTS quadcopter. Images captured during the survey were used to identify and characterize features and develop 3-D maps via post-processing.



Survey Results

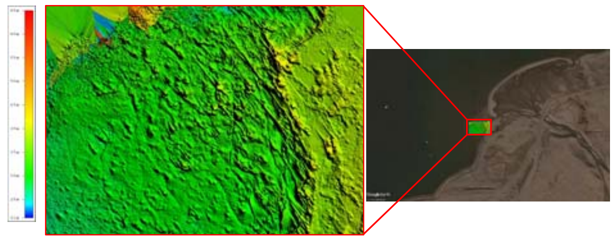


Figure 3. Digital Surface Map (DSM) of rubble field (Global Mapper; **Fig. 1A**).

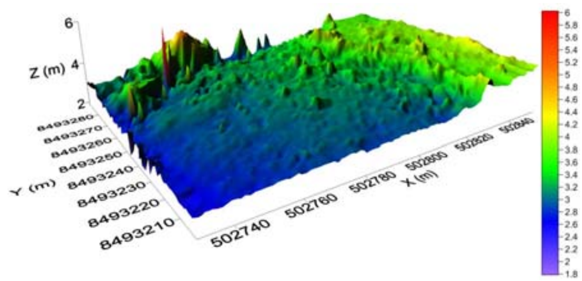


Figure 4. Structure from Motion (SfM) contour of rubble field (**Fig. 1A**) depicted with reference to local xyz grid (Surfer v11).

Figure 3 shows a digital surface map (DSM) of the rubble field surveyed. The DSM is consistent with the reality of the terrain, depicting sloping east-west terrain. The northwest corner of the surveyed area shows an abrupt increase in terrain relief that was not present. The structure from motion (SfM) contour coincides with the DSM and also depicts abrupt spikes in elevation within the sea-ice along the western survey boundary (**Fig. 4**). High-resolution GPS data was post-processed to 0.30-0.50 m at 3 ground control points (GCPs) and 3 test points within the rubble field survey (**Fig. 5A&B**). The GCPs were then used to post-process a point cloud produced from the Pix4Dmapper Pro structure from motion (SfM) algorithm. The root mean square error (RSME) of the position for each test point was calculated to evaluate the accuracy of the post-processed point cloud in a local XYZ-frame. The horizontal RMSE was calculated as 4.4 cm in the x-direction and 34.3 cm in the y-direction, while the vertical RMSE was calculated to be 52.7 cm along the rubble survey grid shown in **Figure 6**.

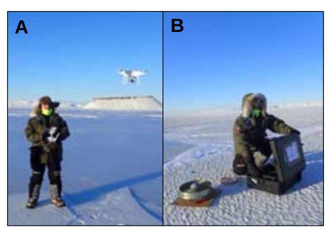


Figure 5. (**A**) DJI Phantom 4 flight and (**B**) laying out Ground Control Points (GCP) for survey.

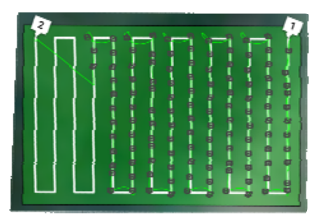


Figure 6. Flight path of ice rubble field on shoreline of North Star Bay, Thule, Greenland. The green line depicts the actual flight path while the white line is the intended path.

Discussion

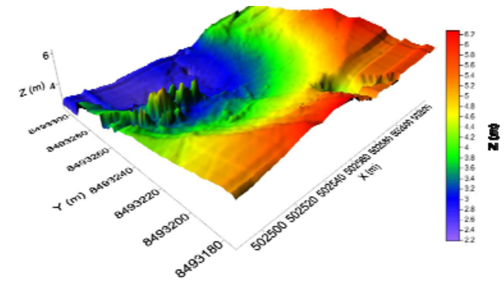


Figure 7. Structure from Motion (SfM) contour of ridge feature(**Fig. 1B**) depicted with reference to local xyz grid (Surfer v11).

In contrast to the single feature artifact in the SfM contour of the rubble field (**Fig. 4**), the SfM contour for the ridge feature is distorted throughout (**Fig. 7**). Distortion along survey boundaries in both cases is because of the absence of overlapping imagery. The clarity and consistency of the point cloud derived from aerial surveys depends on image availability and GPS resolution. Post-processed GPS positions during the surveys were well-below cm resolution due to environmental factors. Satellite connectivity was limited due to the high latitude. Ambient temperatures ranged from -30 to -15 ^{0}F (-34 to -26 ^{0}C) during surveys, far below the operating range for the COTS drone and other equipment. While DJI states that the Phantom drone can compensate for nearly 20 knot winds, unpredictable gusts experienced on 12-13 March and the low GPS signal made the drone's hover and flight path behavior unsteady and unpredictable (**Fig. 6&8**). Efforts were made to account for environmental challenges but the cold was a constant problem, especially during transport, survey set-up, and system initialization.

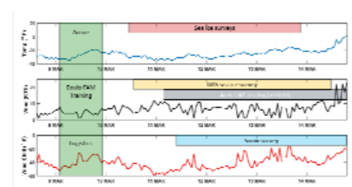


Figure 8. Weather conditions in Thule, Greenland during USNA PS&TP ICEX in March 2017 (courtesy of CDR Shawn Gallaher and MIDN 2/C Patrick Francis, USNA Oceanography Department).

Conclusions and Future Work

- ***Processed imagery collected by COTS UAS quadcopters can be used to identify and describe surface features over sea-ice in polar environments like those in Thule air base, Greenland***
- ***The quality and resolution of post-processed map products derived from aerial surveys using COTS UAS quadcopters over sea-ice in polar environments are dependent on the availability of overlapping aerial survey images and high-resolution geo-location data limited by environmental factors***
- ***Future work will involve improving the COTS UAS quadcopter survey approach and data post-processing to better account for and accommodate local environmental factors whether it be in polar regions or other regions where the Navy and Marine Corps operates or may operate in the future***

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